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Moving the needle on children's physical activity – How to best promote more movement?

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Moving the needle on children's physical activity – How to best promote more movement?

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Editorial: Moving the needle on children's physical activity – How to best promote more movement?

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physical activity, physical literacy, school-aged children, sedentary time, moderate to vigorous physical activity

Editorial on the Research Topic
Moving the needle on children's physical activity – How to best promote more movement?

In this Research Topic, we highlight research and innovative ways in which we can work toward moving the needle on children's physical activity. Globally, the vast majority of children do not meet the World Health Organization's recommendations for daily moderate to vigorous physical activity (MVPA) while at the same time children have become increasingly sedentary (1).

To increase children's engagement in physical activity, this Research Topic includes studies and discussions on school-based interventions (and engaging the home), the broader "context" of the intervention needing to be considered for interventions to be effective, and the need for additional focus on personal attributes such as fundamental movement skills, self-efficacy, and fitness to ensure children can and will engage in physical activity. Not surprisingly, articles in this Research Topic have focused on MVPA and sedentary time, largely in the school setting where children, on average, spend the a great deal of their time and where many interventions have focused on increasing children's PA. Al-walah et al. presented pilot data on a randomized controlled trial (RCT) implemented in Saudi-Arabian pre-schools that targeted both MVPA and sedentary time and attempted to engage the home environment. Implementation was largely successful (with noted challenges in engaging the home), however they were not able to increase PA or decrease sedentary time.

These results are not surprising to many PA researchers. RCTs are still largely considered the gold standard for research funding in this space, even though implementation of such interventions in the school setting is extremely challenging. This point is further demonstrated by the scoping review by Porter et al. and the accompanying commentary by Jago et al. where the authors discuss the limitations of examining PA interventions in the RCT format. They highlight that the community-, school-, and population-specific "contexts" are not often considered, instead rigid research protocols are favored to maintain internal validity (which makes funding agencies and peer-reviewers feel more confident in the possibility of success of an intervention). To overcome this limitation for successful promotion of physical activity in the real world, the authors developed a framework for the design of more tailored interventions but did put forth that interventions in their review (whether successful or not) often did not include context-specific details that would help promote success in this area.

Other articles in this Research Topic also supported the need for consideration of context of the intervention environment. St. Pierre et al. discussed the effectiveness of utilizing "near-peer" coaches in the middle school setting in low-income schools of New Orleans, LA. They discuss how the relatability of these coaches with the kids in the PA intervention trial made it more meaningful amongst a population of youth where consideration of PA and related health outcomes may need to be reconstructed due to competing priorities (e.g., staying in school, poverty). Broader context outside of the school day was also considered by Pfledderer et al., where they reinforced the importance of out-of-school physical activity (organized sports and activities, outdoor play, etc.) on children meeting PA guidelines in a large sample of youth who completed the Texas-SPAN survey.

Beyond the intervention environment, within child context should be considered as well. A re-emerging focus on children's physical literacy (PL), "the competence, confidence, and motivation to be physically active" (2, 3), is another key aspect to foster to ensure that children are physically able to and mentally want to engage in physical activities. Importantly, PL has been shown to be associated with greater levels of PA and as demonstrated by Chai et al. Furthermore, Grauduszus et al. conducted a scoping review of school-based PL interventions which emphasized the growing literature base in this space. There remains, however, a lack of consistent methodologies for measurement of PL as well as variable PA outcomes as a result of PL interventions, again speaking to the need for tailoring interventions to context as well as utilizing methodologies that will enable researchers to discern PL outcomes. PL and PA interventions should also consider the personal characteristics of the individual/child participant (beyond demographics) such as physical fitness levels. Graham et al. demonstrated how children and youth with varying levels of fitness may differentially respond to PA interventions targeting improving PA and related health outcomes.

Additionally, when looking broadly at interventions that have been or can be the most successful among children, two articles in this Research Topic have highlighted the importance of intervening across multiple levels of the social ecological model to ensure greater likelihood of increasing PA among children and youth (Sell et al.; Cholley-Gomez et al.). This ideal is not without its logistical and practical challenges.

Indeed, many school-based interventions are now also targeting the home environment (or family) given the importance of these two environments being key in supporting PA of children. Even within these two areas of influence, there are many aspects to consider in what could help change a child's physical activity patterns. It is also challenging to best measure intervention implementation so that changes in PA are detectable. Finally, all movement should be considered. We should not disregard or not attempt to measure light physical activity in children, even though we currently do not (yet) have guidelines for it. We should think of PA as a continuum, and not either "on (MVPA)" or "off (sedentary time)". Besides issues of how to measure physical activity, we also need to put more emphasis on how to get every child to want to engage in more movement, e.g., by taking up children's motivation (a key component of PL) to be (more) physically active. If we begin to more thoughtfully consider the multitude of ways our children and their environments shape their physical activity patterns and work to make subtle changes in this regard, we can make significant strides in moving the needle on their physical activity.

Author contributions

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Examining the Acute Effects of Classroom-Based Physical Activity Breaks on Executive Functioning in 11- to 14-Year-Old Children: Single and Additive Moderation Effects of Physical Fitness

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Objective: Research supports the efficacy of acute, classroom-based, physical activity breaks on executive functioning in children. However, research pertaining to the effect of physical fitness on the acute physical activity—executive functioning relationship remains limited. The primary purpose of this study was to investigate the acute effects of classroom-based, teacher-delivered, physical activity breaks on executive functioning in 11–14-year-old children. We also investigated the potential moderating effects of both aerobic and musculoskeletal fitness on the acute physical activity—executive functioning relationship.

Method: Participants ($N = 116$) completed pre- and post-test assessments of executive functioning (i.e., inhibition, switching, and updating) separated by a classroom-based physical activity break or sedentary classroom work. We manipulated the dose (i.e., length) and type of physical activity breaks. With regards to dose, participants in the experimental conditions engaged in 5-, 10-, or 20-min of physical activity whereas controls completed sedentary classroom math work at their desk. With regards to type, one experimental condition completed traditional physical activity breaks whereas the other experimental condition completed academic physical activity breaks (i.e., performed mental math and physical activity). Participants' mood, motivation, and self-efficacy were also assessed following the experimental manipulations.

Results: Overall, executive function scores improved across each assessment following the physical activity breaks when compared to sedentary classroom work regardless of dose and type. Participants also reported more positive mood states, higher motivation to complete the executive function tests, and higher self-efficacy to perform the executive functions tests following the physical activity breaks. Single moderation analyses showed that low-moderate levels of aerobic fitness moderated the acute physical activity—executive functioning relationship. Additive moderation analysis showed, collectively, that both aerobic and musculoskeletal fitness moderated the acute physical activity—executive functioning relationship.

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Conclusion: Findings from the present study provide evidence for the acute effects of short (i.e., 5–20 min) classroom-based physical activity breaks on executive functioning and psychological states in children. Results also suggest levels of both aerobic and musculoskeletal fitness moderate these effects, however future research is needed to further elucidate this complex relationship.

Keywords: cognition, youth, exercise, school, mood, motivation, self-efficacy

INTRODUCTION

Strong evidence supports the association between regular participation in physical activity and various cognitive, mental, and physical health outcomes among children and adolescents (1, 2). Despite this evidence and various physical activity initiatives across many sectors of society, the majority of children and adolescents worldwide are not engaging in sufficient levels of physical activity to reap these known health benefits (3–5). Given children spend most of their day in a school setting, many researchers and policy makers have recently devoted a substantial amount of time and resources to understand how the school setting may be used as a means to improve children's overall health through increased participation in physical activity during school hours [for an illustrative review see (6)]. Indeed, emerging evidence provides support for the efficacy of physical activity interventions in school settings to improve various adaptive cognitive, physical, and academic outcomes (7, 8).

Acute Exercise, Executive Functioning, and Classroom-Based Physical Activity Breaks

The school setting has also been targeted due to the evidence supporting the carryover effects of engaging in shorts bouts of physical activity and exercise on aspects of executive functions and cognition (9, 10). Executive functions refer to an array of higher order brain-based, or mental, processes that enable individuals to exert self-control and self-regulation over their behavior (11, 12). Executive functions can be divided into three core processes including "inhibition" which refers to the ability to suppress (or resist) automatic responses such as urges and distractions, "shifting" which refers to the ability to switch one's attention back and forth between multiple rules, mental sets, or tasks, and "updating" which refers to the maintenance of relevant information in working memory and the ability to process that information further. In turn, executive functions are related to many adaptive health outcomes across the life span (13, 14), including regular participation in physical activity (15, 16) as well as academic achievement and learning across a range of subjects (17–20). With regards to the acute effects of physical activity on executive functioning, ample research suggests relatively short bouts (e.g., a single 10–20-min bout) of various forms of physical activity and exercise (e.g., jogging, cycling, and circuit-based activities) can lead to short-term improvements on measures of executive functions (9, 10).

Given the understanding of the impact of acute physical activity on executive functioning, it is not surprising that many researchers have investigated ways to implement physical activity breaks within the classroom setting to not only improve learning and academic performance, but in some cases to increase enjoyment of the subject material and/or the learning environment (7, 19, 21). In these studies, researchers typically lead students through short bouts of various physical activities that can be performed behind a student's desk or as a group in an open area of the classroom. These activities often include aerobic or resistance-based physical activities that can be performed "on the spot" such as jumping jacks, burpees, push-ups, squats, split jumps, and jogging in place (among others). Prior to and following the acute bout of physical activity children are assessed one-on-one, or as a group, on various measures of executive functioning and academic performance (e.g., math). When compared to sedentary control conditions (e.g., regular classroom work), students who engaged in the physical activity break(s) generally show improvements on measures of executive functioning and academic performance both acutely and over time (7, 19, 21). Yet, one limitation to this area of research is that researchers are often the ones implementing the physical activity breaks with very few studies utilizing the teacher as the sole leader of the breaks. This has implications for both the ecological validity of the designs, but also pragmatic concerns over adoption and feasibility of implementation.

Besides the need to increase ecological validity and translate research into practice, it is important to acknowledge that various physical activity initiatives within school settings are not being adhered to at recommended levels. For instance, in Ontario, Canada, the Ministry of Education released a DPA policy in 2005 which mandated that all publicly funded elementary schools provide at least 20 min of sustained moderate-vigorous physical activity to their students each day during instructional time (22). However, since the inception of this mandate, adherence has been very poor (23, 24) with research showing that <50% of students were actually provided with an opportunity to engage in DPA (25). While teachers recognize the value of DPA, they often struggle to implement 20 min of sustained DPA (23, 25). The Comprehensive School Physical Activity Program (CSPAP) model (26), and its iterations [for a review see (6)], stresses the need to not only share information and resources with teachers about DPA but also to provide training opportunities and on-going support during the initial stages of DPA implementation throughout the school day and especially within the classroom setting [also see (27)].

The implementation of physical activity breaks within the classroom setting has also sparked an emerging area of research which incorporates academic content (e.g., mathematics, language, and geography) alongside physical activity (7, 19, 21).

For example, this could include presenting children with mental math problems (e.g., $5 \times 5 = ?$) whereby they are asked to write down the answer to the problem and then perform that many repetitions of a certain physical activity (e.g., 25 jumping jacks). These academic physical activity breaks are not only practical as they can preserve teaching time while also reaping the acute benefits of physical activity, but the efficacy for these breaks is also supported through a combination of neuroscientific, developmental, and embodied cognition perspectives [for reviews see (19, 28, 29)]. In short, these reviews and others (30) have proposed various intriguing reasons for why certain types of physical activity that require a high degree of cognitive engagement may be more beneficial than traditional forms of physical activity due to the unique connection between brain regions governing cognition (e.g., prefrontal cortex) and movement (e.g., cerebellum). For instance, these brain regions are fundamentally interconnected such that they co-activate when performing tasks primarily requiring cognition (e.g., math and reading) or motor behavior (e.g., running and balancing) and together support successful execution and performance on both types of tasks (31–34). In turn, academic physical activity breaks may not only pre-activate the same brains regions and cognitive processes needed for subsequent academic material (35, 36) but they may also strengthen the connection between these regions over time and support performance on related tasks (37). Although research in this area is still emerging, reviews and meta-analyses of intervention studies in children suggest the effects of cognitively engaging physical activity on aspects of executive functioning and cognition are superior to more traditional forms of physical activity (38–41). In addition, acute academic physical activity breaks have been shown to be superior to traditional forms of active and/or sedentary classroom learning environments (19), however the number of studies in this area remains limited.

While the above supports the efficacy for physical activity requiring an enhanced degree of cognitive engagement (i.e., academic physical activity or cognitively engaging physical activity) on aspects of executive functioning and cognition in general, and when compared to more traditional forms of physical activity, it is important to acknowledge and discuss a key difference between these two types of activity. Specifically, *academic physical activity* incorporates academic material alongside physical activity whereas *cognitively engaging (or challenging) physical activity* increases the concurrent cognitive demands of performing the physical activity itself [for a review see (30)]. For example, this could include juggling while jogging or playing a team sport (e.g., basketball) that has additional rules. Although academic physical activity is essentially a subtype of cognitively engaging physical activity, research suggests academic physical activity breaks can facilitate learning to a greater extent when compared to other types of cognitively engaging activity breaks and traditional activity breaks [for a comprehensive review and conceptual model see (19)].

Despite the increasing evidence for traditional, academic, and cognitively engaging physical activity breaks on aspects of executive functioning and cognition, there is no consensus for the optimal length of these acute physical activity breaks. This is not entirely surprising given various findings within the broader literature examining the acute effects of physical activity or exercise on executive functioning. For instance, a meta-analysis by Chang et al. (42) suggested that acute bouts lasting 11-min or longer generally resulted in improvements in executive functioning and cognition. However, as pointed out by Pontifex et al. (10), this conclusion may be partially attributable to the characteristics of the studies included in their analysis and the number conducted up to that point in time. Indeed, the updated review by Pontifex et al. (10) found the majority of studies within the extant literature have utilized acute bouts lasting 16–35 min (88% of the literature) while much less have utilized bouts lasting 10-min or less. In turn, as suggested by Pontifex et al. (10), an 11-min threshold does not negate the fact that shorter durations may also be effective given the array of possible considerations (e.g., population, age, type of activity, length of time between activity bout and cognitive assessment, etc.). Although there are many other factors to consider besides duration (e.g., intensity), it is important to acknowledge that the classroom environment may suit a range of durations (e.g., 5, 10, or 20 min) depending on the subject, grade level, or lesson plan for that day while the intensity may largely be held constant due to the nature of the activities that can be performed in a classroom setting. As such, shorter bouts may be more feasible to implement within the classroom and evidence supports comparable effects between an acute 10- vs. a 20-min classroom physical activity break on math scores (43). Other research has provided support for acute academic physical activity breaks and cognitively engaging activity breaks lasting 10-min in length on aspects of executive functioning and enjoyment within the classroom (36, 44). While the evidence for acute physical activity breaks lasting $<$10-min remains limited, intervention research suggests traditional physical activity breaks lasting 4-min (45) and both traditional and academic physical activity breaks lasting 5-min (46) can improve on-task behavior and math performance over time. Thus, emerging evidence supports the efficacy for the acute effects of short duration classroom-based physical activity across a variety of adaptive outcomes, however the acute effects for activity breaks lasting $<$10-min remains scarce and requires additional research.

Physical Fitness, Executive Functioning, and Acute Exercise

Similar to physical activity, aspects of physical fitness are also intricately linked to overall health, executive functioning, and academic achievement (47–51). For instance, children and youth who have higher levels of aerobic fitness are generally healthier and perform better on tests of executive functioning and academic achievement. While the majority of the literature has focused on aspects of aerobic fitness, emerging evidence suggests aspects of musculoskeletal fitness are also related to executive functioning and academic achievement among children and youth (49, 52–54). Understanding the potential influence that both types of fitness may have on executive functioning, both independently and collectively, is important as recent research suggests high levels of both types of fitness may enact an added or combined benefit on executive functioning (53).

Given the relationship between high levels of physical fitness and executive functioning in general, it is plausible that the effects of acute exercise on executive functioning may also be affected (i.e., moderated) by levels of physical fitness. Despite this intriguing assumption, the evidence remains mixed [for meta-analyses see (42, 55)]. For instance, experimental research has shown that individuals with higher levels of aerobic fitness benefit the most on measures of executive functioning following acute exercise (56, 57) whereas other research showed that those with moderate levels of aerobic fitness benefited the most (58). Yet, a sub-analysis from a meta-analytic review showed no effects for aerobic fitness on the acute exercise—executive functioning relationship (55) indicating that acute exercise uniformly, and positively, affected executive functioning across varying levels of physical fitness. However, these findings were strictly limited to acute aerobic exercise performed at a moderate intensity. More recent experimental evidence continues to remain mixed across aerobic fitness levels, exercise intensities, age groups, and measures of executive functioning [i.e., (59–62)] suggesting future research is warranted to further elucidate this complex relationship.

There are a couple other notable limitations to previous research investigating the potential moderating effects of physical fitness on the acute exercise—executive functioning relationship. First and foremost, as far as we are aware, previous research has solely investigated aspects of aerobic fitness and therefore the potential moderating effects of musculoskeletal fitness remain unknown. In addition, the majority of previous studies have created groups that represented varying levels of fitness (e.g., low, moderate, and high) based on standardized guidelines (e.g., American College of Sports Medicine guidelines) or normative data. While this method is entirely justified in order to investigate different fitness levels based on pre-determined standards or guidelines, it also has certain shortcomings when examining potential moderating effects. For instance, these include various statistical limitations and criticisms against conducting a moderation analysis through the use of groups as the moderator rather than a continuous variable [see (63), *Artificial Categorization and Subgroups Analysis*, p. 263–265]. It is also plausible that there may be a certain point along the fitness continuum where physical fitness may become a meaningful and significant contributor to executive functioning performance following acute exercise. This point, however, can only be identified through probing an interaction of a moderation analysis that used a continuous variable as the moderator. Based on the sample (e.g., children, adolescents, or older adults) and measure of fitness (e.g., graded exercise test, shuttle run, or standing long jump) it may be important to know when fitness becomes a significant predictor and what the relationship may look like following that point (e.g., is the relationship linear or curvilinear) for that specific measure of fitness. In other words, if performance on the shuttle run test is a moderator of the acute exercise—executive functioning relationship among children aged 11–12 years, it would be interesting to know the specific stage or number of laps that was achieved to reap the acute effects of exercise on executive functioning. Within a school setting, this information could be utilized by school boards and physical education specialists whereby this aspect of fitness may be targeted and trained in a similar sample of children in order to reap the benefits of acute classroom-based physical activity breaks on aspects of executive functioning, learning, and academic performance.

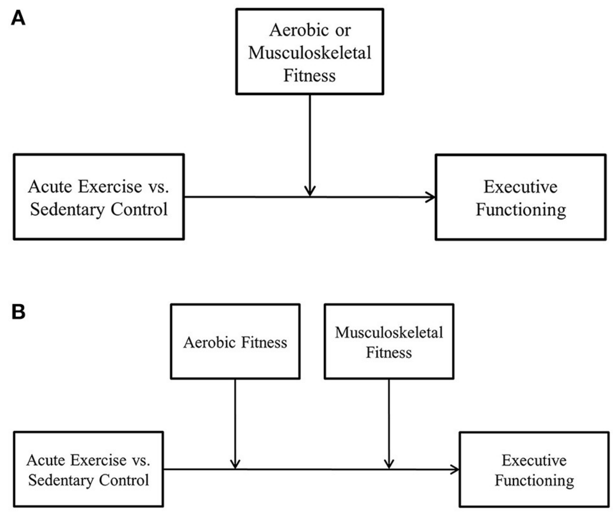

FIGURE 1 | (A) Acute exercise—executive functioning single moderation example. **(B)** Acute exercise—executive functioning additive moderation example.

Furthermore, as recent cross-sectional research suggests both high levels of aerobic and musculoskeletal fitness may provide a combined benefit on executive functioning (53), it is also plausible that both types of fitness may provide a combined effect on executive functioning following acute exercise. Extending the traditional single moderation model (depicted in **Figure 1A**), additive moderation analysis (depicted in **Figure 1B**) provides researchers with the ability to examine the potential combined effect of both types and levels of fitness on the acute exercise—executive functioning relationship within a single analysis.

Purpose and Hypotheses

The primary objective of this study was to investigate the acute effects of a classroom-based, teacher-led, physical activity break on executive functioning in 11–14-year-old children when compared to sedentary classroom work. To maintain a high degree of ecological validity, the study was conducted within a school setting during math class. In addition, we manipulated the dose (or length) of the physical activity breaks as well as the type of physical activity breaks. With regards to dose, children in the experimental conditions completed a 5-, 10-, or 20-min physical activity break whereas controls completed sedentary classroom math work at their desk during this time. With regards to type, one experimental condition completed traditional physical activity breaks whereas the other experimental condition completed academic physical activity breaks. Consistent with the literature reviewed above, we hypothesized that an acute classroom-based physical activity break would lead to improvements in executive functioning when compared to sedentary classroom work regardless of the dose. We also hypothesized that academic physical activity breaks would lead to a greater change in executive functioning when compared to traditional physical activity breaks and the control condition, again regardless of the dose. We chose not to formulate hypotheses relating to dose due to discrepancies within the extant literature regarding the limited number of studies conducted utilizing bouts lasting <10-min (10), the fact that few studies have directly compared the effects of varying durations within a single study [e.g., (43)], and emerging evidence suggesting acute academic physical activity bouts lasting <10-min can lead to improvements in aspects of executive functioning and academic performance (19). Therefore, our analyses with regards to dose were considered exploratory.

A secondary objective was to investigate the potential moderating effects of physical fitness (i.e., both aerobic and musculoskeletal fitness) on the acute physical activity—executive functioning relationship. Given inconsistencies and limitations within the literature discussed above, we explored the potential independent and combined moderating effects of both aerobic and musculoskeletal fitness through the use of a continuous variable as the moderator and by conducting separate single moderation analyses (see **Figure 1A**) and through an additive moderation analysis (see **Figure 1B**).

METHODS

Participants and Design

Participants included 11- to 14-year-old children in grades 6–8 ($N = 116$; $n = 58$ girls, $M_{age} = 12.19 \pm 0.93$) who were part of a larger 6-week intervention study investigating the effects of classroom-based, teacher-led, physical activity breaks on aspects of physical fitness, executive functioning, and psychosocial well-being. The larger study was completed in partnership with the Hamilton-Wentworth Catholic District School Board and utilized a 3 (activity type: traditional physical activity break vs. academic physical activity break vs. sedentary math) × 3 (activity dose: 4 × 5-min vs. 2 × 10-min vs. 1 × 20-min) × 2 (time: pre-intervention vs. post-intervention) between-subjects experimental design. Three schools were chosen to participate by the Hamilton-Wentworth Catholic District School Board and each were assigned an activity dose by the school board so that all of the students in the experimental classes within each school participated in the same dosage of physical activity. The physical activity breaks were delivered daily by the teachers, in the classroom, during a 75-min math class period and the doses were delivered so that physical activity was equally spread throughout the class period. For example, the 2 × 10-min group completed ∼18-min of math, engaged in 10-min of physical activity, completed another 18-min of math, then engaged in 10-min of physical activity, and finally 18-min of math. Whereas, the 4 × 5-min group had four equally spaced interval physical activity breaks throughout math class and the 20-min group only had one 20-min break in the middle of math class.

All of the grade 2–8 students and teachers from each school were invited to participate in the larger study. Students who were not enrolled in the longitudinal study also participated in the daily physical activity breaks alongside their peers who consented to participate in the study. In addition, only students in grades 6–8 who were apart of the larger study were also invited to participate in the acute portion of the study (presented in this paper) due to feasibility issues and in order to minimize class distractions among the younger students as per recommendations from the school board. Teachers who agreed to participate in one of the physical activity conditions were provided with the option to choose either the traditional physical activity break condition or the academic physical activity break condition. If teachers had no preference between the two physical activity conditions, they were then randomly assigned by the researchers to one of the two conditions at the grade level. For instance, if two grade 6 teachers at one school agreed to participate and had no preference, they were randomized so that one teacher delivered traditional physical activity breaks and the other delivered academic physical activity breaks. The study was approved by the McMaster University Research Ethics Board and the Hamilton-Wentworth Catholic District School Board Research Ethics Committee. Parents provided informed written consent and students provided informed written assent before participation in the study.

The present study is an examination of the acute effects of a single physical activity break, compared to sedentary math work, on executive functioning and the potential moderating effect of physical fitness. A randomization schedule was generated (random.org) for grade 6–8 students who agreed to participate in the acute portion of the study. However, due to unforeseen limited access to students from one school, we ended up with unequal group sizes across activity type and dose. That is, our final sample ($N = 116$) included 67 sedentary control participants, 37 academic physical activity break participants, and 12 traditional physical activity break participants. Due to the low number of participants in the traditional physical activity break condition, we combined the participants in the physical activity break conditions to form one condition. Specifically, this study utilized a 2 (activity type: physical activity break vs. sedentary math) × 3 (activity dose: 1 × 5-min vs. 2 × 10-min vs. 1 × 20-min) × 2 (time: pre-manipulation vs. post-manipulation) between-subjects experimental design, which included: a 5-min physical activity break condition ($n = 19$), a 10-min physical activity break condition ($n = 10$), a 20-min physical activity break condition ($n = 20$), a 5-min sedentary math condition ($n = 23$), a 10-min sedentary math condition ($n = 23$), and a 20-min sedentary math condition ($n = 21$).

Procedure

The data was collected over the first 3-week period of the intervention, during math class, within regular school hours (i.e., 8:30 a.m.−3:00 p.m.). Participants were accompanied by a trained research assistant to a quiet room within the school to complete the pre-manipulation study measures. They were first fitted with a heart rate monitor, then completed measures of mood and motivation (see section Secondary Outcome Measures below), followed by the pre-test executive function assessments (see section Primary Outcome Measures below). They were then walked back to their classroom by the research assistant and were exposed to their respective experimental manipulation. Children in the physical activity break conditions participated in a 5-, 10-, or 20-min, teacher-delivered, physical activity break with their fellow classmates. Whereas, participants in the sedentary control condition resumed their regular classroom math work for their assigned dose manipulation (i.e., 5-, 10-, or 20-min of math work).

Heart rate was measured continuously during the experimental manipulations using a Polar H7 chest strap that was synced to an iPad using the Polar GoFit application (Polar Canada, Lachine, Quebec). Exercise intensity was monitored through the Polar GoFit application which was displayed at the front of the classroom on a smartboard. Each student had their own unique identifier box (displayed on a smartboard) and exercise intensity was synced through their heart rate monitor. Exercise intensity was set to 60–80% of the participants' maximum heart rate (HRmax) which was predetermined based off their age (i.e., 220-age = HRmax) and was chosen as it is commonly used when examining the acute effects of physical activity or exercise on executive functioning (10, 64). The participants' unique identifier box would change colors based on their heart rate in relation to the predetermined intensity, with gray indicating too low of an intensity, blue (60–70% of HRmax) and green (70–80% of HRmax) indicating the correct intensities, and yellow (80–90% of HRmax) and red (90–100% of HRmax) indicating too high of an intensity. Participants were encouraged to self-regulate their own intensity throughout the physical activity break so that they kept their unique identifier box in the blue or green intensity zones, however we did not extract heart rate data for this study.

Following the experimental manipulation, the research assistant walked the participant back to the same quiet room to complete the post-manipulation measures. That is, participants first completed the task self-efficacy measure (see section Secondary Outcome Measures below), followed by the mood and motivation measures, and then the post-test executive function assessments. Upon completion of the post-test executive function assessments, participants were provided with a $15 Indigo gift card. See **Figure 2** for an overview of the experimental protocol.

Experimental Manipulations

Activity Type

The physical activity break manipulations were teacher-delivered and occurred during math class. Prior to the study, and in line with expert recommendations (6, 27), our research group shared information with teachers on the acute and long-term benefits of classroom-based physical activity breaks and strategies to effectively deliver these breaks, provided all the necessary intervention materials, and held training sessions with regards to the effective delivery of the physical activity breaks. We also checked in daily to provide additional support, guidance, and to troubleshoot any problems with implementation.

Traditional Physical Activity Break

The traditional physical activity breaks included tasks suitable to be performed standing behind a desk or in a small open space within the classroom. The physical activities were delivered through the Ontario Physical and Health Education Association's (OPHEA) *50 Fitness Activity* cards (https://teachingtools.ophea.net/sites/default/files/pdf/pdm_50fitnessactivities_17se19.pdf). Examples of activities included variations of jumping jacks, running on the spot, lunges, and tuck jumps, among others. The teachers were also provided with cards that had numbers from 1 to 50 printed on them. Teachers delivered the physical activity break by randomly selecting a number (i.e., 10) alongside randomly selecting an activity card (i.e., tuck jumps), and then students would perform that many repetitions of that activity (i.e., 10 tuck jumps). This process would be repeated for the entire duration of the physical activity break. In addition, teachers were encouraged to use number cards ranging from 5 to 20 to maintain a moderate-vigorous physical activity intensity and to be feasible for students to accomplish. However, teachers were also encouraged to adapt their physical activity breaks to the physical ability of the class and could use a larger (i.e., 5–35) or smaller (i.e., 5–15) range of numbers.

Academic Physical Activity Break

The academic physical activity breaks were identical to the traditional physical activity breaks with the exception that teachers were provided with grade-appropriate math problem flash cards in place of the number cards. In other words, teachers would randomly select a math problem card (i.e., 5 × 5 = ?) and then randomly select an activity card (i.e., tuck jumps). Students would then perform mental math, write the answer down on a piece of paper, and perform that many repetitions (i.e., 25 tuck jumps). Again, teachers were encouraged to modify the cards to have manageable solutions so that the number of repetitions performed met the ability of the class. Teachers were also encouraged to create their own mental math problems based on their course content for that day or week.

Sedentary Control Condition

Students in the control condition engaged in their regular classroom math work seated at a desk.

Activity Dose

The activity dose consisted of either 5-, 10-, or 20-min of physical activity or sedentary math work.

Primary Outcome Measures

Executive Functioning

To assess the three core executive functions of inhibition, switching, and updating, three tasks were chosen that have been commonly used in previous research to assess executive functioning in general (65) as well as to assess the effects of acute exercise on executive functioning (10). As described below, these three tasks were administered prior to (pre-test) and following the experimental manipulations (post-test) and were performed in the same order at each assessment beginning with the Stroop task (inhibition), followed by the Trail Making Test (switching), and then the Forward Working Memory test (updating).

Inhibition

The congruent and incongruent versions of the Stroop task (66) were used to assess inhibition. Participants performed the congruent version for 1-min followed by the incongruent version

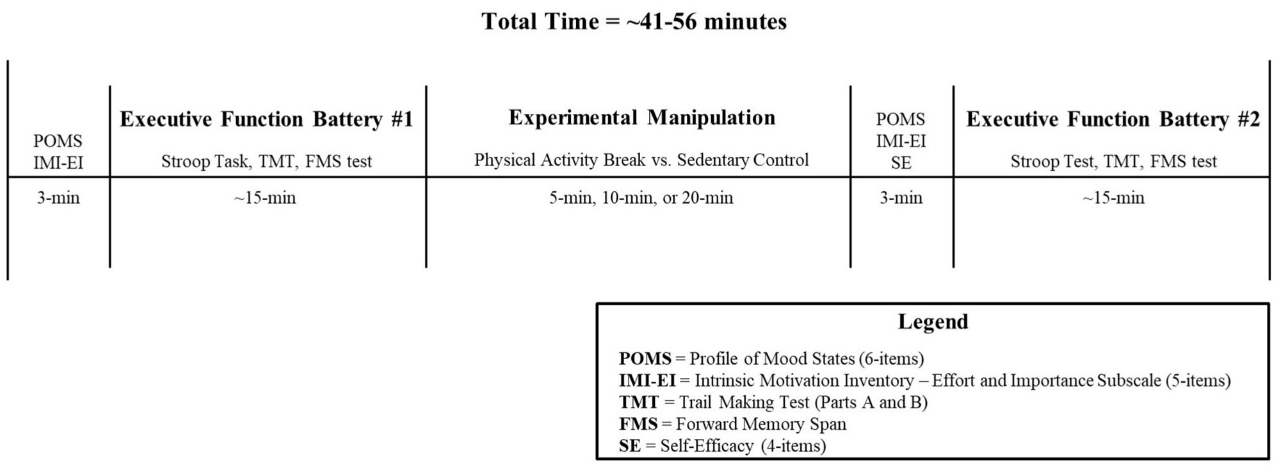

FIGURE 2 | Experimental protocol.

for 5-min. Both versions consisted of lists of words printed on laminated sheets of paper. In the congruent version, the words and the print ink color were matched (e.g., ink color was *green* and the word text read *green*), and participants were asked to read the word aloud (i.e., green). In the incongruent version, the words and print ink color were mismatched (e.g., ink color was *yellow* and the word text read *green*), and participants were asked to say aloud the ink color they saw (i.e., yellow) without reading the word text. In both versions, children were asked to try to respond as fast and accurately as possible. If an error was made it was recorded by the research assistant. Children were often unaware of the errors they made but if they corrected their response it was still recorded as an error by the research assistant. A total Stroop task performance score (i.e., Stroop accuracy) was computed by subtracting the amount of errors made on each version from the amount of words completed on each version, and then summing those values [i.e., Stroop task performance score = (congruent words completed—congruent errors made) + (incongruent words completed—incongruent errors made)]. This calculation was conducted separately for the pre- and post-test assessments and has been used in previous research when investigating the acute effects of physical activity on executive functioning (67). Higher scores indicate better performance on the Stroop task.

Switching

The Trail Making Test [TMT; (68)] was used to assess switching as it is a valid and appropriate measure for children (69). The TMT consists of two parts, Part A and Part B. Part A requires participants to connect number sequences, whereas Part B requires participants to alternate between number and letter sequences. In both versions, participants are required to connect the sequences in order, as fast and accurately as possible, without lifting their pencil or turning the paper. If an error was committed (i.e., connected the wrong sequence) or a pencil lift was made, it was recorded by the research assistant under "total errors." A total TMT performance score was computed by adding the total errors committed to the time (in seconds) it took the participants to complete each version, and then summing those values [i.e., TMT performance score = (total time Part A + total errors Part A) + (total time Part B + total errors Part B)]. This calculation was conducted separately for the pre- and post-test assessments and has been used in previous research when investigating the acute effects of physical activity on executive functioning (67). Lower scores indicate better performance on the TMT.

Updating

The Forward Memory Span (FMS) test from the Leiter International Performance Scale–3rd Edition was used to assess updating as it is a valid and appropriate measure for children (70). The FMS test is a non-verbal assessment whereby the participant is presented with pictures of objects shown in a grid pattern (e.g., a 3 × 3 grid). First, the researcher points to multiple pictures (e.g., 4 pictures) in a predetermined order and then the participant is required to copy the same order. The grid pattern and number of pictures gradually increases as the test progresses. An error is recorded if the participant points to any of the pictures in the incorrect order. The test is terminated when six errors are committed or if the participant advances to the last sequence. A total FMS performance score was computed by summing the correct number of sequences performed, with a maximum score of 28. Higher scores indicate better performance on the FMS test.

Executive Functioning Composite Score

A single measure of executive functioning was calculated using standardized scores from each of the three core performance measures mentioned above. Specifically, standardized z-scores were calculated separately based on the total performance scores for the Stroop task, TMT, and FMS test at both assessments (i.e., at pre- and post-manipulation). However, the TMT z-scores were then multiplied by −1 so that TMT values were consistent with the Stroop task and FMS test values (i.e., positive values reflect better performance and negative values reflect poorer performance). The standardized scores were then summed to obtain separate composite scores for the pre- and post-test assessments, with higher values reflecting greater overall executive functioning performance.

Secondary Outcome Measures

Mood

Positive mood was assessed using a modified version of the Profile of Mood States (71) that is suitable for children in response to physical exercise (72). Mood was assessed prior to pre- and post-test executive function assessments using 6-items from the positive affect subscale. Participants were asked to rate their current feeling state in response to each item on a scale ranging from 1 (*Not at All*) to 5 (*Extremely*). Positive mood items included *Active, Awake, Energetic, Excited, Friendly,* and *Happy*. A total positive mood score was computed by averaging the 6-items at each assessment. Internal consistency at each assessment was acceptable (Cronbach's α's > 0.79).

Motivation

Motivation for performing the executive function tests was assessed prior to the pre- and post-test executive function assessments using the effort and importance subscale from the Intrinsic Motivation Inventory (73). The effort and importance subscale has been successfully used with children in past research examining the effects of acute exercise on motivation and executive functioning (67, 74). The subscale contains 5-items that are rated on a scale ranging from 1 (*Not at all true*) to 7 (*Very true*). Each item was prefaced with the following stem "*For the brain games I'm about to do.*" An example item is: "*I am going to put a lot of effort into these brain games.*" A total motivation score was computed by averaging the 5-items at each assessment. Internal consistency at each assessment was good (α's > 0.89).

Task Self-Efficacy

Self-efficacy to perform the post-test executive function assessments was assessed using a four-item scale adhering to recommendations by Bandura (75) for assessing self-efficacy. This scale has also been successfully used with children in past research examining the effects of acute exercise on self-efficacy and executive functioning (67, 74). Each item was prefaced with the stem "*For the brain games I am about to do, I am confident I can perform....*" The individual items represented gradations of performance that were relative to the participant's performance on the pre-test executive function assessments. They were (1) "*Almost as good as last time*," (2) "*As good as last time*," (3) "*A little better than last time*," and (4) "*A lot better than last time.*" Participants rated their confidence (i.e., self-efficacy) for each item using an 11-point scale ranging from 0 (*Not at all Confident*) to 10 (*Completely Confident*). The task self-efficacy score was calculated by averaging the items. Internal consistency of the scale was acceptable ($\alpha = 0.79$).

Physical Fitness

Assessments of aerobic and musculoskeletal fitness were conducted by trained research assistants during the baseline data collection period for the larger intervention study within the school gymnasium.

Aerobic Fitness

The Leger 20-m Shuttle Run (SR) test was used to represent participants' aerobic fitness levels (76, 77), which is a valid and commonly used field-based measure of aerobic fitness in children (78, 79). The SR test involves running back and forth between two lines set 20 meters apart while maintaining a set pace with an audio signal that increases in difficulty over time (i.e., the signals become shorter). The test is terminated when a participant is unable to maintain the set pace for two consecutive audio signals. The number of laps completed served as the outcome of aerobic fitness. The higher number of laps completed represents better performance on the SR test.

Participants also rated their perceived exertion (RPE) using Borg's (80) CR-10 scale following the SR test. This was done to determine the extent to which they exerted their maximum physical effort on the test.

Musculoskeletal Fitness

Standing long jump (SLJ) was used to represent participants' musculoskeletal fitness, which is a common and valid field-based measure of musculoskeletal fitness in children (78). To perform a SLJ, participants were instructed to jump as far as they could using a 2-foot takeoff and a 2-foot landing from behind a marked line. Distance was measured to the nearest centimeter from the back of the closest heel to the line. Three attempts were made, with the longest distance used as the SLJ performance outcome.

Data Analysis

All statistical analyses were conducted using SPSS 25 (81). Descriptive statistics were computed for all study variables. Chi-square tests and separate one-way analyses of variance (ANOVAs) were computed to assess differences in means between the physical activity and control conditions for demographic, anthropometric, and physical fitness scores. Separate 2 (activity type) $\times$ 3 (activity dose: 5- vs. 10- vs. 20-min) $\times$ 2 (time) repeated measures ANOVAs were computed to assess differences in means between conditions for the primary and secondary outcomes. However, as task self-efficacy was only assessed once (i.e., prior to the post-test executive function assessments), a 2 (activity type) $\times$ 3 (activity dose) univariate ANOVA was computed to assess differences in means between conditions for task self-efficacy.

A series of three separate, *post-hoc* exploratory, 2 (activity type) $\times$ 2 (time) repeated measures ANVOA analyses were conducted on the executive functioning composite scores. These exploratory analyses were primarily conducted due to the low number of participants ($n = 12$) in the traditional physical activity break condition. Specifically, we wanted to investigate (1) whether the academic physical activity break conditions ($n = 37$) and the sedentary control conditions ($n = 67$) differed on executive functioning after excluding the 12 participants from the traditional physical activity conditions, (2) whether the two physical activity break conditions differed on executive functioning, and (3) whether the traditional physical activity break condition and sedentary control condition differed on executive functioning.

Significant interactions were decomposed and evaluated using paired t-tests by comparing group means. Effect sizes for the one-way ANOVAs are reported as Cohen's d (82) and the values for small, medium and large are 0.20, 0.50, and 0.80, respectively. Effect sizes for the repeated measure ANOVAs and univariate ANOVAs are reported as partial eta squared (η_p^2) and the values for small, medium, and large are 0.01, 0.06, and 0.14, respectively.

Tests for single moderation were assessed using Model 1 in the PROCESS v3.5 software macro for SPSS (63). As recommended by Hayes and Scharkow (83), bias-corrected bootstrap procedures were computed utilizing 10,000 simulations. In each of the single moderation analyses (depicted in **Figure 3A**), the post-test executive function composite score served as the dependent variable (covarying for the pre-test executive function composite score), with experimental condition (physical activity vs. control) specified as the independent variable and aerobic or musculoskeletal physical fitness (i.e., SLJ distance or SR laps) as the moderator. The additive moderation analysis was conducted using Model 2 in the PROCESS software macro for SPSS (63) and bias-corrected bootstrap procedures utilizing 10,000 simulations were computed. In the additive moderation analysis (depicted in **Figure 3B**), the post-test executive function composite score served as the dependent variable (covarying for the pre-test executive function composite score), with experimental condition (physical activity vs. control) specified as the independent variable and both physical fitness outcomes (i.e., SLJ distance and SR laps) as the moderators. Significant ($p < 0.05$) moderation and conditional effects are indicated by a confidence interval that does not include zero. As recommended by Hayes (A. Hayes, personal communication, July 18, 2018), interactions that were significant at $p < 0.10$ were probed using either the Johnson-Neyman technique (single moderation) or by exploring the conditional effects of the moderators at the 16th, 50th, and 84th percentiles (additive moderation) as the Johnson-Neyman technique is not programmed in PROCESS when probing interactions in additive moderation analyses.

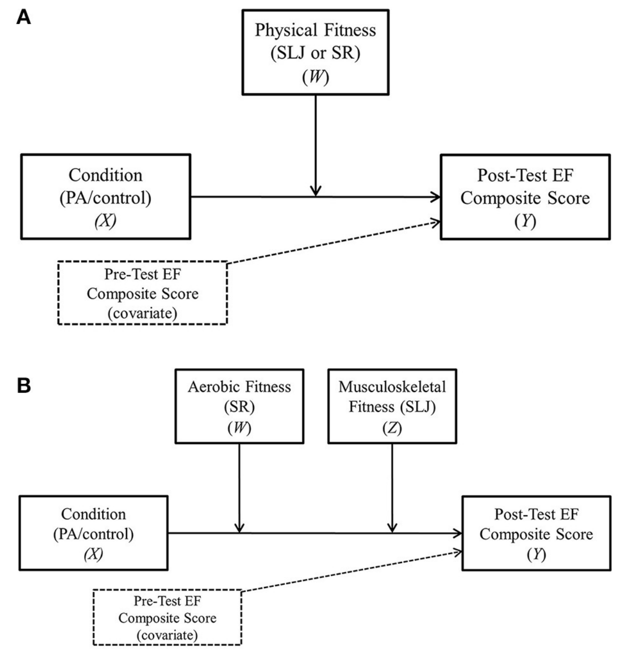

FIGURE 3 | (A) Acute physical activity—executive functioning single moderation model. **(B)** Acute physical activity—executive functioning additive moderation model. SLJ, standing long jump; SR, shuttle run; EF, executive functioning.

RESULTS

Participant Characteristics

Descriptive statistics, chi-square, ANOVA summaries, and effect sizes for demographic, anthropometric, and physical fitness scores are shown, by group, in **Table 1**. Analyses revealed no significant differences ($p > 0.05$) between the sedentary control and physical activity break conditions. The only exception was that height values were significantly larger in the physical activity break condition when compared to the sedentary control condition ($p = 0.03$, $d = 0.43$).

Primary Analyses

Descriptive statistics, ANOVA summaries, and effect sizes for the Stroop task, the TMT, the FMS test, and the executive functioning composite score are shown, by group, in **Table 2**.

Executive Functioning Composite Score

Results of the 2 × 3 × 2 repeated measures ANOVA for the executive functioning composite score revealed a non-significant main effect for time ($p = 0.76$, $\eta_p^2 = 0.001$). However, the time by activity type interaction ($p < 0.001$, $\eta_p^2 = 0.13$) and the time by activity dose interaction ($p = 0.02$, $\eta_p^2 = 0.07$) were significant. The time by activity type by activity dose interaction was not significant ($p = 0.50$, $\eta_p^2 = 0.01$). Specifically, as depicted in **Figure 4A**, the executive functioning composite scores increased significantly among participants in the 5-min ($p = 0.01$, $d = 0.51$) and 20-min ($p = 0.04$, $d = 0.31$) physical activity break conditions, they remained relatively stable in the 10-min physical activity break ($p = 0.91$, $d = 0.02$) and the 20-min sedentary control ($p = 0.69$, $d = 0.04$) conditions, and decreased in the 5-min sedentary control ($p = 0.21$, $d = 0.14$) and 10-min sedentary control ($p = 0.001$, $d = 0.58$) conditions.

Results of the first, *post-hoc*, 2 × 2 repeated measures ANOVA for the change in executive function composite scores between the academic physical activity break conditions and the sedentary control conditions revealed no main effect for time ($p = 0.43$, $\eta_p^2 = 0.01$), however the time by activity type interaction was significant ($p < 0.001$, $\eta_p^2 = 0.15$). Results of the second 2 × 2 repeated measures ANOVA for the change in executive function composite scores between the academic physical activity break conditions and the traditional physical activity break conditions revealed a significant main effect for time ($p = 0.012$, $\eta_p^2 = 0.12$), however the time by activity type interaction was not significant

TABLE 1 | Demographic, anthropometric, and physical fitness scores by group.

	Sedentary control $n = 67$	Physical activity break $n = 49$			
	M (SD)	*M* (SD)	*F*	*p*	*d*
Age	12.22 (1.02)	12.51 (0.96)	2.36	0.13	0.30
BMI	19.69 (4.89)	19.70 (4.59)	0.00	0.99	0.002
Height (cm)	152.09 (11.28)	156.13 (7.15)	4.84	0.03	0.43
Weight (kg)	45.86 (13.55)	48.45 (13.44)	1.03	0.31	0.19
SLJ (cm)	142.24 (26.23)	151.08 (27.25)	3.05	0.08	0.33
SR final stage	5.08 (2.22)	5.15 (1.92)	0.03	0.86	0.03
SR laps completed	38.08 (20.02)	39.02 (18.21)	0.86	0.80	0.05
SR RPE	7.17 (2.13)	7.13 (1.84)	0.01	0.91	0.02
			x^2	*p*	*V*
Girls/Boys	34/33	24/25	0.03	0.85	0.02
White/Other	48/19	36/13	0.05	0.83	0.02

M, mean; SD, standard deviation; BMI, body mass index; cm, centimeters; kg, kilograms; SLJ, standing long jump; SR, shuttle run; d, Cohen's d; V, Cramer's V.

TABLE 2 | Executive functioning, mood, motivation, and task self-efficacy scores by group.

	Sedentary control				Physical activity break						
	Pre		Post		Pre		Post		*F*	*p*	η_p^2
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*			
Stroop task	297.45	(54.25)	326.88	(65.15)	299.04	(54.27)	362.33	(61.00)	25.19[a]	<0.001	0.19
TMT	128.70	(42.09)	126.89	(44.07)	125.53	(37.46)	115.21	(31.45)	1.22[a]	0.27	0.01
FMS test	22.57	(2.43)	22.58	(2.05)	21.96	(2.23)	23.04	(2.48)	6.42[a]	0.01	0.06
EF composite score	0.99	(2.45)	−0.42	(2.30)	−0.13	(2.23)	0.57	(2.21)	16.24[a]	<0.001	0.13
Mood	3.64	(0.57)	3.46	(0.66)	3.37	(0.60)	3.92	(0.71)	42.19[a]	<0.001	0.28
Motivation	5.72	(0.92)	5.77	(0.96)	5.61	(0.99)	5.86	(0.98)	5.61[a]	0.02	0.05
Self-efficacy	–	–	5.70	(1.82)	–	–	7.20	(1.87)	15.76[b]	<0.001	0.08

M, mean; SD, standard deviation; TMT, trail making test; FMS, forward memory span; EF, executive functioning; η_p^2, partial eta squared.
[a]*F-values represent the time by activity type interaction from the 2 × 3 repeated measures ANOVAs.*
[b]*F-value represents the main effect for activity type from the 2 × 3 univariate ANOVA.*

($p = 0.71$, $\eta_p^2 = 0.01$). Results of the third 2 × 2 repeated measures ANOVA for the change in executive function composite scores between the traditional physical activity break conditions and the sedentary control conditions revealed no main effect for time ($p = 0.91$, $\eta_p^2 = 0.00$), however the time by activity type interaction was significant ($p = 0.01$, $\eta_p^2 = 0.08$). Specifically, as depicted in **Figure 4B**, executive functioning composite scores increased significantly among participants in the traditional physical activity conditions ($p = .006$, $d = 0.22$) and academic physical activity break conditions ($p = 0.003$, $d = 0.35$), whereas they decreased among participants in the sedentary control conditions ($p = 0.18$, $d = 0.22$).

Inhibition

Results of the 2 × 3 × 2 repeated measures ANOVA for the Stroop task performance score revealed a significant main effect for time ($p < 0.001$, $\eta_p^2 = 0.19$) and a significant time by activity type interaction ($p < 0.001$, $\eta_p^2 = 0.19$). However, the time by activity dose interaction ($p = 0.13$, $\eta_p^2 = 0.04$) and the time by activity type by activity dose interaction ($p = 0.73$, $\eta_p^2 = 0.01$) were not significant. Specifically, as depicted in **Figure 5A**, Stroop task performance scores significantly increased to a greater extent among participants in the physical activity conditions ($p < 0.001$, $d = 1.10$) when compared to participants in the sedentary control conditions ($p < 0.001$, $d = 0.50$).

Switching

Results of the 2 × 3 × 2 repeated measures ANOVA for the TMT performance score revealed no significant findings for the main effect for time ($p = 0.08$, $\eta_p^2 = 0.03$), the time by activity type interaction, ($p = 0.27$, $\eta_p^2 = 0.01$), the time by activity dose interaction ($p = 0.26$, $\eta_p^2 = 0.02$), and the time by activity type by activity dose interaction ($p = 0.59$, $\eta_p^2 = 0.01$). Although the time by activity type interaction was not significant, *post-hoc* exploratory analyses showed that TMT performance scores decreased significantly (i.e., participants performed better) among participants in the physical activity conditions ($p = 0.03$, $d = 0.30$) whereas they

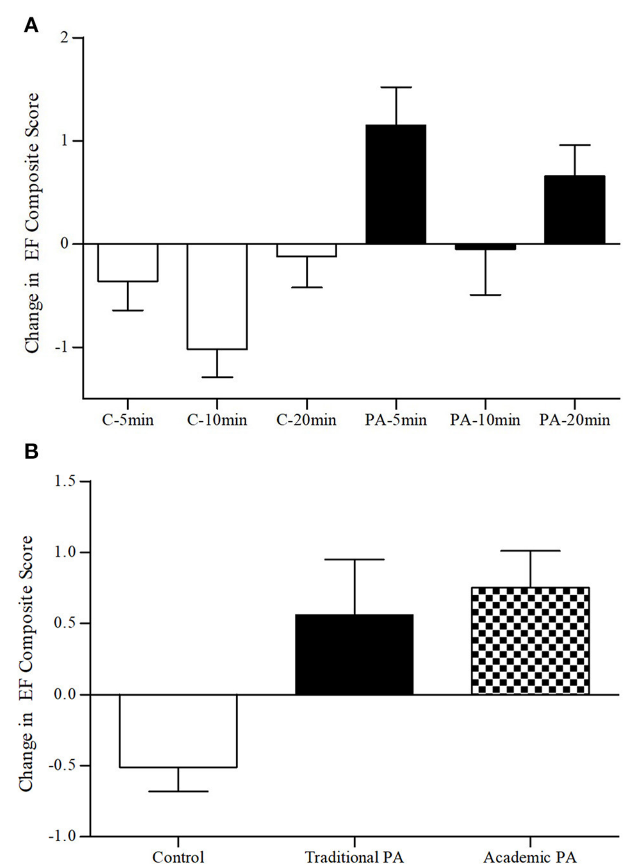

FIGURE 4 | (A) Change in executive functioning composite scores by activity type and dose. **(B)** Change in executive functioning composite scores by activity type. EF, executive functioning; C, sedentary control; PA, physical activity break; min, minutes. Error bars represent SE of the mean.

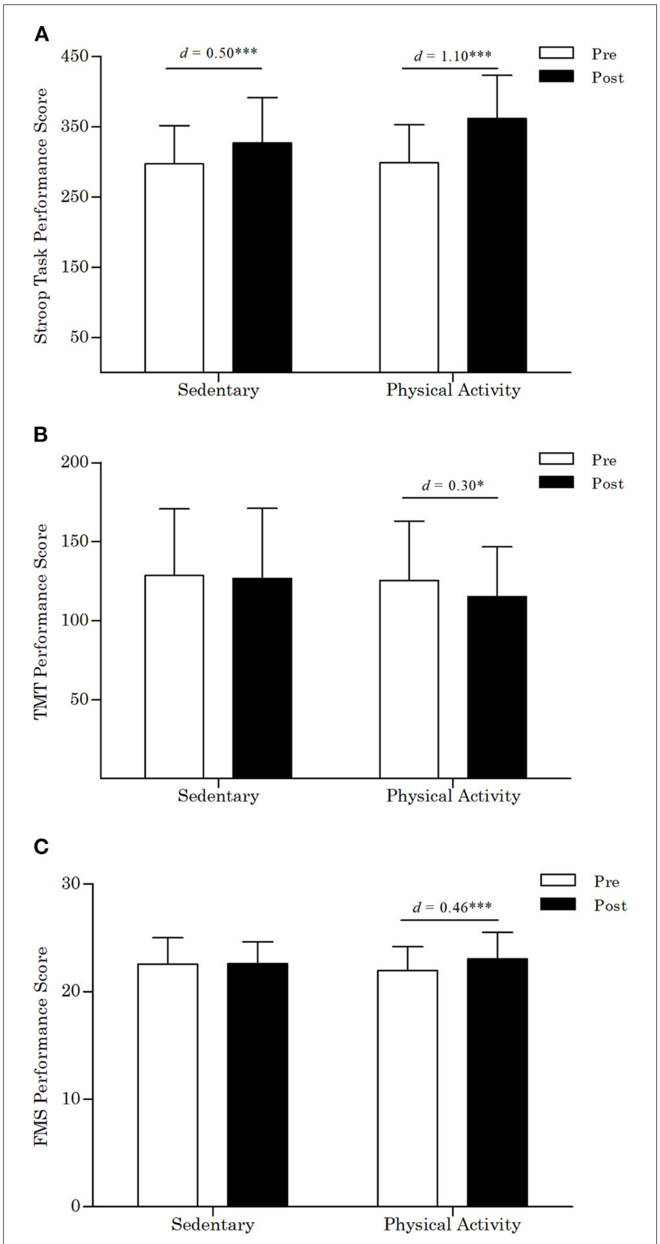

FIGURE 5 | (A) Stroop task performance scores by condition. **(B)** Trail making test performance scores by condition. TMT, trail making test. Lower scores indicate better performance on the TMT. **(C)** Forward memory span test scores by condition. FMS, forward memory span test. *d*, Cohen's *d*, $^{***}p < 0.001$, $^{*}p < 0.05$. Error bars represent SD of the mean.

remained relatively stable among participants in the sedentary control conditions ($p = 0.58$, $d = 0.04$), as depicted in **Figure 5B**.

Updating

Results of the 2 × 3 × 2 repeated measures ANOVA for the FMS test performance score revealed a significant main effect for time ($p = 0.01$, $\eta_p^2 = 0.06$) and a significant time by activity type interaction ($p = 0.01$, $\eta_p^2 = 0.06$). However, the time by activity dose interaction ($p = 0.26$, $\eta_p^2 = 0.02$) and the time by activity type by activity dose interaction ($p = 0.70$, $\eta_p^2 = 0.01$) were not significant. Specifically, as depicted in **Figure 5C**, FMS test scores increased significantly among participants in the physical activity conditions ($p < 0.001$, $d = 0.46$) whereas they remained relatively stable among participants in the sedentary control conditions ($p = 0.95$, $d = 0.01$).

Secondary Analyses

Mood

Results of the 2 × 3 × 2 repeated measures ANOVA for the positive mood scores revealed a significant main effect for time ($p = 0.001$, $\eta_p^2 = 0.10$) and a significant time by activity type interaction ($p < 0.001$, $\eta_p^2 = 0.28$). However, the time by activity dose interaction ($p = 0.13$, $\eta_p^2 = 0.04$) and the time by activity type by activity dose interaction ($p = 0.87$, $\eta_p^2 = 0.003$) were not significant. Specifically, as seen in **Table 2**, mood scores increased significantly among participants in the physical activity condition ($p < 0.001$, $d = 0.83$) whereas they decreased among participants in the sedentary control condition ($p = 0.01$, $d = 0.28$).

Motivation

Results of the 2 × 3 × 2 repeated measures ANOVA for the motivation scores revealed a significant main effect for time ($p = 0.001$, $\eta^2_p = 0.09$) and a significant time by activity type interaction ($p = 0.02$, $\eta^2_p = 0.05$). However, the time by activity dose interaction ($p = 0.57$, $\eta^2_p = 0.01$) and the time by activity type by activity dose interaction ($p = 0.62$, $\eta^2_p = 0.01$) were not significant. Specifically, as seen in **Table 2**, motivation scores increased significantly among participants in the physical activity condition ($p < 0.001$, $d = 0.25$) whereas they remained relatively stable among participants in the sedentary control condition ($p = 0.39$, $d = 0.05$).

Task Self-Efficacy

Results of the 2 × 3 univariate ANOVA for the self-efficacy scores revealed significant main effects for activity type ($p < 0.001$, $\eta^2_p = 0.13$) and activity dose ($p = 0.01$, $\eta^2_p = 0.08$). The activity type by activity dose interaction was not significant ($p = 0.54$, $\eta^2_p = 0.01$). As seen in **Table 2**, on average, self-efficacy scores were higher among participants in the physical activity break conditions when compared to the sedentary control conditions. LSD *post-hoc* analyses revealed that participants in the 5-min conditions reported significantly higher self-efficacy scores when compared to the 10-min ($p = 0.002$) and 20-min ($p = 0.02$) conditions, whereas the 10- and 20-min condition scores were not significantly different from one another ($p = 0.62$). However, as seen in **Figure 6**, higher mean scores for the 5-min break conditions were primarily driven by the 5-min physical activity break condition.

Moderation Analyses

Results of the first single moderation analysis (depicted in **Figure 3A**) revealed no significant main effects for condition (95% C.I. = −1.16, 1.17, $p = 0.99$) and SR laps completed (95% C.I. = −0.03, 0.01, $p = 0.33$) on the post-test executive functioning composite score. However, the condition by SR laps completed interaction was significant (95% C.I. = 0.01–0.05, $p = 0.04$), covarying for the pre-test executive functioning composite score. When probing this interaction, results from the Johnson-Neyman technique revealed a conditional effect ($p < 0.05$) at 25.40 laps and above on the SR test. This indicates, among participants in the physical activity break condition, those who completed 25.40 laps or above (i.e., 26 laps or above) experienced greater increases in executive functioning on the post-test when compared to participants who completed 25 laps or fewer. This was also a linear relationship as the conditional effect gradually increased alongside aerobic fitness levels (i.e., effect for 25.40 laps = 0.71 and the effect for 95.00 laps = 2.63). In other words, as aerobic fitness levels increased, executive functioning performance also increased whereby the most aerobically fit children showed the greatest improvements in executive functioning performance following the physical activity break.

Results of the second single moderation analysis (depicted in **Figure 3A**) revealed no significant main effects for condition (95% C.I. = −0.68, 5.07, $p = 0.13$) and SLJ distance (95% C.I. = −0.02, 0.01, $p = 0.68$), as well as a non-significant interaction (95% C.I. = −0.03, 0.01, $p = 0.49$), covarying for the pre-test executive functioning composite score.

Results of the additive moderation analysis (depicted in **Figure 3B**) revealed no significant main effects for condition (95% C.I. = −0.55, 5.37, $p = 0.11$), SR laps completed (95% C.I. = −0.03, 0.01, $p = 0.35$), and SLJ distance (95% C.I. = −0.01, 0.02, $p = 0.78$). However, the condition by SR laps interaction was significant (95% C.I. = 0.01, 0.08, $p = 0.01$), covarying for the pre-test executive functioning composite score. The condition by SLJ distance interaction was not significant (95% C.I. = 0.04, 0.004, $p = 0.09$), covarying for the pre-test executive functioning composite score. As both interactions were below $p = 0.10$, the conditional effects were examined. Findings revealed that the conditional effect for low levels of aerobic fitness (i.e., at the 16th percentile for SR laps) was not significant ($p > 0.05$) across each level of musculoskeletal fitness (i.e., at the 16th, 50th, and 84th percentiles for SLJ distance). However, as aerobic fitness increased (i.e., at the 50th and 84th percentiles), the effect of musculoskeletal fitness became significant across each level. These results suggest, among participants in the physical activity break conditions, that both aerobic and musculoskeletal fitness influence executive functioning performance but only beginning at moderate levels of aerobic fitness.

DISCUSSION

The present study investigated the acute effects of a classroom-based, teacher-delivered, physical activity break during math class on executive functioning in 11–14-year-old children when compared to sedentary seated classroom work. We also investigated the potential independent (see **Figure 3A**) and combined (see **Figure 3B**) moderating effects of both aerobic and musculoskeletal fitness on the acute physical activity—executive functioning relationship. Findings from the present study support previous literature illustrating how acute physical activity and physical fitness can promote aspects of executive functioning and cognition related to academic achievement and school readiness. Our findings also build on previous literature by demonstrating how aspects of physical fitness (cardiorespiratory and musculoskeletal) moderate the acute physical activity—executive functioning relationship. Together, these findings further highlight the importance of incorporating physical activity breaks throughout the school day and especially within a classroom setting.

Classroom-Based Physical Activity and Executive Functioning

Consistent with our hypotheses, children who participated in the physical activity breaks showed improvements in executive functioning across measures of inhibition, switching, and updating when compared to children in the secondary control conditions (depicted in **Figures 4**, **5**). These findings support previous research showing the efficacy for relatively short, acute, classroom-based physical activity breaks on aspects of executive functioning in children (19). Our findings also suggest that

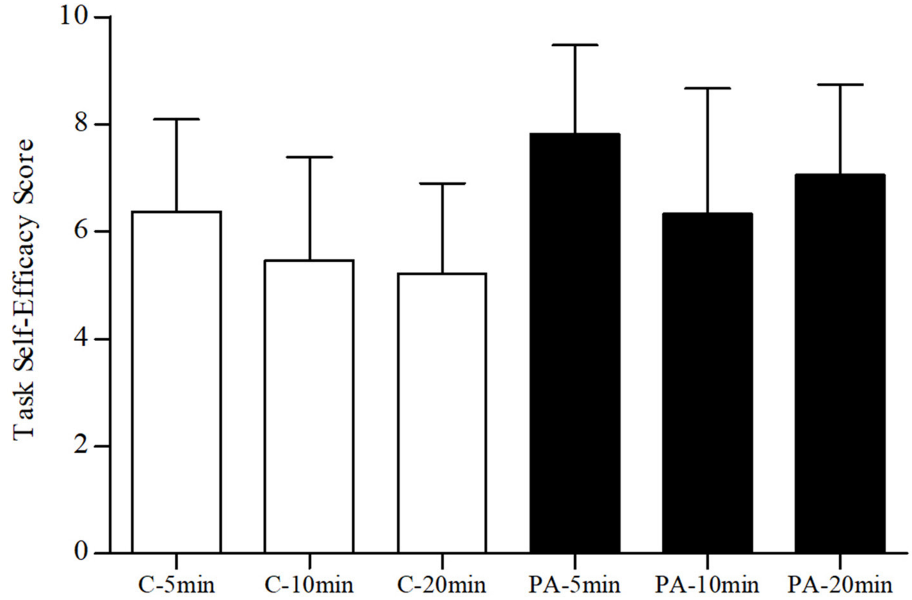

FIGURE 6 | Task self-efficacy scores by condition. C, sedentary control; PA, physical activity break; min, minutes. Error bars represent SD of the mean.

the 5-, 10-, and 20-min physical activity breaks uniformly, and positively, impacted executive functioning. These findings build on limited research examining the effects of different doses of acute classroom-based physical activity on executive functioning within a single study (43).

The lack of findings with regard to dose also have important practical implications as they suggest teachers can not only implement relatively short physical activity breaks (i.e., 5–10 min) and reap subsequent benefits on executive functions related to learning, but they also have implications for the implementation of school-based DPA initiatives across the school day. Specifically, findings from the present study suggest teachers can strategize how they implement DPA over the course of a school day while still reaping the acute benefits of physical activity breaks on executive functioning. For example, depending on the age of the students, subject, or lesson plans for that day, teachers could implement multiple 5- or 10-min breaks across the school day during instructional time to meet the 20-min DPA guideline in Ontario (as discussed in the introduction). Given previous research suggests teachers often struggle to implement 20 min of sustained DPA (23, 25) despite additional support [e.g., (84)], and when they do implement DPA the bouts generally last 5–10 min (25), our findings suggest that utilizing short physical activity breaks over the school day may provide an alternative strategy to implement DPA that could also have positive effects on physical, cognitive, and mental health outcomes over the course of a school year.

We also hypothesized that the academic physical activity breaks would lead to greater changes in executive functioning when compared to the traditional physical activity breaks and the sedentary control conditions. Unfortunately, we encountered an unexpected setback after baseline testing which limited data collection and access to participants at one school. This resulted in substantially fewer participants in the traditional physical activity break conditions ($n = 12$) when compared to the academic physical activity break conditions ($n = 37$). Although *post-hoc* analyses suggested these conditions did not differ significantly on changes in executive functioning and both conditions significantly outperformed the control condition (depicted in **Figure 4B**), our findings are limited when comparing the two types of physical activity conditions. The lack of differences between different types of activities requiring varying degrees of cognitive engagement, when compared to sedentary or control conditions, has also been observed previously (41). From a practical perspective, these results simply suggest that both types of activity breaks can be advantageous when compared to sedentary classroom work and that teachers can preserve instructional time by incorporating academic material within the physical activity breaks.

Results from the secondary psychological outcomes also provide insight to the positive carryover effects of classroom-based physical activity breaks (also see **Table 2**). That is, following the physical activity break, students reported higher levels of positive mood in general (e.g., happy and energetic), were more intrinsically motivated to invest effort into the executive function tests and felt that it was important to do so, and they also felt more confident (i.e., higher self-efficacy) in their ability to do well on the post-test executive function assessments when compared to the pre-test assessments. Independently, the findings with regards to mood, motivation, and self-efficacy are important and represent an underappreciated area of investigation with regards to potential psychological mechanisms for the acute effects of physical activity on executive functioning, including classroom-based physical activity breaks (85). However, collectively, the findings are that much more interesting. For example, it is likely that positive mood (or affective valence) following acute physical activity triggers a cascade of psychological responses that not only influence one's motivation and confidence to perform demanding cognitive tasks that involve executive functions but, in turn, may also help to buffer other maladaptive psychological responses (i.e., anxiety and doubt) that are often negatively associated with demanding cognitive tasks. Indeed, increases in mood, arousal, and affect are associated with both physiological and psychological processes related to task performance including motivation, self-efficacy, and aspects of executive functioning [for examples see (36, 86–92)]. Findings from the present study also suggest children felt the most confident in their ability to perform the post-test executive function assessments following the 5-min physical activity break (see **Figure 6**) which lends additional support to the rationale of breaking up DPA into shorter bouts over the school day and across subject areas.

Moderating Effects of Physical Fitness

Levels of aerobic and musculoskeletal fitness were both found to influence the acute physical activity—executive functioning relationship (depicted in **Figures 3A,B**). With regards to aerobic fitness, we found a moderating effect for performance on the shuttle run (SR) test whereby children in the physical activity conditions who completed 25.40 laps (i.e., 26 laps) or higher performed significantly better on the post-test executive function assessments when compared to children who completed <25 laps. In addition, a linear relationship was observed in the conditional effect output from the Johnson-Neyman technique indicating executive functioning performance increased as aerobic fitness increased. These findings support the potential influence of high levels of aerobic fitness following acute physical activity on executive functioning, however additional research is needed given inconsistencies within the literature (42, 55, 56, 58–62).

With regards to musculoskeletal fitness [i.e., standing long jump (SLJ)], findings from the single moderation analysis were not significant. However, findings from the additive moderation analysis (depicted in **Figure 3B**) were significant and extend previous cross-sectional research on the relationship between aspects of physical fitness and executive functioning in children (53). Specifically, findings revealed that levels of both aerobic and musculoskeletal fitness interact and positively influence executive functioning following acute physical activity beginning at moderate levels of aerobic fitness (i.e., 50th percentile = 37 laps on the SR test) across levels of musculoskeletal fitness (i.e., 16th percentile = 118.76 cm on SLJ, 50th percentile = 145.00 cm, and 84th percentile = 173.24 cm). In other words, musculoskeletal fitness enhances executive functioning following acute physical activity to a greater extent among children with moderate levels of aerobic fitness whereas musculoskeletal fitness has no added benefit for those with low levels of aerobic fitness (which aligns with findings from the single moderation analysis of aerobic fitness in the sense that low levels of aerobic fitness had no influence on executive functioning following physical activity). Moreover, examination of the conditional effects output suggests the interacting effects of aerobic and musculoskeletal fitness on executive functioning are, on average, highest among those with higher levels of aerobic fitness (i.e., 84th percentile = 57.48 laps on SR test), again highlighting the importance of high levels of aerobic fitness. Collectively, these results provide preliminary insight on the moderating effects of both aerobic and musculoskeletal fitness (i.e., when included as continuous variables) when examining the acute physical activity—executive functioning relationship. Yet, future research is needed to replicate these results.

The interacting effects of aerobic and musculoskeletal fitness on executive functioning following acute physical activity provide important considerations for school based physical activity initiatives. Specifically, many initiatives' primary focus is to increase physical activity levels throughout the school day to meet recommended guidelines and help eradicate the physical inactivity crisis among children and youth [as discussed by (6)]. In addition, these initiatives discuss various ways to increase physical activity during the school day, during before/afterschool programs, and the importance of using health and physical education courses to educate students on the value of engaging in physical activity regularly and, ultimately, to learn to be physically active for a lifetime. However, findings from the present study suggest that targeting physical fitness levels should also be a focus alongside increasing physical activity among school-based physical activity initiatives. For instance, it may be advantageous to target aspects of physical fitness during physical education (in addition to educating students on how to increase their fitness and physical activity levels) and then target physical activity levels within the classroom. By doing so, physical education specialists can indirectly affect students' academic achievement and school readiness (through physical fitness) while teachers can also directly reap these additional benefits following classroom-based physical activity breaks, especially if the breaks contain academic content. Although our findings are preliminary and were among 11–14-year-old children, the interacting effects of physical fitness on the acute physical activity—executive functioning relationship likely apply to other age groups where the acute effects of physical activity have been previously observed (e.g., preschool, elementary and high school-aged children, and youth). This however requires future research for confirmation.

Given the SR test is one of the most widely used and valid field-based measures of aerobic fitness among children and youth (78), very large datasets have been amassed that present normative ranges across sexes and age groups (79). As seen in **Table 1** from the present study, the average SR laps completed for the physical activity break condition was 39.02 and subsequent analyses within that condition indicated that boys completed 42.64 laps on average and girls completed 34.91 laps on average. As indicated in Table 3 from Tomkinson et al. (79), the 50th percentile range for boys aged 11–14-years-old is 36–48 laps and the 50th percentile range for girls aged 11–14-years-old is 28–29 laps. Using Table 3 and the quintile framework[1] outlined in Tomkinson et al. [(79), *p*. 7], boys in the present study would be

[1]Tomkinson et al.'s [(79), p. 7] quintile framework categorizes cardiorespiratory endurance levels as "very low" (below the 20th centile), "low" (between 20th and

classified as having "moderate" levels of aerobic fitness (between 40th and 60th percentiles) whereas girls would be classified as having "high" levels of aerobic fitness (between 60th and 80th percentiles). However, findings from the aerobic fitness single moderation analysis in the present study indicated children in the physical activity condition who completed 25.40 laps and above (i.e., 26 laps and above) experienced greater increases on the post-test executive function assessments when compared to children who completed fewer than 25.40 laps. Again, using Table 3 and the quintile framework outlined in Tomkinson et al. (79), 25.40 laps fall within the 20th percentile and a "low" level of aerobic fitness for boys aged 11–14-years old whereas 25.40 laps fall within the 40th percentile and a "moderate" level of aerobic fitness for girls. Therefore, findings from the present study suggest that, for children aged 11–14-years old, boys with low levels of aerobic fitness (and above) and girls with moderate levels of aerobic fitness (and above) show greater improvements in executive functioning following acute physical activity when compared to their peers with lower levels of aerobic fitness.

The above findings could have important implications within a school setting whereby teachers and/or the physical education specialist(s) have their 11–14-year-old students complete the SR test at the beginning of the school year to establish baseline levels of aerobic fitness. Results of this test would help identify if any boys or girls scored lower in aerobic fitness (i.e., below "low" for boys and "moderate" for girls) whereby they may not reap the additional cognitive benefits of an acute classroom-based physical activity break. If any students fall below this aerobic fitness "threshold," the physical education specialist may wish to target exercises, games, or sports that increase aerobic fitness early in the school year. As discussed by Tomkinson et al. (79), previous research suggests a 12-week aerobic training program in children (93) can lead to an increase in ∼20 centile points and should move children who score "very low" or "low" to a higher level of aerobic fitness whereby they reap the cognitive benefits of acute physical activity. In addition, aerobic training over time should also improve various aspects of physical health among the majority of boys and girls within this age range based on criterion-referenced standards for the SR test (94, 95).

Strengths, Limitations, and Future Directions

Findings from the present study provide several exciting avenues for future research, however there are several limitations that should be discussed. For example, although the study has high ecological validity as it was conducted in a classroom-setting, during math class, and teachers delivered the physical activity breaks to the entire class, we cannot be certain that each teacher delivered the physical activity breaks as instructed. Similarly, it is equally important to ensure that the physical activity breaks are delivered safely while maintaining a high degree of quality instruction. To achieve this, it may be worthwhile for teachers to receive a form of group exercise certification and/or work in conjunction with a physical education specialist.

Future research may wish to utilize pre-recorded videos designed for classroom settings, such as HOPSports Brain Breaks® (96), to ensure each student receives the same amount of physical activity. However, this may be challenging with regards to incorporating academic learning material alongside the physical activity breaks based on the subject, age, and lesson plan. As such, a mix of teacher-delivered and video-delivered activity breaks may be the most appropriate for the classroom setting. In addition to ensuring students receive the same dose and type of physical activity, it would be beneficial to assess whether students are actually engaging in the physical activity breaks. Following expert recommendations and previously established models, such as the CSPAP model [see (6)], is also encouraged in future work within school settings.

Another limitation was the small number of participants in the traditional physical activity break conditions due to complications we experienced with regards to our ability to collect data at one school. This also coincided with a relatively small sample within the 10-min physical activity break conditions as that school was assigned to the 10-min activity break conditions. While these setbacks were not anticipated, future research is encouraged to replicate the current study with equal cell sizes.

Although we observed some interesting differences between boys and girls with regards to the moderating effects of physical fitness, we recommend that future research investigates these relationships in greater detail. For instance, we found that boys with low levels of aerobic fitness (and above) and girls with moderate levels of aerobic fitness (and above) show greater improvements in executive functioning following acute physical activity when compared to their peers with lower levels of aerobic fitness. Given data suggests girls are generally less physically active and less physically fit when compared to boys and this gap tends to increase as they get older [e.g., (79, 97–99)], it would be worthwhile to investigate whether girls' executive functions (and academic performance) may benefit to a greater degree than boys over time through physical activity and physical fitness intervention research.

As previously mentioned in the introduction, research examining the effects of cognitively engaging physical activity and the integration of academic learning material alongside physical activity has been gaining significant interest. Various physiological and cognitive mechanisms as well as theoretical viewpoints have been proposed for the added benefit of this type of physical activity on executive functioning, cognition, and learning (19, 28, 29, 35, 36). However, with regards to classroom settings, Mavilidi et al. (19) recently proposed an innovative conceptual model and instructional method emphasizing the importance of considering which aspects of physical activity may be the most relevant (or similar) to the learning material. When the physical task and the cognitive or learning task are high on both integration and relevance [see Figure 1 on *p.* 7 from (19)], aspects of cognition and learning should be enhanced to a greater extent when compared to other combinations. For instance, traditional physical activity breaks during math class would be considered low on relevance and low on integration as the physical activity it not related to math. On the other hand, academic physical activity breaks that include solving

40th centiles), "moderate" (between 40th and 60th centiles), "high" (between 60th and 80th centiles), and "very high" (above the 80th centile).

math problems during math class would be considered low on relevance and high on integration since math is included during the break but the physical activity itself (i.e., jumping jacks, squats, running on the sport, etc.) is not related to the learning material. In turn, academic physical activity breaks should be more effective due to the higher degree of integration that facilitates cognition and learning. Mavilidi et al. (19) discuss several studies that fall under high integration/high relevance and future research is encouraged to utilize some of these strategies and to test this proposition both acutely and longitudinally across other age groups and subject areas.

CONCLUSION

The present study has provided supporting evidence for the acute effects of classroom-based, teacher-delivered, physical activity breaks on executive functioning. The results suggest 5-, 10-, and 20-min physical activity breaks led to similar improvements in executive functioning when compared to sedentary conditions. Following the physical activity breaks, participants reported higher levels of positive mood, were more intrinsically motivated to invest effort into the executive function tests and felt that it was important to do so, and they also felt more confident in their ability to do well on the tests of executive functioning. Moderation analyses suggest both aerobic and musculoskeletal fitness impact the acute physical activity—executive functioning relationship, however additional research is necessary to replicate these moderating effects.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by McMaster University Research Ethics Board and the Hamilton-Wentworth Catholic District School Board Research Ethics Committee. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

JG conducted the data analyses and drafted the initial version of the manuscript. JG and EB designed the study, coordinated and carried out participant recruitment, and data collection. BF assisted in data collection. JC supervised the design and execution of all phases of the study. All authors reviewed and approved the final manuscript.

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Rethinking children's physical activity interventions at school: A new context-specific approach

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Physical activity is important for children's health. However, evidence suggests that many children and adults do not meet international physical activity recommendations. Current school-based interventions have had limited effect on physical activity and alternative approaches are needed. Context, which includes school setting, ethos, staff, and sociodemographic factors, is a key and largely ignored contributing factor to school-based physical activity intervention effectiveness, impacting in several interacting ways.

Conceptualization: Current programs focus on tightly-constructed content that ignores the context in which the program will be delivered, thereby limiting effectiveness. We propose a move away from uniform interventions that maximize internal validity toward a flexible approach that enables schools to tailor content to their specific context.

Evaluation designs: Evaluation of context-specific interventions should explicitly consider context. This is challenging in cluster randomized controlled trial designs. Thus, alternative designs such as natural experiment and stepped-wedge designs warrant further consideration.

Primary outcome: A collective focus on average minutes of moderate-to-vigorous intensity physical activity may not always be the most appropriate choice. A wider range of outcomes may improve children's physical activity and health in the long-term. In this paper, we argue that greater consideration of school context is key in the design and analysis of school-based physical activity interventions and may help overcome existing limitations in the design of effective interventions and thus progress the field. While this focus on context-specific interventions and evaluation is untested, we hope to stimulate debate of the key issues to improve future physical activity intervention development and implementation.

KEYWORDS

physical activity, children, trial, context, intervention—behavioral

1. Introduction

Despite their considerable potential, current school-based interventions for children and young people have had limited effect on device-measured physical activity, and have not met their primary aim of increasing physical activity at a population level (1–3). A key challenge for the field is therefore to identify why these interventions have not yielded the hypothesized impacts and how they could be improved. In this paper we argue that context, which includes a combination of school setting, ethos, staff, and sociodemographic factors, is a key and largely ignored contributing factor to physical activity intervention effectiveness (4). Context impacts on the effectiveness of interventions in several interacting ways. The first is the way in which interventions are conceptualized. Most school-based physical activity interventions are tightly-constructed programs that fail to take account of the context in which the program will be delivered. This failure to take account of the context negatively affects generalizability and scalability. Second is ignoring context in the evaluation. We need to find a better trade-off between optimizing internal validity and understanding which interventions are effective and in which contexts. The third, often integrated, element is the focus on average minutes of moderate-to-vigorous intensity physical activity (MVPA) as the primary outcome, which may not always be the most appropriate choice or indicator of success. To address these issues, this paper first defines what we mean by context and outlines why failure to address context has hindered our ability to increase children's physical activity. We then propose an alternative **context-specific approach** to intervention design, in which the context informs the intervention content, choice of outcomes, evaluation design, and analysis. Finally, we provide an example of a forthcoming project that uses a context-specific design, the challenges that the study poses and how we intend to address them.

2. What is context?

Context has been conceptualized as a "a set of characteristics and circumstances that consist of active and unique factors that surround the implementation" of an intervention and its evaluation (4). This includes the cultural, social, economic, political, and/or organizational setting as well as the demographic, epidemiological, and socioeconomic characteristics of those delivering and receiving the physical activity intervention (5, 6). For school-based physical activity interventions, this includes the setting of the school, the demographic profile of the pupils, the facilities available, the attitudes, training and skill of school staff as well as school priorities and the interests of the children. It is important to note that some aspects, such as priorities, attitudes and training, are amenable to change, while others, such as school size, location, and pupil demographics, are fixed constraints.

3. Why is physical activity important for children and young people?

Physical activity is associated with improved physical and mental health across the life course (7, 8). Among children, physical activity is associated with lower levels of risk factors such as cholesterol and blood lipids, favorable blood pressure, and lower adiposity (9). These risk factors are more prevalent in children with a lower socioeconomic position (10). Physical activity is also associated with improved well-being, self-esteem, and academic performance in young people (11). Physical activity tracks from childhood into adulthood, with more active children likely to engage in both a higher amount and wider range of physical activities in adulthood (12, 13).

The World Health Organization recommends that children and young people engage in an average of 60 min of MVPA per day that can be accumulated across the day (7, 14). International collaborations and national surveys indicate, however, that many children and young people do not meet the current physical activity guidelines (15–17). Physical activity levels decline during childhood and adolescence with a steeper decline for girls than boys (16, 17). For example, data from around 2,000 children from 57 schools in the Bristol B-Proact1v cohort begun in 2012/13 showed that mean minutes of MVPA per day on weekdays declined by 2.2 min per year (95% confidence interval 1.9 to 2.5), between 6 and 11 years of age. National lockdowns during the COVID-19 pandemic resulted in acute changes to physical activity opportunity and provision, and emerging data show that physical activity and mental well-being declined during this time (18–22). The impacts of COVID-19 were more marked for children from lower socio-economic backgrounds and those without access to outdoor space (20, 23). Collectively, these data highlight a need to increase physical activity and prevent the age-related decline among children and young people.

4. How effective are current school-based approaches to increase children's physical activity?

Most attempts to increase physical activity among children and young people have been delivered at the school site, as schools provide opportunities to implement universal public health interventions to large numbers of children (24). Although there has been recognition that whole-school physical activity interventions, in which more than one element of the school physical activity provision is changed, hold considerable promise (1), most of the intervention literature describes single-component interventions (e.g., changing aspects of physical education) (2, 3). Meta-analyses have shown that, with a small number of exceptions, these programs have not yielded increases in MVPA (2, 3, 25–27). Often the "failure" of these interventions can be attributed to implementation issues such as the failure to deliver the program as intended, poor attendance, or lack of access to the intended resources, space, or time. For example, the Action 3:30 project trained existing school staff to deliver physical activity programs after school (28–30). The program was highly valued by the school, cost far less than existing provision, and found that children were more active on the days that they attended sessions, with an impact during the after-school period for those who attended. However, challenges within the school in relation to attendance and delivery (context) impacted on the overall efficacy, and the classic trial analysis found no overall

Abbreviations: MVPA, Moderate-to-vigorous intensity physical activity; RCT, Randomized Controlled Trial difference in children's physical activity (28–30). This is an example of an intervention that holds considerable promise in theory, but in practice, issues around school setting and delivery diluted the intervention effect and as a result, a potentially very useful program was deemed to be ineffective.

One way that context can impact on school-based research is the provision of outcome data. For example, the adherence to accelerometer wear time protocols has been identified as a moderator of whether a study reported a positive effect, with poor measurement adherence more likely in disadvantaged schools (3). Lower levels of data provision in more deprived areas can mean that a potentially impactful intervention can be missed as there are less data to determine whether or not the intervention was successful. A related issue is that pilot and feasibility studies are often conducted in carefully selected schools that are more supportive of the research process (i.e., a more supportive context), and tend to come from more affluent settings (31) This can result in an over-estimate of any intervention effect (31). Thus, there is a need to understand how context can impact on the data provided.

5. Why are current "normal" approaches not working?

We have identified how adherence to intervention fidelity and effectiveness of school-based physical activity interventions differ in different contexts, but context has rarely been considered in the design of physical activity interventions. A key issue here is that researchers often focus on implementing new programs rather than improving programs that already exist within a school, which results in additional content that may have limited buy-in or fit within the context. To improve existing provision, we need approaches that recognize and respond to differences at the school level (school-specific context) which affects both the way in which interventions have been conceptualized and the framework (both design and analysis) used to evaluate the interventions. Each of these is discussed below.

5.1. Context in school-based physical activity interventions

Globally, most school-based physical activity interventions have been developed using processes that are consistent with the MRC framework for complex interventions (32). This includes conceiving content based on models of behavior change, intervention mapping, and qualitative research to inform intervention content. New content is then piloted, feasibility studies are conducted and then if there is 'evidence of promise', studies progress to a definitive trial, usually a cluster randomized controlled trial (RCT). A key limitation of the way in which these steps have been conducted is that research teams have often paid little attention to the context within which the programs will be delivered.

We recently conducted a systematic review of paired pilot and definitive obesity prevention trials that involved children or young people (≤18 years of age). Most of these studies included a physical activity component. We then looked at whether there was risk of generalizability bias in the paired study (31), that is, features or context of the pilot study that were not generalizable to a full trial. Many of these studies failed to scale when tested in a larger trial as they did not focus on how the studies would be implemented in larger settings or different contexts, and had both delivery agent (delivered by highly competent members of the research team) and implementation support (extra support provided) biases (31). When the results from this review were combined in a meta-analysis, reductions in delivery agent and implementation support were associated with an attenuation of the effect size from pilot study to full trial. Further analysis showed that these biases were particularly likely to have been present in small pilot studies, where implementation biases led to misleadingly positive findings that were not replicated when scaled up in a full trial (31). This often reflects an over-reliance on highly-skilled deliverers who are motivated to see the intervention fully delivered, and these circumstances cannot be replicated in wider practice (33). Similar issues have been reported when attempting to implement programs that have been shown to be effective in 'efficacy studies' (34). Conceptually, this work also highlights the difficulty in trying to separate complex interventions from their context. It also raises the question of whether we should even be trying to separate content and context, as interventions are more than the sum of their parts, and the interactions and synergies across parts are likely to be essential for effectiveness. The recently updated MRC guidance for complex interventions highlights that "complexity might also arise through interactions between the intervention and its context" (35). It is therefore important to ensure that any intervention is "fit for purpose" within the context it will be delivered after the research period has ended. In practice this implies that for maximum impact, all school-based interventions should be tailored to the local context.

The current focus is on designing intervention content and ensuring that uniform intervention content is delivered in the same way in each school, regardless of context. Teams then evaluate whether the intervention is delivered as planned, with a focus on internal validity (2, 36). This is unhelpful, as schools may ultimately change some elements to make them work within their setting. As such, it may be more informative to conceptualize intervention components as "essential" and "peripheral." For example, we might argue that the provision of a new after-school physical activity club is a core component of an intervention but playground markings to support that activity (which may be important for a specific school, and their local context), would be peripheral. If we accept that there will be local adaptation, then identifying the degree of acceptable adaptation for just the essential components, and monitoring what adaptation occurs would be beneficial. This is in contrast to the standard approach of the field where the focus has been on tightly constrained interventions that are not adapted to the local context. This standard approach is not optimal as not only does it not take account of the culture, ethos, priorities, context, and complex systems in each school, but it actively attempts to control these factors to achieve consistency across settings. This results in the estimation of an average treatment effect which is unlikely to reflect un-controlled "real life" effects (Figure 1A). Instead, we argue that the focus should be on creating the best intervention approach for each setting for the agreed outcome of interest, and then seek an evaluation design that facilitates the assessment of the efficacy of that approach.

Understanding rather than ignoring the context is important because some schools will be in affluent, well-resourced areas with financial and in-kind support from parents, local authorities, and

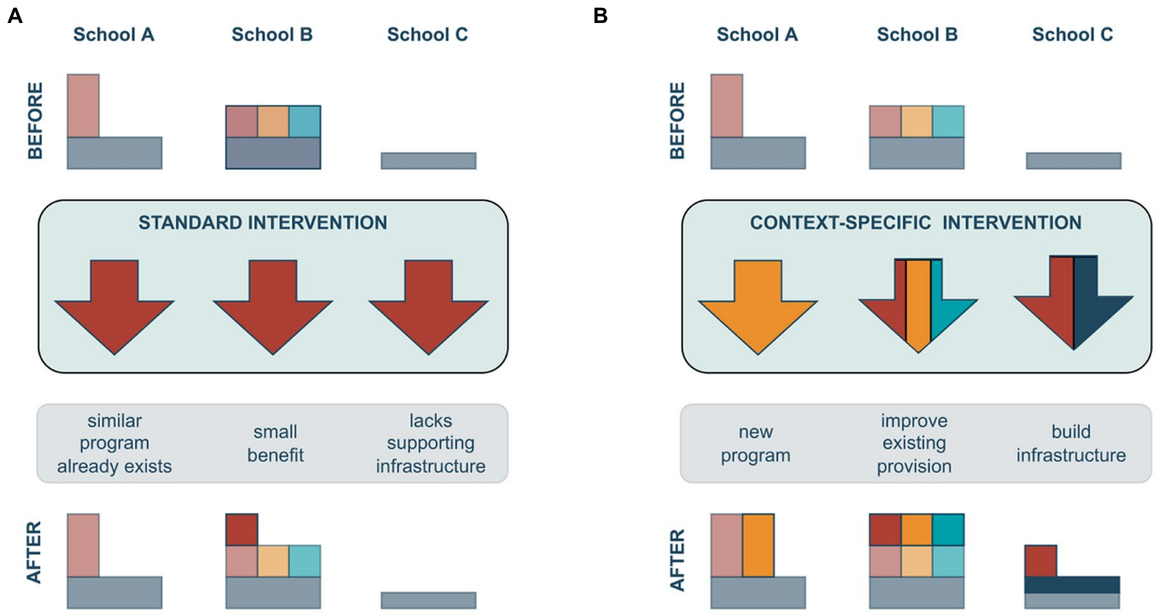

FIGURE 1
Standard intervention **(A)** compared to context-specific intervention **(B)**. In a standard intervention, each school receives the same intervention, regardless of school-specific context. In a context-specific intervention, the intervention is tailored to be most effective for each specific school.

third-sector groups, while other schools will be in more economically challenged or rural areas and may have very limited budgets, space or other challenges. These contextual factors have the potential to impact implementation within schools (37) and will shape what kind of physical activity intervention would be appropriate and successful. Schools may already have an initiative that mimics or is identical to an intervention program being offered, and so a "new" program may not be optimized for maximal impact. In other schools, specific activities may not be the best option due to logistical challenges such as space, staff ability or the interests of pupils. A more effective use of resources would be to provide support to extend the current provision. This is consistent with Beets' Theory of Expanded, Extended, and Enhanced Opportunities (38) which argues that focusing on expanding, extending, and/or enhancing the quality of physical activity provision, depending on the context, are ways to design more effective interventions for increasing physical activity among children within settings. This could be achieved *via* the creation of overall (all schools in a study) and local (school-specific) logic models or program theories to identify how the intervention is intended to operate in different contexts (Figure 1B).

While the importance and role of context has been discussed in the implementation of broader public health interventions (6), context is rarely considered at the earlier stage in designing a physical activity intervention (37). Any new initiative needs to work within existing infrastructure, school policy, staff capacity, pupil needs, and other aspects of the curriculum (39). An approach that works closely with schools, staff, and families from the outset of a project could enable a greater understanding of the particular communities, school culture, and any localized issues which may affect participation in physical activity. This could involve school staff working with pupils to co-create and prioritize activities and then sharing findings with all members of the school community to change the culture in the school. In this approach, there would be a procedure for co-creation that is universal for all schools and includes options provided for potential content. However, the final content in each school is decided upon by the school community. This would result in an individualized intervention at the school level with content tailored to the needs and preference of the school. Time spent building relationships over a long-term and embedding co-production principles such as the sharing of power, including all perspectives and skills, and reciprocity may also improve recruitment and commitment to an intervention (40, 41). This approach would prioritize programs that are consistent with the ethos and priorities of the school and students and thus have greater external validity (38).

5.2. Context in the evaluation of interventions

The evaluation of interventions comprises both the evaluation design and analysis methods. These are interlinked, as the study design dictates the available data and in turn the analysis that is possible, while the proposed analysis informs the design. Almost all physical activity interventions in children have been evaluated *via* cluster RCTs (2, 25–27). The cluster RCT design is well-understood and statistically robust, and a pragmatic choice when the intervention is randomly allocated at a group level and the focus is on individual outcomes. In a cluster RCT, context is typically treated as unmeasured factors to be addressed *via* randomization, which creates two interchangeable populations satisfying the conditional exchangeability assumption. However, school context factors occur at cluster-level and in a school-based intervention, there are often comparatively few clusters. While measured and unmeasured confounding factors are balanced between the two groups on average, estimates in any single trial may be far from the truth (42), and school context may differ substantially between control and intervention arms, especially with few clusters. Moreover, in a cluster RCT, unmeasured confounders will be present at both individual and school level. To understand how the effectiveness of interventions depends on different contexts, a cluster RCT should be designed specifically with this aim in mind, to ensure that a suitable range of contexts are included and that the study is powerful enough to allow comparisons between school contexts. This also affects the analysis, as not all standard analysis methods are capable of accounting for non-random differences in school context (for example, marginal models), and those that are will often be underpowered when using standard power calculations. As such, focusing on context may require adaptations to the study design.

School-level variability, which may be indicative of contextual differences, can be considerable and highlights the need to consider context. For example, analysis of the B-Proact1v data showed that between-school variability (attributable to unmeasured school-level factors) accounted for 15% of the total variability (43), compared to just 8% accounted for by key individual variables such as age, gender, and socio-economic position. These unmeasured school factors might include differences in intervention implementation (local context), differences in intervention dose, as well as covariates which differ between schools both randomly (random variation) and systematically (structured variation) such as school policies, ethos, and demographics. School-based physical activity interventions are typically both randomized and applied at school level, which means that school-level factors and between-school variability in outcomes become more relevant; for example, intervention effects can occur at both the individual and group level. This is particularly true if we seek to design interventions that take advantage of the school context, where it is important to understand not just whether an intervention works overall but also how it works, for whom, and in what setting. However, many traditional analysis approaches focus mainly on estimation of the average treatment effect, averaged across all schools (and thus contexts), and are underpowered for estimating school-level heterogeneity (44). Careful planning at the design stage is required to explore contexts where the intervention works well or poorly, for example to identify and collect relevant data, and ensure that there is sufficient variation across schools to enable estimation of differential intervention effects. Without considering such issues at the planning stage, evaluations will have limited ability to explore or fully exploit the context-specific features of an intervention that will best facilitate behavior change.

5.3. Outcome measures

The majority of school-based physical activity interventions have focused on the impacts of a program on physical activity and specifically average minutes of MVPA (26). This is driven by national and international physical activity guidelines which recommend that all children and young people engage in an average of 60 min of MVPA per day (7, 8, 14). Many studies are then powered to either detect a difference in the proportion meeting that threshold or a clinically-meaningful difference in mean minutes of MVPA based on a hypothesized change in potential future disease reduction (45–48). It is important to recognize, however, that the physical activity guidelines also recommend the development of motor skills, regular vigorous intensity physical activity and/or activities that develop cardiorespiratory fitness as well as muscle and bone strength. Apart from vigorous intensity physical activity (which can be determined using accelerometers), these elements are hard to quantify and are typically measured *via* self-report surveys. These outcomes and especially cardiorespiratory fitness (49, 50) can be linked to future health, and approaches that focus on improving these outcomes should be encouraged.

Improvements in physical activity during a discrete period, such as physical education lessons, can provide important benefits both in terms of short-term impacts on health and well-being and longer-term motor skill and competency development. These impacts are unlikely to be detectable when conducting a trial to test MVPA that is averaged and therefore attenuated across the week. This is a particular issue as trials of school-based physical activity interventions often have poor compliance with accelerometer protocols (3) and as such we would argue for consideration of a wider range of outcomes in the field. An example of a study with a non-MVPA primary outcome is the Burn 2 Learn RCT which focused on high-intensity activity breaks involving aerobic and resistance exercise in secondary schools (key for muscle and bone strengthening). This study showed that cardiorespiratory and muscular fitness were improved in the intervention group, but there was no impact on accelerometer-assessed average minutes of MVPA (51, 52). Similarly, the Activity and Motivation in Physical Education intervention increased MVPA during physical education lessons (primary outcome) but had no effect on overall MVPA (53), suggesting that a small impact on MVPA during one part of the day can be diluted when looking at averaged MVPA across the entire day. Each of these studies yielded a positive impact on a physical activity related outcome but would have been considered a "failure" if the studies had used the conventional focus on average minutes of MVPA, and highlight the potential utility of a wider set out outcomes.

6. Possible solutions

The evidence presented above highlights a need for a new approach to designing and evaluating school-based physical activity interventions. We have argued firstly that interventions should focus on the context within which an intervention will be delivered (targeting each school's needs) and secondly that the selected context-specific intervention should dictate the evaluation, rather than vice versa, and ensure that the design can answer relevant questions about relevant outcomes (Figure 2). As a result, we may need to consider alternative interventions, designs, and analyses (35, 54).

6.1. Intervention content

A co-produced intervention is an alternative to researcher-controlled and developed intervention content. Researchers could work with staff, pupils, and parents/carers to identify the current strengths and weaknesses of the school physical activity provision, strategies that focus on identified areas for improvement, and then develop components for that priority area (9). This would involve a level of engagement and collaboration with school staff that is consistent with the Creating Active Schools approach (55). Identification of intervention components could be informed by the

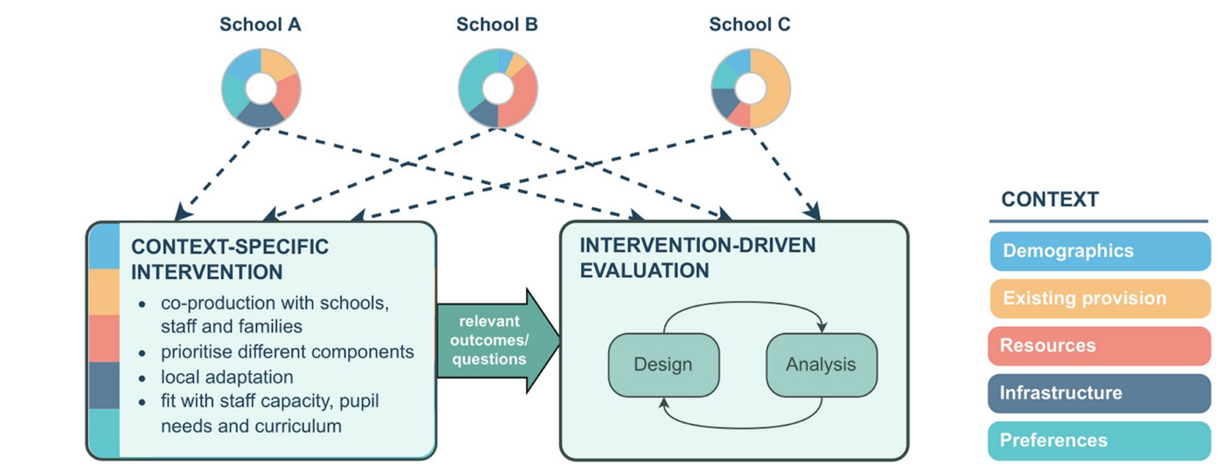

FIGURE 2
School-specific context feeds into the intervention design, and the intervention informs both the design and analysis.

Consolidated Framework for Implementation Research which encourages researchers to think about: (a) innovation characteristics, such as the adaptability of the "intervention" being implemented; (b) outer setting, such as external polices; (c) inner setting, such as school-specific resources; (d) characteristics of participants, such as pupil demographics and activity levels; and (e) the implementation process, that is, how the program is implemented in each school (10, 37, 56, 57). This approach was used to inform the design of the Burn 2 Learn study highlighted above (58) as well as the iPLAY intervention (59, 60). While this approach would have less consistency between schools and would require time to adopt, implement, and embed new programs, it would have far greater external validity as it reflects actual practice.

6.2. Evaluation designs

The evaluation design should be informed by the intervention itself, and one consequence of this is that design and analysis of an evaluation may need to be more complex, which may require additional statistical expertise. RCTs and cluster RCTs are traditionally considered the gold standard of evaluation design (61), and synthesis of studies in the area typically assess study "quality" against risk of bias criteria that are based on key aspects of the RCT design (62–64). However, the trade-off between bias and precision means that estimates are not necessarily more credible than those from any other design (42). As well as other randomized controlled designs, the importance of alternative evaluation designs is recognized in the recently updated UK Medical Research Council guidance for complex interventions which explicitly recognizes the need to consider a wider range of designs than just randomized controlled trials (35), including natural experiment designs (65).

6.2.1. Non-randomized designs

Non-randomized designs (natural experiments/quasi-experimental studies) (66), have the marked advantage that they can evaluate policies or programs as they are implemented in practice and so can provide "real-world" evaluations (67). Quasi-experiments, in which allocation to intervention arm is not randomized by the researcher, facilitate the assessment of whether a program or intervention is implemented and can be particularly useful when randomization is not possible, for example when a program has already been put in place, perhaps in some areas but not others, or when schools choose themselves whether to deliver a program. This therefore has the potential for greater external validity and comparisons can be made by matching to a control group, or estimating a counterfactual. However, as the allocation to intervention is not randomized, there are likely to be confounders that need to be accounted for (68).

Natural experiments are often used to evaluate polices or large-scale structural changes. They include a range of different designs including before and after, difference in differences, interrupted time series and synthetic controls (67). One limitation of natural experiments is that routine data on physical activity outcomes at an appropriate geographical and time scale may not be available. An example of an opportunistic natural experiment is the evaluation of the impact of the 2019 Australian bush fires on children's physical activity (69), where children were encouraged by local public health officials to limit outdoor physical activity during the fires due to poor air quality. In this study, the authors used data that were already being collected in a cluster RCT (59) to examine the impact of the bushfires on the device-measured physical activity of 8 to 10-year-olds. This design was possible as some children lived in areas that experienced bush fires while others did not. The authors used propensity score matching and a difference-in-differences design to compare those exposed to bush fires and those who were not. The study found that there was little evidence that the targeted public health advice had an impact on the children's physical activity so the specific intervention of advice during a challenging public health situation had limited impact. This evaluation is an example of how opportunistic natural experiments can answer key policy questions.

6.2.2. Randomized controlled designs

As discussed above, cluster RCTs are commonly used in the evaluation of school-based physical activity interventions, but these have limitations when considering context-specific interventions. The strength of the cluster RCT lies in estimation of the average treatment effect with minimal assumptions, but this is also their limitation when trying to understand how the effectiveness of interventions depends on different contexts as they can identify only the mean of the distribution of treatment effects. In complex situations, we may not be able to guarantee unbiasedness (for example, due to lack of blinding, or differences in the intervention delivery) and may additionally suffer from low precision due to potentially large between-school differences. More complex extensions may require custom power calculations, such as simulation-based methods (70), that focus explicitly on both the number of clusters, as well as the number of individuals. A key issue is that a much larger number of schools will be required compared to a standard cluster RCT design to ensure representation of a good range of contexts in both intervention and control schools. While techniques such as stratification or matching can address baseline differences in context, these are limited to a small number of clearly measurable factors, and so are not useful in isolation. In practice, it is not clear what school context factors affect children's physical activity, and there are likely to be many interacting factors, including difficult-to-measure factors such as school priorities, attitudes, and culture.

A design where each school acts as its own control would reduce the number of schools needed and maximize the information available on factors associated with the intervention. One example of this is the cluster randomized crossover design, where schools receive both control and intervention, with the order allocated at random (71). However, this is problematic for school-based interventions as it assumes that the intervention has no lasting effects, i.e., no carryover. For a context-specific intervention, this is an important consideration, as the order of intervention/control changes the context.

An alternative, pragmatic design is a cohort-based stepped wedge design in which all schools begin in the control arm and transition in a randomized order from control to intervention (see Supplementary Figure 1) (72). The stepped wedge (and related designs such as the Dynamic Wait-List design (73)) is a form of cross-over trial with randomization in a unidirectional sequence. The repeated measures make it possible to separate within and between-school variability to explore differences between schools and provides considerable statistical efficacy. For example, a standard two-arm cluster RCT with 50:50 randomization to intervention and control results in a quarter of all measurements being post-intervention. By contrast, a stepped wedge design has half of all measurements taken post-intervention and includes repeated measurements from schools. This still allows evaluation of the overall intervention effect but can additionally be used to explore school-specific factors, heterogeneity of treatment effects and change over time. However, because measurements taken under control conditions are systematically earlier than those under intervention conditions, there is greater risk of bias due to confounding by time, such as secular trends over time, between and within school correlations that change over time, and time-varying treatment effects (74). These must be treated analytically and so are at risk of misspecification and result in increased complexity in design, analysis and reporting (75).

7. Example: PASSPORT project

The goal of the **PASSPORT** project is to create a physical activity portfolio intervention that is sufficiently flexible to be adapted to the context of each school and includes elements that can be delivered across the school day to maximize the options within a school-specific context. In this approach, component parts of interventions that have shown promise will be identified by key stakeholders at the school (pupils, teachers, parents, and any relevant community groups), resources to deliver the content will be developed, and schools will combine elements to produce their own portfolio of components. A key focus will be adopting an implementation support framework so that the program is ready for dissemination based on the PRACTIS guide (76).

In this project, we are interested in evaluating the overall portfolio approach, i.e., the ability to select components and build something that works for each school, rather than any individual school-specific portfolio. However, we are also interested in how the effectiveness of the intervention varies with different school contexts, over time and in the individual effectiveness of selected core components. In this instance, the outcome of interest could either be average minutes of MVPA across the week or it could be a more context-specific weekday MVPA as the primary outcome with MVPA across the week as an important secondary outcome.

Initial power calculations suggested that a cluster RCT powered to explore all these questions would require an infeasible number of schools. Instead, we chose a stepped wedge design, which can evaluate the overall approach, but also maximizes the ability to explore school context factors, due to more intervention measurements and schools serving as their own control. It also lends itself naturally to looking at change over time. Furthermore, the repeated-measures inherent in the stepped wedge design mean that selected individual intervention components can be analyzed as a multi-arm stepped wedge natural experiment. Conceptually, this is related to a difference-in-differences design, but with the additional stepped wedge structure. We therefore plan to draw on several designs to best address the intervention-specific questions raised above.

8. Conclusion

Physical activity is critical for children's current and future physical and mental health, but current school-based approaches to increasing physical activity have had limited impact. Alternative approaches to both the design and evaluation of school-based interventions are needed. In this paper, we argue that knowledge of the school context is key, and we propose that the field should move away from tightly-constructed interventions that focus on maximizing internal validity, toward a more flexible approach that enables schools to tailor content to their specific setting, and for which the results will be more generalizable. We have also argued that the evaluation of interventions should be driven by the intervention itself, and that cluster RCTs have several limitations for school-specific interventions which depend on the school context. Alternative designs such as natural experiment evaluations and stepped-wedge designs warrant further consideration, as does the use of a wider range of primary outcomes that match the context of the intervention. We accept that the focus on context-specific interventions and evaluation is untested, but we hope that by presenting this argument, we can stimulate a debate of the key issues to improve future physical activity intervention development and implementation.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

RJ and RS conceived the paper, with ideas developed further by extensive discussions with FdV, MB, DH, DL, and CW. RJ is the study Principal Investigator. RJ and RS wrote the first draft of the paper. All authors reviewed the paper and made key intellectual contributions to content and reporting and approved the final manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1149883/full#supplementary-material

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Effectiveness of multilevel interventions based on socio-ecological model to decrease sedentary time in children: a systematic review of controlled studies

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Objectives: Preventive actions of sedentary behavior (SB) based on the socio-ecological model are needed among children and young adolescents. The aim of this systematic review is to ascertain the effectiveness of multilevel interventions (i.e., involving consideration of at least two interventional levels) in reducing sedentary time (ST) in children aged 5–12 years.

Methods: Adhering to PRISMA guidelines, a systematic literature search was conducted in three databases (PsyInfo, PubMed and ERIC) until July 2021.

Results: 30 trials met the eligibility criteria and were included. They showed acceptable (< 8, $n = 18$) and high (≥ 8, $n = 12$) methodological quality. Among studies targeting 2 ($n = 2$), 3 ($n = 19$) and 4 levels ($n = 9$), 1 (50%), 9 (47%) and 7 (78%) were effective and reported significant reduction of ST, respectively.

Conclusion: Interventions tend to be more effective when they involve 4 levels, using both agentic and structural strategies (targeting intrinsic determinants, in the organizational environment of the child). Findings underline the relevance of multilevel strategies to reduce ST in children, but also raise issues about operationalization of the socio-ecological perspective.

Systematic review registration: PROSPERO, identifier: CRD42020209653.

KEYWORDS

sedentary, intervention, prevention, socio-ecologic, multilevel

Introduction

Sedentary behavior in young populations: an increasing public health concern

Sedentary lifestyle or sedentary behavior (SB) refers to "any waking behavior characterized by an energy expenditure ≤1.5 metabolic equivalents (METs)" (1), such as reading, watching TV, or working on a computer. Among SB, "screen-related" SB (2) are particularly worrying this last decade. Indeed, Sedentary Time (ST) has been associated with poorer health outcomes in children (3, 4).

However, a significant part of children and young adolescents does not reach active lifestyle recommendations (5): SB (i.e., ≥4 h 30 min of daily sitting time) was identified in 76.8% of European adolescents in 2017 with no differences between girls and boys (6), and over the world, 81% of adolescents aged 11–17 years were insufficiently physically active in 2016 (7). In France, national surveys showed that screen-time increases with age: more than 50% of school-aged children (6–10 years) spent at least 3 h/day [ESTEBAN 2014–2016 survey, see Balicco et al., (8)]; and between 2007 and 2015 [Inca2, 2007, and Inca3, 2015, see Dubuisson et al. (9)], screen time was increased by 20 min on average.

The socio-ecological approach of sedentary behavior

There is a great demand in research for addressing public health issues by focusing on structural social determinants, particularly within the field of PA and sedentary lifestyle (10–14).

The socio-ecological model, based on the original work of McLeroy et al. (15) provides a useful comprehensive framework for this purpose. It marks a break with the cognitive behavioral-based approaches, by considering the social mechanisms of the production of health issues (16). The visual metaphor is a series of concentric circles representing different levels of influence on behavior. With a reciprocal determinism, each environmental level contains multiple types of environments (i.e., social, physical) and is in interaction with others.

Applied to the determinants of SB, this multifactorial approach states that these behaviors can be influenced by a multiplicity of levels, from the most proximal to the broader settings: intrapersonal [Psychological (e.g., self-esteem, attitudes toward SB) and physiological elements (e.g., capacities, health)], interpersonal [Social support of caregivers (parental rules, peers' behavior, encouragement from teachers...)], and organizational [Home; institution (care center, school): physical and social aspects (e.g., school wellness policy, garden equipment)] characteristics, and finally societal level including community Neighborhood, community environment (e.g., local associations) and public policies (Laws, national and local regulations (e.g., transport system, media, sports facilities in the city) (17).

The growing literature claiming for multilevel interventions assumed a larger effect on health outcomes, in comparison to single-level (intrapersonal) strategies but this argument suffers from limited empirical evidence (18–20).

Interventions targeting sedentary lifestyle in school-aged populations

Preventive actions of SB are more and more needed among children and young adolescents [WHO guidelines, (5)]. Studies evaluating these actions in children have been increasing these recent years, and several systematic reviews and/or meta-analyses were published this last decade. Overall, these studies highlight the high heterogeneity of trials and the difficulty to establish strong evidence regarding interventions for the promotion of a less sedentary lifestyle. However, promising strategies are mentioned such as behavior change interventions (21, 22), electronic TV monitoring devices or TV turn-off (13, 23). Family and high parental involvement is a crucial interventional strategy (22, 24, 25), and, when focusing on school environment and policy, studies showed that adequate and accessible facilities for PA, and that educational materials, pedagogic practices and standing desks in classroom are significant opportunities in reducing ST (13, 23, 26, 27).

Multi-component and mixed interventions, incorporating both behavioral and environmental components (27, 28) were also mentioned as promising.

To this day, no study has systematically examined the effectiveness of multilevel, socio-ecological-based, interventions on ST-SB only, depending on the types and number of levels targeted by the strategies used. A few reviews have investigated socio-ecological or multilevel interventions specifically but none has focused on the reduction of ST/SB: Mehtälä et al. (29) investigated socio-ecological-based interventions aiming to increase the level of young (2–6 years) children's PA; the review of Kellou et al. (30) aimed to analyze the effectiveness of interventions preventing overweight in youngsters by promoting PA; in a recent review, Bernal et al. (20) compared the effectiveness of school-based multi-component vs. mono-component interventions carried out to promote children's PA.

Therefore, the aim of the present review is to systematically summarize evidence regarding the effectiveness of socio-ecological model-based multilevel intervention strategies to reduce ST in children and young adolescents. It aims to answer the following research questions: are interventions using multilevel/socio-ecological framework and targeting SB effective to reduce ST in children? Are these interventions more effective when they target more levels? In addition, as previously mentioned, to reduce ST, family-based interventions could be more effective if they use a strong parental involvement as a key strategy and not just as a supervisory role. This has led us to consider, in this review, not only the settings or the levels of the intervention, but also the involvement or not, and the degree of involvement of caregivers or social support surrounding the child (e.g., parents, teachers): are these multilevel interventions more effective when they involve a stakeholder/level representative (e.g., teacher, parent) at a strong degree?

Methods

The present article reports a systematic review that has been conducted according to The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines. The review aims and methods were registered on PROSPERO (registration nr CRD42020209653).

Systematic literature search and inclusion/exclusion criteria

Studies were included when they met the following PICOS criteria:

(i) P(Population): studies on healthy human subjects (i.e., no clinical population) that involve school-aged children (i.e., between 5 and 12 years-old) were included; studies with preschool < 5 years old and adolescents aged more than 12 were then excluded; studies involving only high-risk populations, defined as children or young adolescents being overweight with high risk of obesity, obese, or specific clinical populations (e.g., young with pathologies, e.g., cancer, or any disease) were excluded. Studies comparing normal weight children and obese children were included when results for the normal weight children were described separately.

(ii) I (Intervention): I (Intervention): intervention had to consider the reduction of ST, even if other health behaviors (e.g., nutrition habits, PA) could be mainly targeted; studies with interventions targeting at least two among the five levels of intervention according to the socio-ecological model of McLeroy et al. (15) (i.e., intra-, interpersonal, organizational, community-, society-based) were included;

(iii) C (Control), only studies with a control, or a comparison group (e.g., alternative intervention) were considered;

(iv) O (Outcome): studies had to report measures related to SB (e.g., TV viewing, computer-use, sitting-time); either objective (e.g., accelerometry) or reported (e.g., questionnaire) measures were considered.

(v) S (Study design): to be included, the study design had to test an intervention and to involve a comparative group. Randomized (or cluster randomized) studies were included but randomization was not mandatory. Studies performed in laboratory settings, studies without a control or comparative group, and cohort studies were excluded.

Searching process

An electronic database search of PubMed (MEDLINE), PsycInfo and ERIC has been performed through the end of July 2021 (data published from 2000 to the present days, July 2021) languages restricted to English and French. We decided to start selection in 2000 as there has been growing consideration regarding ST and SB, and more particularly for a wide range of "screen-time related behaviors" (2) in these last two decades. Studies targeting only TV-viewing or computer-use seem to not accurately reflect a growing reality for children and young adolescents. Indeed, in young populations, most of the ST is made up of modern screen items that arose in the 2,000 decade (e.g., computer/laptop, smartphone, tablet (31). We used a combination of keywords related to sedentary lifestyle and screen-related behavior, public health interventions, preventive actions, and socio-ecological model, multilevel strategies or studies targeting several environments.

Finally, the research algorithm was the following: (sedentar* OR screen* OR multimedia) AND (intervention* OR promot* OR prevent*) AND (multi* OR ecologic* OR environment* OR context*) NOT (disease* OR patholog*). Limiters were the following: age ranging from 5 to 12 years; the study design: comparative, controlled, multicenter studies were included; the languages English and French; and the period of publication, starting from 2000 to July 2021.

First, the first author MCG selected eligible studies based on the title and/or the abstract and assessed the inclusion criteria to determine preliminary eligibility of studies. Following the PRISMA guidelines, at this first step of the selection on abstract, the author applied the PICOS method to check if the data fit the following inclusion criteria.

Second, MCG and MC separately read the full text, using the inclusion PICOS criteria to assess the final inclusion of articles. Any discrepancies were discussed until consensus was reached. MCG and SL extracted relevant data including methodology, participants, outcomes, and results. The following data were extracted: concerning the methodology, population details (country of intervention, number of and age mean or range of participants in control and intervention group), duration of intervention, use and type of theoretical framework, main setting (e.g., school, home) of intervention, study timelines. Each level targeted were identify; for the intrapersonal level, type of strategies (i.e., informational vs. behavioral) was detailed; in the interpersonal level, the type and degree of involvement ("+" if strong, meaning being active, "-" if rated weak, meaning passive) of caregivers (e.g., teachers, parents) were indicated. At the organizational level, type of setting was mentioned (e.g., school, home) with, for each of them, an indication of the kind of environment components (i.e., Physical, P, Social, S) targeted. Finally, results on SB-ST were briefly reported.

These elements are documented below in the summary Table 2, and described in results.

SL, PD, and MC checked the salient data and the methodological quality of trials included. Any discrepancies were resolved by discussion.

Methodological quality

The methodological quality of each trial was examined using an 11-item scale derived from Cochrane collaboration's tools for assessing risk of bias in RCTs (81). This adapted scale, used by Gourlan et al. (82) in their review, assesses information of studies regarding (1) the eligibility criteria for participants; (2) the details of the intervention provided for each intervention level; (3) if the process of the intervention implementation was monitored; (4) the specific objective(s) of the study clearly mentioned; (5) the calculation technique used to determine the sample size was mentioned; (6) the method used to randomize participants [if randomization was used]; (7) the blinding to group assignment of assessors; (8) the participants flow; (9) the characteristics of the care providers performing the intervention; (10) the baseline data of participants are described for intervention and control groups; and (11) the number of participants included in each analysis is mentioned. All items were coded as "yes" (+), "no" (-) or "not applicable" (NA).

Results

Studies selection process

The literature search yielded a total of 6,166 publications: 1,821 in Pubmed, 1,590 in ERIC and 2,755 in PsychInfo. The

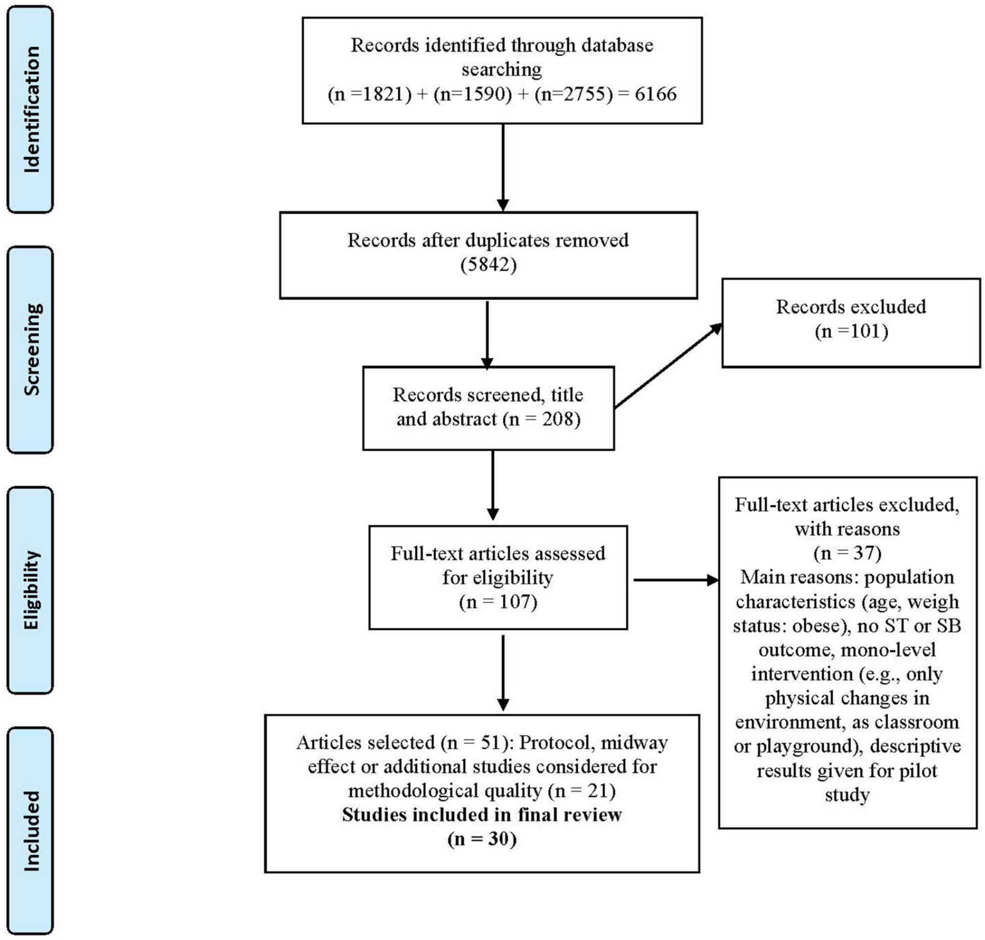

FIGURE 1
PRISMA flow diagram of the review (83).

searching and selection process is summarized in the flow chart presented below, Figure 1. After removing duplicates ($n = 5{,}842$) and checking eligibility of the studies, a total of 30 relevant studies were finally included in this systematic review (reported by 51 publications, including e.g., protocol, midway, follow-up publications).

Methodological quality

Briefly, based on the quality assessment form, most of the trials ($n = 18$ out of 30) demonstrated acceptable quality (i.e., rated under 8, on a total of 11 points), and 12 high quality (i.e., scoring ≥ 8). Concerning the criterion, the calculation technique used to determine the sample size of the trial was mentioned in less than half of the studies ($n = 12$ out of 30), and blinding to group assignment of assessors was mentioned in two trials only. Four studies were not randomized and among the others, 15 trials did not mention the method used to randomize participants. All studies clearly provided specific objectives, and most of them provided details of the intervention for each level ($n = 28$), participants' eligibility criteria ($n = 21$) and baseline characteristics ($n = 29$).

The following Table 1 summarizes the methodological quality assessment and reports the rate for each criterion and for each study selected.

Characteristics of trials included

The salient data are summarized in Table 2 with a description of the participants' characteristics and main details of the intervention (duration, settings, theoretical framework, assessment methods, main results on ST-SB, strategies by level targeted, degree of caregiver's involvement).

Briefly, the 30 trials were published between 2000 and 2020, in 2006 for the earliest and in 2020 for the most recent with 23 (77%) studies in the last decade. Eleven interventions were conducted in the USA, 15 took place in Europe (e.g., Poland, Sweden, France, Belgium), and 4 in New Zealand, or Australia. Populations from 10 trials were made up of low-income groups from deprived areas; one study (71) solely targeted boys. Baseline sample sizes ranged from 29 children in a pilot study (59), to 3,147 in a trial (79) involving young populations from five European countries. The duration of the delivered interventions ranged from 4 months in the pilot study

TABLE 1 Methodological quality assessment of interventions selected for the review (detail by criterion and global quality score).

	Eligibility criteria for participants	Details of the intervention provided for each level	Process of the intervention implementation was monitored	Specific objective(s) mentioned	Calculation technique used to determine the sample size mentioned	Method used to randomize participants	Blinding to group assignment of assessors	Participants flow chart	Characteristics of the care providers performing the intervention	Baseline data of participants (Int/cont groups)	Number of participants included in each analysis	Quality assessment score
Breslin et al. (32)	+	+	-	+	-	NA	-	-	+	+	+	6
Carson et al. (33)	+	+	+	+	+	+	-	+	+	+	-	9
Duncan et al. (35)	-	+	+	+	-	-	-	-	-	+	+	5
Elder et al. (36)	+	+	-	+	-	-	-	-	+	+	+	6
Elder et al. (37)	+	+	+	+	-	-	-	+	+	+	+	8
Engelen et al. (38)	+	+	-	+	+	+	-	+	-	+	+	8
Escobar-Chaves et al. (40)	-	+	-	+	-	-	-	-	-	+	-	3
Folta et al. (41)	+	+	+	+	-	NA	-	+	+	+	-	7
French et al. (43)	+	-	+	+	-	-	-	-	+	+	+	6
Gentile et al. (45)	-	+	+	+	+	-	-	+	+	+	-	7
Harrison et al. (47)	+	+	+	+	-	-	-	-	+	+	-	6
Kattelmann et al. (48)	+	+	+	+	+	+	-	-	+	-	-	7
Kipping et al. (84)	-	+	+	+	-	+	-	+	+	+	+	8
Kipping et al. (50)	+	+	+	+	+	+	+	+	+	+	+	11
Kobel et al. (55)	+	+	+	+	+	-	-	+	+	+	+	9
Lynch et al. (56)	+	+	+	+	-	+	-	-	+	+	-	7
Madsen et al. (57)	+	+	+	+	+	-	-	-	+	+	+	8
Ni-Mhurchu et al. (59)	+	+	+	+	+	+	-	+	+	+	+	10
Nyberg et al. (60)	+	+	+	+	-	-	-	+	+	+	+	8
Pablos et al. (62)	+	+	-	+	-	+	-	-	+	+	+	7
Pearson et al. (63)	+	+	+	+	-	+	-	+	+	+	-	8

(Continued)

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TABLE 1 (Continued)

	Eligibility criteria for participants	Details of the intervention provided for each level	Process of the intervention implementation was monitored	Specific objective(s) mentioned	Calculation technique used to determine the sample size mentioned	Method used to randomize participants	Blinding to group assignment of assessors	Participants flow chart	Characteristics of the care providers performing the intervention	Baseline data of participants (int/cont groups)	Number of participants included in each analysis	Quality assessment score
Salmon et al. (64)	+	+	+	+	+	+	-	+	+	+	-	6
Simon et al. (66)	+	+	+	+	+	-	-	-	+	+	+	8
Taylor et al. (70)	-	+	-	+	+	-	-	+	+	+	+	7
Todd et al. (71)	+	+	-	+	-	+	+	-	+	+	-	6
Van Kann et al. (72)	-	-	-	+	-	NA	-	+	+	+	-	4
Van Stralen et al. (73)	-	+	+	+	-	NA	-	-	-	+	-	4
Verloigne et al. (75)	-	+	+	+	-	-	-	-	+	+	+	6
Vik et al. (79)	-	+	+	+	+	-	-	-	+	+	+	7
Wright et al. (80)	+	+	-	+	-	-	-	+	+	+	+	7

of Lynch (2016) (56) to 30 months for the trial led by Wright (2013) (80).

Social-cognitive theories (of behavior change/motivation) (85, 86) and socio-ecological models (12, 15) are the most frequently theoretical backgrounds mentioned. However, most of the studies ($N = 18$) do not refer to the socio-ecological perspective, or any ecological anchoring, and six studies do not mention any theoretical background.

Among the 30 included studies, the main setting of intervention is school in 24 trials. More precisely, three studies targeted only the home environment, four interventions only the school environment, two studies involved home and community (city recreation center; participatory research) and almost half of the trials ($N = 14$) school and home. For the remaining studies ($N = 7$), interventions were implemented or involved both school, home and community (partnership with community stakeholders, e.g., medical staffs, community health workers, local municipalities, PA club educators, territorial and community agencies in charge of transportation infrastructures).

Reported outcomes included ST or SB for all of the studies, and in 28 (93%) trials, PA outcomes (e.g., steps, sport participation, MVPA) was measured as well; only two trials did not targeted PA: screen-time was assessed in addition to dietary variables, and beverage consumption and BMI (43, 63). Regarding sedentary assessment, 16 (53%) trials used only subjective assessment of ST-SB: 11 studies reported only self-declared assessment; parental/caregiver questionnaire only, and combined with self-reported measures, were respectively used in 4, and one (45) study; one trial (36) used observational data recorded by researchers. Objective assessment was used in 8 trials, that solely used a monitored or device-based method (e.g., pedometer, accelerometer). Finally, a combination of self-declared and device-based, and parent's and device-based assessments were reported in 3, and 2 studies, respectively.

Intervention components and strategies by level targeted

Table 2 summarizes the main characteristics of trials, and, for each targeted level, the type of strategy delivered. For the interpersonal level, we also considered the stakeholders/caregivers involved, and the strength of their participation.

Strategies used to deliver interventions can be described according to each socioecological model level.

Regarding the individual level (e.g., intrapersonal characteristics, such as attitudes, intrinsic motivation, skills), strategies were informational (e.g., passive: curriculum school program is designed to include health promotion and recommendation components about SB, energy-balance). Children sometimes received an educational program with key learning messages concerning various health determinants. Indeed, several interventions chose to include a multi-component strategy in delivering healthy messages: lessons and information could concern ST, PA, nutrition, or other health behaviors [e.g., (35, 48, 50)]. In this case, when the intervention aims to combine the messages on SB and physical activity with other health

TABLE 2 Main characteristics of trials and strategies by levels targeted.

References study name, design [additional study]	Population details; Country	Duration	Theoretical framework	Main settings	Study timelines	Assessment of SB-ST	Results on SB-ST	Intrapersonal level (Informational, behavioral components)	Interpersonal level (social support) and Caregivers' involvement (strong +/weak -)	Organizational level (physical (P) and social (S) components)	Community level
Breslin et al. (32) Sport for LIFE CT	N = 416 IG, n =209; Mage = 9.12 (0.37) CG, N = 207; Mage = 9.09 (0.35) low SES; Ireland	12 w	Social cognitive theory	School	Baseline and post	ST: accelerometers Screen behavior: Children survey	IG: ↓ SB (15 h-18 h and 18 h-bedtime)	Knowledge and behavior (class sessions and computer tailoring program; personal tailored feedback with specific suggestions to reduce screen-behavior)	Teachers (+) lead the implementation; principals and health nurses involved; Parents (+) (fact sheets informing and encouraging involvement in SB regulation + committees)	School and home (S)	
Carson et al. (33) Transform-Us! RCT [Salmon et al. (34)]	N = 293, 7 to 9y [SB] N = 74; [PA] n = 75; [SB+PA] N = 80; GC = 64; Australia	24 m	Social cognitive and behavioral theory; ecological systems model	School and family	Baseline and midway (5–9 months)	ST: accelerometers	[SB + PA] group: ↓ ST in weekday	Knowledge and behavior key learning messages (class lessons) (e.g., social support, feedback); standing class lesson per day (30mn) and 2-min light active break	PE teachers (+): delivered content and active break, promoted PA at recess, made equipment available parents (-): newsletters supporting the key learning messages delivered	School and home (S and P environment: standing opportunities in classroom, PA equipment and asphalt line in playground)	
Duncan et al. (35) Healthy Homework RCT pilot study	N = 97; (57 IG, 40 CG) 9-11y; low SES; New Zealand	6 w	Social cognitive/Behavior change theories	School and home	Baseline and post	Self-reported screen time: Children daily diary	No effect on SB	knowledge and behavior: homework booklet (5 PA and 5 nutrition topics) with reward, and in-class teaching resource; group presentations; Healthy Homework website	Teachers (+): active assistance, Parents (+) homework, tasks designed to encourage parental participation and knowledge formation	School and home (S)	

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TABLE 2 (Continued)

References study name, design [additional study]	Population details; Country	Duration	Theoretical framework	Main settings	Study timelines	Assessment of SB-ST	Results on SB-ST	Intrapersonal level (Informational, behavioral components)	Interpersonal level (social support) and Caregivers' involvement (strong +/weak -)	Organizational level (physical (P) and social (S) components)	Community level
Elder et al. (36) Aventuras para Niños RCT	13 schools, 5-7y children low-income neighborhood; USA	1y	Social ecological model	School	Baseline and post	Direct observation: Researchers collected SOPLAY data	Supervised area; Area with equipment: ↑ number of boys engaged in SB (IG) Area organized activity: ↑ number of boys engaged in SB (CG	Behavior Trained ambassadors; "walking clubs", "Super Aventuras" (activities options); incentives for participation (e.g., stickers, jump ropes, balls), training sessions	Parents (+): help for playground game marking Teachers (-): received feedback by the "promotoras" who led the implementation	School (S and P): line marking playground	
Elder et al. (37) MOVE/me Muevo RCT	541 families with children 5-8 y Public recreation centers in IG (n = 15), and control (n = 15); USA	2y	x	City recreation centers and Home	Baseline and post	ST: accelerometers	Non-significant differences on ST		Parents (+): household rules. 10-min telephone survey; 1½ hour group workshop with tip sheets (and by mail) at the recreation center, and a one-hour home visit. FU 10mn phone calls Recreation center directors (+): attendance of community members and enrollment of children in PA programs. Monthly meeting of recreational with intervention personal: action plan, monitor progress, and implement sustainable health policies	Home and recreation center (P and S aspects, e.g., healthy food and beverage offerings within the centers)	Health policies (recreational center) "community members"

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TABLE 2 (Continued)

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Engelen et al. (38) It's child play RCT [Bundy et al. (39)]	226 children (5–7 y); Australia	13w	Intrinsic motivation	School (playground)	Baseline, post and post+2years	ST: accelerometers	IG: ↓ in sedentary activity during break times during breaktime: ↓SB (IG p=0,01) after 2 years: maintain of the gains		Teachers (-) and Parents (-): task and discussion: examine their own experiences and beliefs regarding the benefits and risks associated with active free play	School (S and P: loose materials for playground)	
Escobar-Chaves et al. (40) Fun Families RCT	202 families (101 int/GC) children 8.2 ± 0.8 y; USA	6m	Socio-cognitive theory; mapping intervention process	Home	Baseline and post	Parent's survey: media environment, media used by child and family screen habits	IG: less likely to report the TV being on when nobody was watching and to have a TV in the child's bedroom trend toward reducing actual media consumption but did not reach statistical significance	Knowledge and behavior discussions about puppet show (TV and media), creation of his hand puppet, brainstorming about alternative activities, make a healthy snack	Parents (+): 2-hour workshop (puppet show, interactive, and discussions) and 6 bimonthly newsletters. Behavioral objectives (e.g., no TV in the child's bedroom); Common work families and children: ≪ Fun family plan ≫ alternative activities	Home (S and P: no TV in bedroom)	
Folta et al. (41) CT Shape Up Sommerville; [Economos et al. (42)]	GI = 647; GC = 1074 6-8 y culturally diverse urban communities; USA	2y	Social Ecological Model	School, home and community	Baseline and post	Family survey form filled by parents/caregivers	IG ↓ screen time ↓ Overall screen time (-0,24h/day)	Knowledge and behavior taste tests with adult coordinators, who supervised the meal and modeled healthy eating. Walk to School Campaign	Parents (-): home environment was targeted through parent nutrition forums and newsletters	School (S and P: beverages provided for snack in the classroom, sold as a la carte snacks to meet nutritional guidelines)	Community environment: restaurants: alternative to sugar-sweetened beverage partnered with community members (+) (id, design and implement/ evaluation)

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TABLE 2 (Continued)

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French et al. (43) RCT, pilot study; NET-Works; [French et al. (44)]	IG: $N = 25$ GC: $n = 15$ (5-12 y); lower-income, minority and overweight children; USA	6m	Socio-ecological and behavior change	Home	Baseline and post	ST: accelerometers Parents survey reported child screen habit	IG: TV viewing alone (h/day) was lower than CG after 24 months (-16%) and 36 months (-12%); TV and computer use was lower than CG after 24 months	Behavior Work with parents and children to limit screen time on all devices	Parents (+): home visit and 5 monthly telephone calls, TV locking device with discussion and agreement; other small screens: work to limit child use and implement family home rules	Home (S and P: locking device on TV, non-caloric beverages given)	
Gentile et al. (45) RCT Switch program; [Eisenmann et al. (46)]	GC $n = 674$ GI: $n = 685$ Mage = 9.6 (0.9); USA	9m	Brofenbrenner's Ecological Model	School and community	Baseline, post and 6months FU	Screen time reported by both parents and children	Post-intervention: ↓parents reported screen time (persistency after 6 month)	Knowledge and behavior Identify healthy behavior, attitudes toward changeset (Do, view, Chew); achievement, short- and long-term goals; monthly: materials and resources to facilitate healthy target behaviors; behavioral tools to assist parents and children	Parents (+): identify health behaviors, resources and materials for behavioral change Teachers (+): materials and ways to integrate key concepts into their existing curricula not required to participate	Home, community and school (S)	public education intervention leadership group: leaders and project grantors from education, health care, government, business and the faith communities
Harrison et al. (47) "Switch Off—Get Active" RCT	$N = 312$ 10.2±0.7 y school social disadvantage area; Ireland	16w	Social cognitive theory for behavior change	School	Baseline and post	Self-reported "1-day previous day physical activity recall" survey (PDPAR)	IG: no difference in self-reported ST individual school analysis: ↓ Screen time: for 4/5 IG and 2/4 CG		Teachers (+) (10-lesson, teacher-led intervention) Parents (+) encouraged in writing to support children in their attempts &check behavior	School and home (S)	

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TABLE 2 (Continued)

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Kattelmann et al. (48) iCook 4-H RCT; [Franzen-Castle et al. (49)]	228 youth (9-10y) –adult pairs; low-income and/or rural populations USA	12w	Social Cognitive Theory 4-H model of empowering youth	Home	Baseline and 4, 12, and 24 months	ST: accelerometers	IG: ST increased	Knowledge and behavior I-Cook 4H: curriculum about cooking, eating, and playing together for healthful lifestyles; website to share and interact	Parents (+): family activities; monthly newsletter that included the monthly challenge winners; Booster events: interact with other families (group playing games)	Home (S)	Community-based participatory research: Steering committees (research team, extension/4-H staff, Expanded Food and Nutrition Education Program staff (EFNEP), community members, and graduate students)
Kipping et al. (50) Active for life RCT, pilot study	*N* = 679 (9–10y); UK	5m	Social Cognitive Theory	School	Baseline and post	Screen based activities self-reported by questionnaire	IG: less time on screen-viewing than CG (non-significant). These differences were imprecisely estimated	Knowledge and behavior Lessons on healthy eating, PA and reducing TV viewing; games and activities	Teachers (+): led lessons	School (S)	

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TABLE 2 (Continued)

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Kipping et al. (50) AFLY5 - AFLY5 RCT [Lawlor et al. (51, 52); Dreyhaupt et al. (53); Anderson et al. (54)]	$N = 2221$; 8-9 y; IG $N = 1064$; CG $N = 1157$; UK	1y	Social Cognitive Theory	School	Baseline, post and 1-year FU	ST: accelerometers Screen viewing: self-reported by questionnaire	No effect on objective ST; After taking account of multiple testing in analyses: effect on self-reported time spent on screen viewing at the weekend (Saturday) in IG	Knowledge and behavior lessons on school-time (contents promoting PA, healthy nutrition, and strategies to achieve healthy behaviors) and games (same topics), family activities at home	Parents (+): newsletter and homework parent-child interactive homework activities (e.g., "freeze my TV", alternative active activities) Teachers (+): 16 lesson plans and teaching materials	School and home (S)	
Kobel (55) "Join the Healthy Boat" RCT	$N = 1736$; IG: $N = 954$; CG: $N = 782$ (7.1 ± 0.6 years); Germany	1y	Social Cognitive Theory	School	Baseline and post	Screen media use (SMU): parental questionnaire	SMU: IG: for girls, children without a migration background and children whose parents have low education level: ↓ screen media use by day.	Knowledge and behavior lessons (curriculum) and teaching materials offering action alternatives for recreational activities without screen media, PA, and a healthy diet + website to interact	Teachers (+): led lessons	School (S)	
Lynch et al. (56) Let's Go! 5-2-1-0 RCT, pilot study	$N = 51$, IG = 29, CG = 22 Mage = 8; USA	4m	x	School	Baseline and post	Reported ST: "Healthy Habits Survey" completed by caregiver	No statistical difference for ST	Knowledge key daily messages; Topics: weight, fruits and vegetables, recreational screen-time, PA, nutrition, sugary drink	Parents (-) and teachers (-): packet of information, prepared by the study team and sent home by teachers curriculum administered by nursing student, public health nurse, or a patient education specialist	School and home (S)	

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Madsen et al. (57) Energy Balance 4 Kids EB4K with Play RCT [Myers et al. (58)]	$N = 879$ GI = 583 GC = 296 4th and 5th grade low-income,; USA	2y	x	School	Baseline, midpoint, and endpoint	ST: accelerometers	no difference for ST; *post-hoc* analyses stratified by grade: 4th-grade IG: ↓ school-day ST	Knowledge and behavior 12-week nutrition and energy balance education/PA curriculum Playworks coach structured recess activities before and during school hours to encourage active participation and led a PA session with individual classes every other week	Parents (+) and teachers (+): trained to implement Playworks games and classroom management strategies in PE sessions team of school staff and parents to implement classroom wellness policies and make improvements in school food	S and P school environment: classroom wellness policies/school food packaging equipment for the district's central kitchen	Partnerships with national organization Play works; afterschool sports leagues
Ni-Mhurchu et al. (59) RCT, pilot study	$N = 29$ IG $N = 15$; 10.4 ± 0.9 y; CG $N = 14$; 10.4 ± 0.9 y; New-Zealand	6w	x	Home	Baseline and post	Frequency and duration of TV watching self-report by questionnaire	Time spent watching TV ↓ by 4.2 h/week in the IG but difference not statistically significant. Both groups reported decreases in total ST, between-group differences were not statistically significant		Parents (+) discussion: use of the Time Machine in the household, ideas to manage TV watching (e.g., rules as no TV during meal times, moving the TV)	Home S and P (time monitor)	

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TABLE 2 (Continued)

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Nyberg et al. (60) Healthy School Start RCT; [Nyberg et al. (61)]	$N = 243$, 6y and parents low to medium SES; Sweden	6m	Social cognitive theory	School and home	Baseline, post-intervention and at 6-months FU	ST: accelerometry SB: parent reported (EPAQ questionnaire)	Subgroup analyses showed a significant gender-group interaction: ↑ST in boys from IG	Knowledge and behavior classroom activities: children's knowledge, attitudes and preferences and parents' role modeling for healthy behaviors Homework activities with parents	Parents (+): brochure sent home: Health information facts and advice (e.g., PA, screen-time) Motivational Interviewing: provide support + choose goal (target child's diet or PA), agenda tool Teachers (+) led classroom activities (with teacher's manual), involved in material/tools development	School and home (S)	
Pablos et al. (62) Healthy Habits Program (HHP) RCT	$N = 158$; CG; $N = 76$; IG; $N = 82$ 10-12y; Spain	8m	x	School	Baseline and post	SB self-reported by questionnaire (Inventory of Healthy Habits)	SB: no significant changes (goal of less than 2 hours of total ST was not achieved)	Knowledge and behavior Healthy habits (diet, PA sleep and hygiene) + physical exercise session with games and worksheets	Parents (+) and teachers (+): talks for parents and teachers about healthy habits for school children; worksheet to complete at home, had to be signed each week by the parents	School and home (S)	

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TABLE 2 (Continued)

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Pearson et al. (63) Kids FIRST RCT, pilot study	ST and Snacking $N = 21$; ST $N = 25$ Snacking $N = 14$; CG $N = 15$ 9-11y UK	12w	Social ecological and Social Cognitive theories of behavior change.	School and home	Baseline and post	Screen Time self-reported by questionnaire (adaptation of ASAQ)	↓children's school day and weekend day TV/DVD viewing and computer game use in the ST + Sn (snacking) and ST, self-reported smartphone use ↑; study was not powered to detect statistical changes	Knowledge and behavior Key learning messages (knowledge about ST/Sn outcomes) delivered in online child classroom lessons; homework activities/challenges; learning message to be positive role models to family and friends	Parents (+): 1 online session and a package of resources (e.g. newsletters) strategies to participate in healthy ST and/or consumption of healthy snacks, Guide on how to implement behavior modification social support: learning message to be positive role mdels	School and home (S)	
Salmon et al. (64) Switch-2-Activity RCT; [Salmon et al. (65)]	$N = 1048$ 9-12 y; Australia	20w	Social cognitive and behavioral choice theories	School and home	Baseline, post and 18-months FU	Screen-based behaviors self-reported by survey	Screen based behavior: sex as moderator IG: ↓ST on week end for boys (-20min) self-efficacy reducing TV viewing: sex interaction IG > CG average change score IG: positive effect on boys and girls	Knowledge and behavior Introduction to AP and health; patterns of TV viewing and self-monitoring; selective TV viewing and behavioral contracting; identifying alternative activities and games; walking (pedometer) and games and activities developed by the children	Teachers (+) Delivering material (many teachers reported modifying it in some way)	School and home (S)	

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Simon et al. (66) ICAPS RCT; [Simon et al. (67–69)]	$N = 954$ CG: $n = 479$ IG, $n = 475$ 11-12y; France	4y	Socio-ecological model	School, home and community	Baseline, post and 2 years FU	ST Self-reported (adaptation of the MAQ questionnaire)	6months (Simon, 2006): proportion of IG adolescents spending > 3 h/day in sedentary occupations ↓ post: IG: ↓of TV viewing time (-16 min/day) FU (2014): differences in ST maintained	Knowledge and behavior objective: changing attitudes through debate and access to attractive activities during breaks and after-school hours, encouraging social support emphasis on fun, meeting with others and absence of competitive aspects	Parents, teachers, educators (+) social support: fostered to promote PA and to increase sports participation of children	school and home (S and P components) providing environmental conditions (e.g., accessibility) that enable PA	Event-specific activities numerous partnerships (medical staffs, PA and club educators, families, territorial and community agencies in charge of recreational areas and transportation infrastructures)
Taylor et al. (70) Active Schools: Skelmersdale (AS:Sk) pilot RCT	$N = 232$, 9–10 y CG: $n = 115$, IG: $n = 117$ low income; England	8w	Socio-ecological model, TEO, behavior change models	School	Baseline and post	ST: accelerometer	IG ↓ 9mn school ST	Behavior active breaks, bounce at the bell (suggested jump routine), 'Born To Move' videos, Daily Mile or 100 Mile Club (challenge), playground activity challenge cards	Teachers (+) PE teacher training Parents (+): newsletters, homework activity and letters	School and home (S and P components: playground installations)	

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Todd et al. (71) Pilot RCT	IG: $N = 11$ (10.0 ± 0.8) CG: $N = 10$ (9.7 ± 1.2) boys (excessive screen-use); USA	20w	x	Home	Baseline, midpoint (10w), endpoint	Electronic media time self-recorded on logbooks	10 weeks: IG: ↓ of electronic media use (-47%/day) and achieved target (< 90min/day); CG also ↓ (-24%) but exceeded the IG and the target (+29 min) At 20 weeks, IG media use remained 8 min/day below the target, CG 5min/day	Knowledge and behavior participants were matched in pairs; seminar designed to enhance awareness of electronic media use and to set goals to minimize use: family-centered interactive session,	Parents (+) follow-up daily with the children for completing data; interactive family session (TV), 3 newsletter (TV), follow-up phone call with recommendations	School and home (S and P components: monitor device on TV and computer)	
Van Kann et al. (72) Active Living project CT	$N = 791$ 8–11 years; deprived areas Netherlands	1y	Ecological systems theory	School	Baseline and 1y effect	ST: accelerometer	IG:−5,9% in SB (nonsignificant) -female gender: significant predictor for more SB (follow up) -children in 7th grade: more time in SB (follow up) intervention components: More and higher intensity PSI= ↓SB (after 12 months)	Knowledge presence of posters in school	Parents (-) communication in parental newsletters Teachers (+): Schools were supported in implementing physical and social schoolyard interventions to stimulate children's PA, e.g., teachers introducing schoolyard games	School S and P (equipment for playground, working budget)	Working groups, chaired by a municipal health service employee to identify environmental changes needed

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van Stralen et al. (73) Jump-In CT; [De Meij et al. (74)]	$N = 600$; GI $n = 259$ GC $N = 341$ Mage = 9.8 ± 0.7 y; disadvantaged areas; Netherlands	2y	Precede-proceed model, ecological and socio-cognitive theories	School, home	Baseline and post (20months)	self-reported TV-viewing behavior and computer use	Non effective in reducing TV-viewing or computer time	Knowledge and behavior Pupil follow up system, yearly monitoring instruments of PA, BMI and motor skills, personal workbooks for children and their parents with assignments to perform in class and at home and an instruction book for the school staff	Teachers/School staff (+) and parents (+) Parental information services including information meetings, courses and sport activities for parents	School and home S and P environment (e.g., offer of structural and easily accessible school sport activities)	Sports club and local municipalities (short term sports courses, sports competitions and PA game), coordinators and trainers of these local sports activities
Verloigne et al. (75) ENERGY project RCT, pilot intervention; Verloigne et al. (76, 77), Van Lippevelde, et al. (78)	$N = 372$ Mage = 10.9 ± 0.7 y IG= $N = 141$; CG: $N = 231$; Belgium	6w	Social ecological perspective	School	Baseline and post	ST: accelerometers	No differences in ST between IG and CG	Knowledge and behavior lessons: awareness and evaluation of sitting time, influencing factors at home, possibilities for activity breaks and active transportation, and Family Fun Event, brainstorming, homework and activities	Parents (+): newsletters to involve the parents; personalized messages and homework tasks to be completed at home Family Fun Event Teachers (+): six weeks lasting intervention was conducted by the teachers	School and home (S)	

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TABLE 2 (Continued)

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Vik et al. (79) UP4Fun RCT	$N = 3147$ Mage = 11.2 IG: $N = 1569$ CG $N = 1578$ 5 European countries	6w	Planned Promotion for Population Health and socio-ecological models	School	Baseline and post (short-term)	Screen time and breaking up sitting time reported by questionnaire, total ST and breaking up sitting time by accelerometry	No significant intervention effects on ST, neither for self-reported or accelerometer-assessed ST	Knowledge and behavior lessons: awareness and evaluation of sitting time, influencing factors at home, possibilities for activity breaks and active transportation, and Family Fun Event, brainstorming, homework and activities	Parents (+): newsletters; personalized and homework tasks Family Fun Event Teachers (+): six weeks lasting intervention was conducted by the teachers	School and home (S)	
Wright (80) Kids N Fitness RCT	$N = 251$; 8–12y urban, low-income neighborhoods; USA	4m	Community-academic partnered participatory research (CPPR)	School, home and community	Baseline, 4 months, and 12 months post	TV viewing/ computer game playing self-reported by questionnaire	TV viewing significantly decreased (to 4 months); effect was sustained at 12 months for males only	Knowledge and behavior: weekly 90-min sessions, PA/SB, nutrition education/behavior modification, and family involvement creative ways to exercise in a non-structured exercise program	Educational staff (+): staff professional development in health promotion and parents (+) family involvement sessions, newsletters and involvement as "active community stakeholders"	School (S) (School Wellness Policy involving dietary changes, staff professional development	Partnerships with local community clinics; nurse, trained community health workers and PE specialist; active community stakeholders (academicians, school administrators, teachers, parents)

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information, in an attempt to be more effective, it can be not easy to determine which component or part of the strategy was effective in reducing specifically ST, or an outcome isolated. Few studies (56, 72) mentioned informational determinants or knowledge in the intrapersonal level: e.g., delivering key learning messages (topics about weight, vegetables, recreational screen-time), presence of posters in the school. Cognitive components of strategies delivered could include goal setting to reduce electronic media, brainstorming, action-plan to achieve healthy behaviors or strategies to find alternative games and activities to replace SB. Mainly behavioral components were used in three interventions (36, 43, 70): e.g., active breaks bounce at the bell, playground activity challenge cards, training sessions, work with parents and children to limit screen-time. Most studies ($N = 21$) used a combination of informational and behavioral strategies (e.g., key learning messages during school lessons and a light active break; behavioral tools to modify behaviors and material and resources to identify healthy behaviors).

At the interpersonal level, one intervention component repeated in several designs of studies was the involvement of caregivers. Social support strategies were operationalized with the participation of parents, or other significant caregivers. The social circle, composed of people closed to the child, could be passively or actively involved: caregivers involved were mainly teachers and/or parents, but in some trials, school staff as principals, educators, health nurses, recreation center directors were also associated in the interpersonal level of intervention. Involvement was rated as "weak" (-) when passive: e.g., teachers who did not lead the lessons, but who were present during the intervention, who sent some information to the child's parents, who just received feedback from the research team who led the implementation. When their involvement was rated as strong (+), teachers could conduct the intervention, participate in material or tools development. Parents who took an active part in the intervention could attend workshops/meetings with their children, had activities or homework tasks to complete with children, or followed educational/motivational sessions with them. These study designs posit that having a supportive family environment can promote the targeted behavior change and be effective in reducing children's ST. Among studies ($N = 27$) targeting parents as social support (i.e., at the interpersonal level), 22 actively or strongly involved them, other studies targeted parents but with a more passive strategy (e.g., informational, as sending newsletters). In most studies ($N = 20$), implication of parents is linked with an involvement of school staff to target the entire social support of children (e.g., teachers, PE educators, nurses, educational staff in health promotion, recreational directors). This involvement is active in 17 trials.

At an environmental level (e.g., organizational, or institutional), almost half of the studies ($N = 14$) reported some physical components targeted: as for example, changes in the home or school physical environment (e.g., removing TV from the child's bedroom, install an electronic TV monitoring device, provide equipment and resources for physical activities, draw an asphalt line in the playground). Many studies were school-based [one was also recreational center based, (37)], some of them with a combination of school and home components strategies; few studies also included partnership with local municipalities, non-governmental partners, community stakeholders and external professionals (in the shape of collaborators in the field of nutrition, health staff, local community clinics, associations, municipal health employer, local sport clubs). Some actions were thus implemented outside of the initial institutional setting (e.g., steering committees with community members, afterschool sport leagues, sport competitions organized by sports clubs and local municipalities, event-specific activities in the community).

Few studies were community-based with a participatory research design (41, 45, 48, 80). In their intervention, Folta and others (2014) (41) targeted home and recreational centers, and the community environment by working with restaurants across the city to provide healthier options (e.g., offering more low-fat dairy products); the authors used a social ecological and systems approach, using community-based participatory research and involving community members in the development and implementation of the intervention. Kattelmann et al. (48) also used a similar design and formed steering committees composed of members of the research team, Expanded Food and Nutrition Education Program (EFNEP) staff, community members, and graduate students. Simon et al. (66) proposed, at the community level of their intervention, event-specific activities and established numerous partnerships (i.e., with medical staff, club educators, territorial and community agencies in charge of recreational areas and transportation infrastructures).

Effectiveness of interventions

Two studies targeted 2 levels (interpersonal and organizational), and all (100%) had high methodological quality (i.e., score equal to or higher than 8). Then, 19 studies targeting 3 levels (mainly intrapersonal, interpersonal and organizational), of which 14 (74%) had high methodological quality. Last, 9 trials used four-level strategies (i.e., intra-, interpersonal, organizational and community-based), of which 2 (22%) showed high quality, and 7 (78%) a lower quality score. No study achieved to target the macro-environment or public policies level (e.g., social and cultural norms via media, urban planning, transport system).

Effectiveness on sedentary outcomes was analyzed according to the number of levels targeted by the intervention, based on the socio-ecological model level stratification (see Figure 2). A trial was considered as effective when the study reported a significant impact of intervention on a sedentary measure at post- vs. pre-intervention; if several sedentary measures were reported and at least one showed a significant decrease of ST, the study was classified as effective.

As shown in the Figure 2, 1 (50%) of studies targeting 2 levels, 9 (47%) that targeted 3 levels and 7 (78%) trials that targeted 4 levels of intervention, were effective in reducing ST-SB.

Table 3 summarizes, for each trial, the effectiveness according to the number and type of levels targeted and to the methodological quality score.

As presented in Table 2, among the trials that used a 2-levels based intervention, all ($N = 2$, 100%) having high methodological

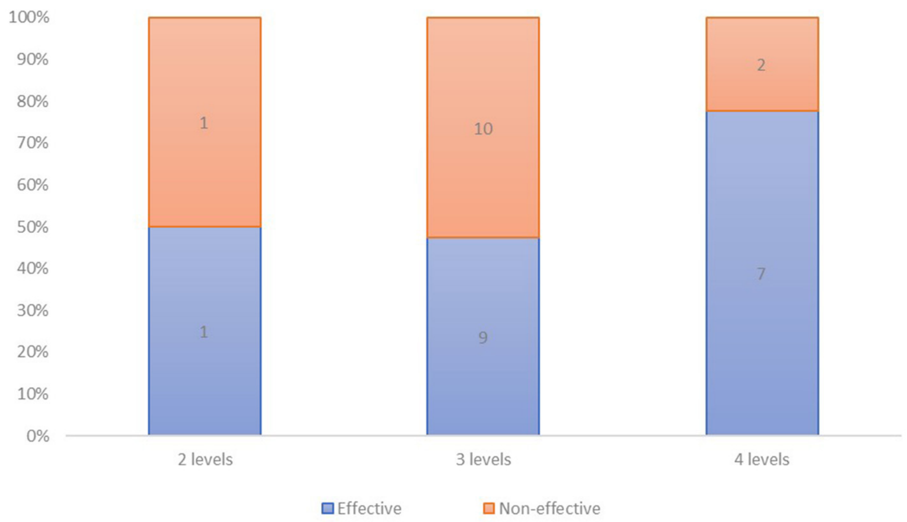

FIGURE 2
Number of interventions respectively reporting effectiveness and non-effectiveness on sedentary outcome, according to the number of levels targeted.

TABLE 3 Effectiveness on ST-SB of trials according to methodological quality score, number and type of interventional levels targeted (as defined by the socio-ecological model).

Number of levels targeted	Type of Levels targeted	Methodological quality score			
		≥8		< 8	
		Effectiveness on ST-SB	No effectiveness	Effectiveness on ST-SB	No effectiveness
2	Interpersonal and organizational	$N = 1$ Engelen et al. (38)	$N = 1$ Ni-Mhurchu et al. (59)		
3	Intrapersonal, interpersonal and organizational	$N = 6$ Carson et al. (33); Kipping et al. (50, 84); Subg: Kobel et al. (55)[a]; Nyberg et al. (60)[b]; Salmon et al. (64)[b]	$N = 7$ Escobar-Chaves et al. (40); Elder et al. (36); Harrison et al. (47); Lynch et al. (56); Pablos et al. (62); Verloigne et al. (75); Vik et al. (75)	$N = 3$ French et al. (43); Taylor et al. (70); Todd et al. (71)	$N = 2$ Duncan et al. (35); Pearson et al. (63)
3	Interpersonal, organizational and community		$N = 1$ Elder et al. (37)		
4	Intrapersonal, Interpersonal, organizational and community	$N = 2$ Simon et al. (66); subg: Madsen et al. (57)[c]		$N = 5$ Breslin et al. (32); Elder et al. (36); Folta et al. (41); Gentile et al. (45); Van Kann et al. (72); on subg: Wright et al. (80)[b]	$N = 2$ Kattelmann et al. (48); Van Stralen et al. (73)

[a]Gender and background migration; [b]gender; [c]grade.

quality, 1 (50%) was effective in reducing ST-SB. Among the high ($N = 14$) and the acceptable ($N = 5$) quality studies of the 3-levels trials, 6 (43%) and 3 (60%) were effective, respectively. Lastly, among the 2 high-quality and the 7 lower quality score interventions that used a four-level strategy, 2 (100%), and 5 (71%) were effective, respectively.

Regarding high quality studies, 9 (50%) reported effectiveness on ST-SB, and among those, 1 included 2-level, 6 involved 3-level, and 2 presented 4-level based interventions. Regarding lower quality studies, 8 (67%) reported effectiveness on ST-SB, and among those, none included 2-level, 3 involved 3-level, and 5 presented 4-level based interventions.

The second aim of our review was to consider the involvement, and the degree of involvement of caregivers or social support close to the child (involvement is reported in Table 2). Involvement was considered as strong when the stakeholder had an active role (e.g., a teacher-lead intervention during school class), and weak when only passive (e.g., parent receiving a newsletter with information about ST). Among the 22 studies targeting parents as social support with a strong or active involvement, 10 (45%) were effective in reducing ST-SB; among the 5 studies that targeted parents with a more passive strategy, 4 (80%) have reported effectiveness; in 3 of these trials, teachers, community members and recreational centers directors were also, and strongly, involved. Above the 30 included interventions, implication of parents is often associated with an involvement of educational stakeholders (e.g., teachers, educators in health promotion, educational staff, recreational directors, nurses). Among the 17 effective trials that considered social support as an intervention strategy, 2 (12%) involved parents only; 3 (18%) involved educational stakeholders only and 11 (70%) involved both parents and caregivers from the educational environment, one involving parents and community stakeholders.

Finally, among the 21 studies involving educational stakeholders (e.g., teachers, educators in health promotion, educational staff, recreational directors, nurses) with a strong or active involvement, 13 (62%) were effective in reducing ST-SB; among the 5 studies that included weaker involvement of educational stakeholders, 1 (20%) has reported effectiveness.

Discussion

An important part of the scientific literature states that health behaviors linked with SB are influenced by intrapersonal factors, but also interpersonal and environmental determinants (11, 16, 17). Consequently, socio-ecological models and structural perspectives are drawing the attention of researchers (10, 13, 87). On a practical level, the combination of agentic and structural approach is operationalized by multi-level interventions that target multiple determinants, and use strategies at several levels of influence.

The purpose of this systematic review of the literature was to study and critically summarize controlled multilevel trials (i.e., targeting at least two levels of intervention) aiming to reduce SB (e.g., specific SB as TV-viewing, general ST), as primary or secondary outcome (e.g., it could first targeted PA) in young populations (children, from 5 to 12 years-old), and evaluate their effectiveness in relation to the number and the type of levels targeted (i.e., intrapersonal, interpersonal, organizational, and community), the methodological quality and the strategies (e.g., informational, behavioral, involving family and teachers) used in each level. To our knowledge, this is the first review that targets multilevel interventions specifically aiming for sedentary outcomes.

Main findings

Final review included 30 controlled studies (most of them were published in the last decade) that involve 2, 19, and 9 interventions targeting 2, 3, and 4 different levels, respectively. Most of the included studies showed a high methodological quality score. However, in line with previous findings (22, 23, 30), the characteristics of included studies were heterogeneous, regarding the duration of the intervention (pilot studies had a shorter duration), population characteristics (e.g., size, age range, socioeconomic profile), settings (e.g., home, recreational center, school), assessment methods of ST-SB (i.e., subjective, objective, a combination of both measures), interventional strategies raised, leading to a difficulty to draw clear conclusions regarding the strategies and components that could preferentially reduce ST in children. Very few studies targeted 2 levels of intervention, also resulting in difficulty to make strong conclusions and to allow meaningful comparisons between 2-levels trials and other multilevel (i.e., 3- and 4-levels) studies. Most of the included multi-level interventions targeted 3 levels, mainly intrapersonal factors, interpersonal or social support level and organizational level (e.g., school, home). As young populations usually spend most of their time at school, this institution is a critical and major setting of interventions. Some interventions involved the community level, but none included study has achieved to target the society level (macro-environment).

Regarding effectiveness to reduce SB in children, effectiveness was reported in 1 (50%), 9 (47%) and 7 (78%) interventions targeting 2, 3, and 4 levels, respectively. Results suggest that interventions could be more often effective when the strategies used are deployed along 4 levels. However, only two studies used a 2-level strategy, providing insufficient evidence to rigorously conclude, and more than 70% of the 3-level studies have a high quality, whereas the majority of 4-level trials (78%) has an acceptable methodological quality.

This review secondly aimed to consider the involvement of caregivers in the effectiveness of trials. Again, the low number of trials and the heterogeneity of the interventions does not allow to drive specific and clear conclusions and, therefore, to answer this question. However, it seems that an involvement of caregivers (parents but also educational stakeholders, teachers in particular) could be a relevant strategy, targeting the entire social support of children. This design is based on the assumption that having a supportive family environment can promote the targeted behavior change and be effective in reducing children's ST. In this study, results show that among effective trials that considered social support as an intervention strategy, most of them (70%) involved both parents and educational caregiver or community members and among the studies strongly involving educational stakeholders, 62% were effective in reducing ST-SB.

Results ultimately suggest that the key ingredients of a successful intervention may involve a combination of several components: (i) at the intrapersonal level, both behavioral (e.g., setting screen-time goals) and informational strategies (e.g., often in the regular curriculum of the child), (ii) at the interpersonal level, a supportive and highly involved social circle by including teachers and parents, (iii) at the organizational level, targeting several child's environments (school and home) and (iv) at a community level including stakeholders (e.g., partnership with local sport clubs, local municipalities).

Limitations and perspectives

Limitations of this work could be mentioned. First of all, a meta-analysis would have led to strongest conclusion. However, as previously raised, trials of very different nature met the inclusion criteria and were included and reviewed. Given the large heterogeneity in study design and intervention's characteristics, strong and relevant comparisons and analyses were difficult and it appeared that a meta-analysis was not relevant. This work also raised some methodological issues. The systemic approach proposed by the socio-ecological model is promising (10, 13), but also intimidating, integrating and conceptualizing different levels of the environment. Therefore, a challenge still remains in the *operationalization* of this model, such that *socio-ecological* is not a "buzzword" in public health (19), and in finding the methods for assessing the degree of integration of the socio-ecological model into research (87–89).

Future studies should analyze the impact of their intervention on ST-SB by specifying the type of SB (e.g., time spent reading, watching TV) and context (e.g., location or social situation). It is highly unlikely that a reduction in a specific SB will be directly replaced with PA; actually, it has a greater chance to be allocated to other SB (21, 22, 90).

When subjective assessments are used, different types of SB should be taken into account and lead to a comparison between different distinct behaviors (e.g., computer time vs. screen time) targeted by interventions (22). Domain-specific SB should be identified, with, as suggested by Owen et al. (13), a consideration of passive (e.g., TV viewing) vs. mentally active (e.g., reading, computer use) SB. Future trials should target other types of sedentary behavior, including non-screen-based measures, and consider the recent technological changes (3), given that this last decade, the use of small screens, as smartphones and tablets, is increasing in children.

In addition to the identification of domain-specific SB, there is a growing need to operationalize the distinction between passive (e.g., TV viewing) vs. mentally active (e.g., reading, computer use) SB (13). Moreover, the challenge of school-based interventions, even when they include home activities or home components in their strategies, is to reduce ST both at school and out of school. Another perspective thus concerns the need to interrupt ST during the whole day, as pointed out in the literature (30, 91, 92) and in the latest worldwide guidelines (5).

Targeting intrinsic levers in intervention strategies is important as only focusing on the environment of the child is not enough, considering that young people tend to select sedentary activities, even when physically active alternatives are available (22, 90, 93). On the other hand, targeting intrapersonal determinants to the detriment of the broader environment and of structural and political changes is an incomplete strategy. Future studies should use ecologic approach -e.g., targeting norms, physical components-, with a strong and active involvement of caregivers (social support) in the various environments (e.g., school staff, parents at home) of the child, in addition to curriculum or behavioral punctual strategies. Multilevel or socio-ecologic interventions should involve community level and the broader environment, as none included study has achieved to target the society level.

Conclusion

A paradigmatic shift is occurring in the literature, and interventions targeting health behaviors are more and more multi-level or socio-ecological based. To our knowledge, no study had systematically reviewed and assessed the effectiveness of multilevel controlled trials targeting ST-SB in young (5–12 years) populations. Our findings show that more than half of the included interventions based on socioecological model (i.e., multilevel) have reported effectiveness of children SB. Indeed, among included studies, effectiveness on children SB was reported in 50%, 47%, and 78% interventions targeting 2, 3, and 4 levels, respectively. Therefore, results suggest that interventions could be more often effective when the strategies used are deployed along 4 levels. In addition, it seems that targeting four different levels i.e., intrapersonal, interpersonal, organizational and community, tend to led to more successful interventions to reduce SB.

This review highlights the need for additional randomized controlled trials evaluating multilevel interventions targeting ST-SB in young populations. More studies designing and implementing multilevel interventions are needed to "address the gap between theory and practice" (19) and remove operational and empirical hurdles. In addition, more reviews and meta-analyses are required to clearly assess their effectiveness and the key strategies underlying their effectiveness. Also, a theoretical and methodological reflection to quantify the degree of integration of the socioecological model in studies has to be continued to correctly evaluate the socio-ecological perspective.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

MC-G selected eligible studies and assessed the inclusion criteria to determine preliminary eligibility of studies based on the title and/or the abstract. Following the PRISMA guidelines, MC-G applied the PICOS method to check if the data fit the following inclusion criteria. MC-G and MC separately read the full text, using the inclusion PICOS criteria to assess the final inclusion of articles. Any discrepancies were discussed until consensus was reached. MC-G and SL extracted relevant data including methodology, participants, outcomes, and results. CD brought his expertise to this work and ensured the overall review of the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Configurations of actual and perceived motor competence among elementary school children in China: differences in physical activity

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Background: Actual motor competence (AMC) and perceived motor competence (PMC), as determinants of children's active participation in physical activity (PA), were important for children's healthy development. The correlation between the two had been confirmed. To further understand this relationship, this study investigated the current status of AMC, PMC, and PA in Chinese school-age children, used a person-centered approach to reveal the characteristics of the development of motor competence (MC) in Chinese school-age children and the differences in the level of PA among different MC profiles of children.

Materials and methods: A total of 532 children (age: M = 9.37, SD = 1.80 years-old) from grades 1 to 6 participated in this cross-sectional study (male, n = 284, 53.4%; female, n = 248, 46.6%). The Test of Gross Motor Development-3 (TGMD-3) was used to measure children's AMC, the Pictorial Scale of Perceived Movement Skill Competence (PMSC) to measure children's PMC, and the revised Chinese version of Physical Activity Questionnaire for Older Children (PAQ-C) to assess children's PA levels.

Results: There were some gender differences in AMC but no significant gender differences in PMC and PA in children. AMC and PA levels increased as the children aged, while PMC showed some decline. Cluster analysis identified four groups of children with different MC profiles. Two groups of children had corresponding AMC and PMC levels (the "high-high" cluster, N = 200, 38.91%; the "low-low" cluster, N = 63, 12.26%), and the other two groups were inconsistent in AMC and PMC (the "high-low" cluster, N = 100, 19.46%; the "low-high" cluster, N = 151, 29.38%). Significant differences in PA levels were found between children with different MC profiles. The "high-high" cluster children had the highest PA levels, whereas the "low-low" cluster children demonstrated the lowest PA levels.

Conclusion: AMC, PMC, and PA in Chinese school-age children were consistent with the pattern of child growth and development. Children with high AMC and high PMC usually had high levels of PA. Therefore, it was recommended to seize the best opportunity to intervene with children, and family, school, and community should synergize to help children improve AMC and PMC, and then actively participate in PA.

KEYWORDS

physical activity, school-age children, motor competence, actual motor competence, perceived motor competence

1 Introduction

Motor competence (MC) referred to the ability to skillfully perform physical skills and movement patterns (1). When an objective measure method was used to assess MC, it could be referred to as actual motor competence (AMC); when an individual's assessment and perception of his or her own level of MC was used, it could be referred to as perceived motor competence (PMC) (2). In developmental psychology, AMC and PMC had an important status. Since childhood was a period of rapid development of MC, in this study, the AMC in childhood was reflected by the performance of fundamental motor skills (3), and PMC was an individual's beliefs about performing a certain motor skill or self-perception of AMC (4). Research had shown that children's AMC and PMC were important factors influencing children's participation in physical activity (PA) (5–7).

An increasing number of studies had explored the relationship between AMC and PMC (8–10). Quantitative research had become the main research paradigm, and there were different voices on the research paths, one path was variable-centered and the other was person-centered. Most of the current studies had mainly used a variable-centered approach (e.g., regression analyses) to examine the relationship between AMC and PMC in children and adolescents (11–13), which described the correlation between the two variables. Most studies had found a positive correlation between AMC and PMC in children and adolescents of different ages (14, 15). A meta-analysis study also found a low to moderate strength correlation between FMS and PMC ($r = 0.19–0.46$) (10). However, some studies had also found no significant correlation between the two (16). Diao et al. (16) examined the relationship between children's FMS and their self-perception at different ages, using the TGMD-3 to measure children's FMS and the PMSC to measure PMC, and found that there was no correlation between FMS and self-perception in preschool children, but a lower correlation existed between FMS and self-perception in school-age children. Inconsistencies in the strength of these relationships could be due to cultural differences, variability in the level of cognitive development of children at different ages, and the use of different measurement instruments (17).

A small number of studies had used a person-centered approach. A person-centered approach allowed for the classification of subjects according to different characteristics and explored group heterogeneity that could not be distinguished by a variable-centered approach (18). Weiss and Amorose (19) first used a person-centered approach to determine whether children overestimated, underestimated, or accurately estimated their MC, identifying five clusters, but they used a teacher-reported measure of children's AMC. Recent studies had assessed children's AMC using objective measures, De Meester et al. (20) identified three clusters of children with different MC profiles among 6-12-year-old in the U.S. Two clusters of children had AMC and PMC levels that corresponded to each other (i.e., low-low, 34.26%, and high-high, 33.70%), and one group of children had AMC and PMC levels that were different (i.e., low-high, 32.03%). In contrast, De Meester et al. (21), in another study of Belgian adolescents aged 13–15 years, identified four groups of adolescents with different estimations of their MC profiles, with the presence of two overestimated (51%) and two accurately estimated (49%) groups, and with the overestimated MC group of adolescents having stronger motivation to participate in sports and levels in PA, especially in the case of adolescents with low AMC and high PMC adolescents. Bardid et al. (22) explored how children with different MC profiles differed in terms of motivation to exercise and overall self-worth, identifying four groups of children with different profiles, two with corresponding levels of AMC and PMC (i.e., low-low and high-high), and two with varying levels of AMC and PMC (i.e., high-low, low-high), and they found that lower PMC children demonstrated lower levels of exercise motivation and lower levels of overall self-worth, even though they had higher AMC.

PA was critical to physical health, cognitive development, and psychological and social adaptation in children and adolescents (23). Previous studies had shown that MC was one of the factors that promoted children and adolescents' participation in games, sports, or other types of PA (24, 25). On the relationship between MC and PA, Stodden et al. (26) proposed a model of dynamic mechanisms affecting PA changes in children based on previous studies, demonstrating the relationship between AMC, PMC, PA, and obesity risk. The model assumed that AMC and PA worked synergistically to influence the weight status of children and adolescents. In a positive spiral of engagement, higher levels of AMC and PA were associated with healthy weight status and lower obesity risk, whereas in a negative spiral of disengagement, lower levels of AMC and PA were associated with unhealthy weight status and higher risk of obesity. Many studies had demonstrated a positive association between AMC and PA levels in children (27–29), and this relationship strengthens with age (30). Stodden et al. (26) also suggested that the interrelationships and dynamics of AMC and PA were mediated by factors such as healthy fitness and PMC throughout childhood (26), identifying PMC as a key intervening factor in explaining how AMC could affect PA in children (31). Related studies had shown that AMC interacted with PMC as one of the most powerful potential mechanisms influencing the motivation and persistence of children's PA participation (32, 33). Some studies had identified AMC rather than PMC as the main factor influencing physical activity participation in children and adolescents (34, 35), but some studies had suggested that children with high AMC and PMC were more physically active and had emphasized that the development of both AMC and PMC during childhood was an important factor in increasing physical activity levels and participation (36). Therefore, AMC and PMC were potentially important factors influencing physical activity levels and participation in children and adolescents, and more research evidence were needed to confirm the role of AMC and PMC in promoting physical activity, which had positive implications for the healthy development of children and adolescents.

Although the relationship between AMC and PMC had been explored in the past literature, there were still some issues that required further research. First, most studies used a variable-centered approach. Although the variable-centered approach could yield total variable scores and the relationship between different dimensions and different outcome variables, there were still some limitations in this approach (37). The variable-centered approach made it difficult to find out which best combination of AMC and PMC contributed most to an individual's health behavior. For children with differences in AMC and PMC (e.g., high AMC and low PMC, or low AMC and high PMC), a variable-centered approach could provide only limited revelations (33). Second, although some researchers had begun to turn their attention to person-centered approaches in recent years (20–22), they were still only a minority, especially on the developmental characteristics of children's MC in the Chinese cultural context. The person-centered approach no longer focused on the examination of specific variables and could better reflect the comprehensive characteristics of individuals (38). This approach could reveal the relationship between the combination of different levels of AMC and PMC and PA, suggesting that different individuals had different MC profiles, which in turn allows for targeted interventions for these individuals. Finally, the results of the clustering of individual MC profiles still showed some differences (19–21). This could be related to the fact that the researchers chose different measurement tools, the cultural context in which the samples were located, and the age group of the samples. In addition, previous studies had mostly explored the relationship between MC and PA in children and adolescents from the perspective of variables, and had validated or supplemented Stodden's model (12, 31, 39), while less exploring the performance of children's PA levels under different MC characteristics.

Based on the above, the present study was rooted in the Chinese cultural context and adopted a person-centered approach to reveal the characteristics of MC development and differences in PA levels among Chinese schoolchildren in order to provide targeted guidance for future interventions. Specifically, this study included the following three main purposes. First, this study aimed to investigate the levels of AMC, PMC, and PA in schoolchildren aged 6–12 years old in the Chinese cultural context, and to explore the differences that exist in these variables across gender and age groups. Second, a person-centered approach was used to identify groups of children with corresponding levels or different levels of AMC and PMC. Based on developmental models (26) and previous researches (19–22), we hypothesized that four groups of children with different combinations of MC characteristics would be identified (i.e., low-low, high-high, low-high, and high-low). Third, the present study also aimed to explore how groups of children based on various MC profiles behaved differently in PA. Based on previous research (20, 35), it was hypothesized that the low-low group of children would perform the lowest level of PA, while the high-high group of children would perform the highest level of PA.

2 Methods

2.1 Participants

This study adopted stratified cluster sampling method to select a primary school from urban, rural–urban fringe and suburban areas of Beijing to ensure that the sample is balanced in terms of rural and urban distribution, and randomly select one class from grades 1–6 of each school for testing and filling in questionnaires. Before testing pupils in each elementary school, the principal of each school was contacted and permission was obtained from the school district and institutional review board in which the three elementary schools were located to conduct the study. Then, each student and their parents were given informed consent for the study. A member of the research team read the informed consent form to the students in the class, and the students answered whether they would like to participate. All the students were willing to participate in the study. After school, students would take the informed consent form of parents back home, and parents would fill in whether their children were willing to participate in the study. Informed consent from parents of all students was obtained for this study. A total of 562 children from grades 1 to 6 participated in the study, of which 20 children withdrew from the test due to physical reasons, and 10 children did not attend school to fill in the questionnaire. This study finally collected complete data of 532 students, of whom 284 were male, accounting for 53.4%; 248 girls, accounting for 46.6%; The mean age was 9.37 years (SD = 1.800 years, range from 6 to 12 years); Students had an average BMI of 18.59 (SD = 4.10); Boys' average BMI was 19.21(SD = 4.37) and girls' average BMI was 17.88 (SD = 3.66). The specific information of the subjects was shown in Table 1.

2.2 Measures

The Test of Gross Motor Development-3 (TGMD-3) was used to assess school-age children's AMC, which was specifically designed for structured assessment of the level of development of fundamental movement skills in children aged 3–10 years (40). It had been proved that TGMD-3 had good applicability to Chinese children aged 3–12 years, and could be used as an effective tool to assess AMC of Chinese children (41). The administration of TGMD-3 involved the

TABLE 1 Demographics of the participants ($N = 532$).

Characteristic	Total	Percentage
Gender		
Boy	284	53.4
Girl	248	46.6
School district		
Urban area	184	34.6
Rural–urban fringe	184	34.6
Rural area	164	30.8
Grade		
One	89	16.7
Two	86	16.2
Three	88	16.5
Four	90	16.9
Five	91	17.1
Six	88	16.5
Eye sight		

completion of two parts: (1) locomotor skills (run, gallop, hop, skip, slide, and horizontal jump), and (2) object control skills (two handed strike, one handed strike, catch, kick, overhand throw, underhand throw, and stationary dribble) (42). All six testers were trained prior to the test in order to master the standardized motor skills required for the demonstration and to clarify the scoring criteria, and the test is scored by on-site observation and video recording methods. Each skill assessment consisted of 3–5 standardized movement observation indicators. All test items were completed in a designated standardized field and procedure. The tester guided the subject child through each skill test 2 times. When a criterion was performed, "1" was recorded, and the opposite was recorded as "0." The higher the score for each movement, the better the mastery of that movement. The scores of the 2 tests were aggregated into a total score assessment and the study was statistically analyzed using raw scores. The total score for locomotor skills was 46, and the total score for object control skills was 54, and the total AMC was 100 points. The tests lasted for 1 month and were all completed during physical education lessons in each class. In this study, the Cronbach's α coefficient of the scale was 0.859, demonstrating a good reliability, and the goodness of fit (χ^2/df = 1.157, GFI = 0.964, AGFI = 0.941, RMSEA = 0.024) showed a good validity. The formal test also included an inter-rater reliability test and a re-test reliability test. During the test, all testers scored 10 subjects at the same time, and 20% of the total number were retested 2 weeks after the first test. With a total of six testers in this study, the Kendall's Harmony Coefficient was used to assess inter-rater reliability (43). The results showed that the Kendall's Harmony Coefficient value for TGMD-3 test was 0.873, which was greater than 0.8 and reached the level of significance, indicating a high degree of consistency in the inter-rater scores of the test (44). The intraclass correlation efficient (ICC) was used to assess the retest reliability, and the results showed that ICC of TGMD-3 was greater than 0.75, which indicated that TGMD-3 had a good retest reliability (41).

The Pictorial Scale of Perceived Movement Skill Competence (PMSC) was adopted to assess school-age children's PMC (45), which was confirmed to have good retest reliability, internal consistency, and construct validity in Chinese children aged 4–9 years (46). The test instrument had 2 manuals for boys and girls, and each had 13 items (6 items for perceived locomotor skills and 7 items for perceived object control skills). Each movement was presented using two cartoon pictures, one for the movement that was done well and one for the movement that was not done so well. Below each picture there were four circles, and each circle had a corresponding score, with a maximum of 4 points (e.g., 4 = I'm really good at running) and a minimum of 1 point (e.g., I'm not too good at running), depending on how well the movement was performed. The test procedure was as follows: first, the tester introduced the subject to what movement the boy/girl was doing in the picture. Second, the subject was told which boy/girl was doing the movement well and which was not so well, and the child was asked to choose the picture of the child that most resembled him/herself. Finally, the tester told the child what each circle represented and recorded the corresponding score. The mean scores of the scale were analyzed in this study. The Cronbach's α coefficient of the scale was 0.844, showing a good reliability. Meanwhile, the scale had a good validity (χ^2/df = 2.524, GFI = 0.956, AGFI = 0.932, RMSEA = 0.055) in the present study.

Children's PA were measured using the revised Chinese version of Physical Activity Questionnaire for Older Children (PAQ-C) (47, 48). The PAQ-C employed memory trails to facilitate childrens' recall of participation in PA, and numerous studies had shown that the questionnaire had good psychometric properties, had been shown to have good reliability, validity, and cross-cultural stability, and was applicable to the measurement of PA levels in school-age children (49, 50).

The PAQ-C questions were clear and easy to understand, and children did not need to recall detailed information about the duration and intensity of exercise, which could significantly reduce recall bias and make it suitable for large samples of people. The PAQ-C consisted of 7 question items that asked subjects to recall the number of days, time, and frequency of participation in high, moderate, and low intensity PA over the past 7 days. The scale was based on a 5-point scale, and the PA score was the average of the 7 items, with higher scores representing higher levels of PA. PAQ-C 1 surveyed children's intensity of activity in sports such as running, basketball, and badminton (1 = 0 times, 5 = 7 or more times); PAQ-C 2–5 surveyed children's PA level during physical education classes, after school, and on weekends (1 = low level, 5 = highest level); PAQ-C 6 surveyed children's overall PA level in the past week in out of class time (1 = low level, 5 = highest level); PAQ-C 7 surveyed children's everyday PA in the past week (1 = never, 5 = very often). In this study, the scale had a good reliability (Cronbach's α coefficient = 0.835) and good validity (χ^2/df = 1.8888, GFI = 0.985, AGFI = 0.971, RMSEA = 0.042).

2.3 Analysis

In this study, the Statistical Package for the Social Sciences (IBM SPSS Statistics for Windows, version 26.0. Armonk, NY, United States: IBM Corp.) was used for descriptive and inferential statistical analysis (with $p < 0.05$). The common method bias was tested by Harman single factor test. Taking the eigenvalue greater than 1 as the standard, principal component analysis was used to extract the common factor, and the partial correlation was obtained by isolating the first common factor (51). The results showed that the variance explanation rate of the first factor without rotation was 18.297%, which was less than the critical standard of 40%. Therefore, there was no serious common method bias in this study.

Aim 1: Children's ages were divided into three stages based on their developmental stages of perceptual abilities. First, descriptive statistics were performed on the scores of AMC, PMC, and PA on the three age groups. Second, independent samples *t*-tests were performed for gender differences in the variables at each age. Finally, one-way ANOVA was performed for differences in variables across age groups, and *post hoc* comparisons were conducted using the LSD method.

Aim 2: Before performing the cluster analysis, the AMC and PMC scores were standardized first and univariate and multivariate outliers were removed. Eight univariate outliers (values that deviated from the mean by more than three times the standard deviation) and 10 multivariate outliers (determined using the Mahalanobis distance measure) were found. A final sample of 514 was included. Cluster analysis was performed using both hierarchical clustering and K-means clustering. First, through hierarchical clustering, the number of variables clustered was determined by looking at the spectrogram using the clustering method of intergroup linkage and squared Euclidean distance measurement intervals. The spectrograms and clustering coefficients indicated that clustering the children's MC

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characteristics into four classes was more desirable and reasonable (each cluster explains at least 50% of the variance on both AMC and PMC). Second, further results were obtained by K-means clustering, setting the K value to 4, for each clustered element. Finally, the results of clustering on children's AMC and PMC were further tested accordingly.

Aim 3: One-way ANOVA was used to test for differences in PA levels among groups of children with different MC profiles, and the LSD method was used for *post hoc* comparisons.

3 Result

As shown in Table 2, there was no significant gender difference in locomotor skills of 6–7 year old children, while object control skills ($p < 0.01$) and AMC ($p < 0.05$) of 6–7 year old boys were significantly better than those of girls; locomotor skills of 8–9 year old girls were significantly better than those of boys ($p < 0.001$), while object control skills of 8–9 year old boys were significantly better than those of girls ($p < 0.001$), and AMC of 8 to 9-year-olds AMC did not have significant gender differences; 10–12-year-old boys had significantly better object control skills than girls ($p < 0.001$), and 10–12-year-olds mobility skills and AMC did not have significant gender differences. PMC as well as the two dimensions and PA did not show significant gender differences at all ages ($p > 0.05$). From the overall view of AMC test results, the total AMC test scores of children showed a trend of gradual increase with age. Children's PMC differed significantly across age groups, with PMC in children aged 6–7 years significantly higher than those in children aged 10–12 years. Overall, children's PA levels gradually increased with age, with children aged 10 to 12 years having significantly higher PA levels than children aged 6–7 years.

Classifying the sample categories based on relative AMC (high vs. low) and PMC (high vs. low), it was found that four clusters of children with different MC profiles could be identified (e.g., Figure 1). Children in cluster 1 ($N = 100$, 19.46%) were found to have higher AMC and lower PMC compared to children in the other clusters, and thus named the "high-low" cluster. Children in cluster 2 ($N = 63$, 12.26%) had lower AMC and PMC compared to children in the other clusters, hence the name the "low-low" cluster. Children in cluster 3 ($N = 151$, 29.38%) were characterized by their lower AMC and higher PMC, hence the name the "low-high" cluster. Children in cluster 4 ($N = 200$, 38.91%) had higher AMC and PMC compared to the other clusters, hence the name the "high-high" cluster. Chi-square test indicated that boys and girls were equally represented in each cluster ($\chi^2 = 1.992$, df = 1, $p = 0.158$). The four clusters were significantly different ($p < 0.001$) for both AMC and PMC (as shown in Table 3). In terms of AMC, significant differences were found between the "high-high" cluster ($M = 81.355$, SD = 8.575) and the "high-low" cluster ($M = 80.190$, SD = 4.735) on the one hand and the "low-high" cluster ($M = 67.000$, SD = 5.062) and the "low-low" cluster ($M = 66.746$, SD = 5.448) on the other hand. With respect to PMC, the "high-high" cluster had the highest mean score ($M = 3.718$, SD = 0.216), followed by the "low-high" cluster ($M = 3.548$, SD = 0.250), the "low-high" cluster ($M = 2.948$, SD = 0.268) and the "low-low" cluster ($M = 2.706$, SD = 0.283).

It could be seen from Table 4 that children with different MC profiles had significant differences in PA levels ($F = 16.317$, $p < 0.001$). From the average score of the PA level of each group, the "high-high" cluster ($M = 3.588$, SD = 0.825) had the highest PA level, and the "low-high" cluster ($M = 3.212$, SD = 0.905) had the second highest PA level. The "high-low" cluster ($M = 3.113$, SD = 0.658) had the third highest level of PA, and the "low-low" cluster ($M = 2.876$, SD = 0.781) had the lowest. The "high-high" cluster had significantly higher levels of PA than the other three groups, and the "low-high" cluster had significantly higher levels of PA than the "low-low" cluster.

4 Discussion

This study investigated the AMC, PMC and PA level of Chinese school-age children, adopted a person-centered approach to explore the relationship between AMC and PMC of Chinese school-age children, identified children groups based on different MC profiles, and explored how different groups of children differed in PA levels.

This study found that the locomotor skills of girls aged 8–9 years were significantly higher than that of boys, the object control skills of girls at all ages were significantly lower than that of boys, and the AMC of boys aged 6–7 years was higher than that of girls, which was consistent with previous research results (52–55). Children's FMS produce certain gender differences, which could be related to socio-cultural and environmental factors. During childhood, boys were more likely to choose ball games and equipment, while girls were more likely to choose dance and rhythmic gymnastics. In addition, some children, especially girls, showed relatively unfamiliar use of equipment during the test, which could lead to a certain impact on the test effect. Ning et al. (56) also found that boys' object control skills were significantly better than girls' among Chinese pre-school children aged 4–7, indicating that boys' object control skills were already better than girls' from early childhood.

This study did not find gender differences in PMC and PA levels among school-age children. In fact, no conclusion had been reached on gender differences in children's PMC. For example, Diao et al. (16) found that there was no significant gender difference in children's self-perception of FMS in pre-school age (4–6 years old), but school-age (7–9 years old) boys' self-perception of FMS was significantly better than that of girls. LeGear et al. (57) found that girls' perceived physical abilities were higher than boys'. The inconsistent results of gender differences in PMC could be attributed to the selection of samples from different regions. Intuitively, the results of the present study may promote additional study in order to provide extended knowledge on gender differences in PMC. As for PA, most studies had found that boys engaged in more moderate-to-vigorous PA than girls (58–60). The reason why there was no gender difference in children's PA level in this study could be that this study collected data by means of self-report. Children generally had a high perception of their own athletic competence, and 3–5 physical education classes were generally offered in schools every week, and children had more opportunities for PA in school. Therefore, both boys and girls could report more time and frequency of PA.

This study found that the AMC and PA level of school-age children had obvious age characteristics, which was consistent with previous studies and in line with the growth law of children to a certain extent (61–63). According to Newell's constraint model, the outcome of an individual's MC development is the result of a combination of personal, task, and environmental factors (64). Influenced by family, community, and school environments, Children's

TABLE 2 Descriptive statistics.

Variables	Full score	6 ~ 7 (A)				8 ~ 9 (B)				10 ~ 12 (C)				*F*	*p*	Multiple comparisons (LSD)
		Total (*n* = 104) *M* (SD)	Boy (*n* = 57) *M* (SD)	Girl (*n* = 47) *M* (SD)	*p*	Total (*n* = 167) *M* (SD)	Boy (*n* = 88) *M* (SD)	Girl (*n* = 79) *M* (SD)	*p*	Total (*n* = 261) *M* (SD)	Boy (*n* = 139) *M* (SD)	Girl (*n* = 122) *M* (SD)	*p*			
Locomotor skills	46	36.096 (5.224)	35.982 (5.636)	36.234 (4.733)	0.808	37.838 (4.624)	36.557 (5.040)	39.266 (3.640)	<0.001	37.100 (5.292)	36.776 (4.931)	37.467 (5.673)	0.294	3.784	0.023	A<B
Object control skills	54	34.375 (6.579)	36.088 (6.495)	32.298 (6.125)	0.003	35.850 (6.612)	37.602 (6.356)	33.899 (6.376)	<0.001	39.720 (5.913)	40.863 (5.369)	38.418 (6.248)	0.001	35.035	<0.001	A<C B<C
Actual motor competence	100	70.471 (9.165)	72.070 (8.944)	68.532 (9.148)	0.049	73.688 (8.708)	74.159 (9.607)	73.165 (7.610)	0.462	76.820 (9.232)	77.640 (8.287)	75.885 (10.158)	0.126	19.487	<0.001	A<B<C
Perceived locomotor skills	4	3.542 (0.548)	3.608 (0.554)	3.461 (0.535)	0.174	3.450 (0.490)	3.396 (0.516)	3.510 (0.456)	0.132	3.291 (0.535)	3.265 (0.542)	3.321 (0.526)	0.399	10.101	<0.001	A>C B>C
Perceived object control skills	4	3.427 (0.603)	3.511 (0.595)	3.325 (0.604)	0.118	3.353 (0.499)	3.386 (0.485)	3.316 (0.515)	0.368	3.322 (0.532)	3.352 (0.545)	3.287 (0.482)	0.311	1.461	0.233	
Perceived motor competence	4	3.480 (0.539)	3.556 (0.534)	3.388 (0.536)	0.114	3.398 (0.451)	3.391 (0.448)	3.406 (0.457)	0.827	3.308 (0.490)	3.312 (0.506)	3.302 (0.474)	0.877	5.037	0.007	A>C
Physical activity	5	3.097 (1.014)	3.151 (1.050)	3.031 (0.975)	0.551	3.246 (0.857)	3.209 (0.901)	3.286 (0.810)	0.563	3.388 (0.759)	3.447 (0.783)	3.321 (0.727)	0.183	4.690	0.010	A<C

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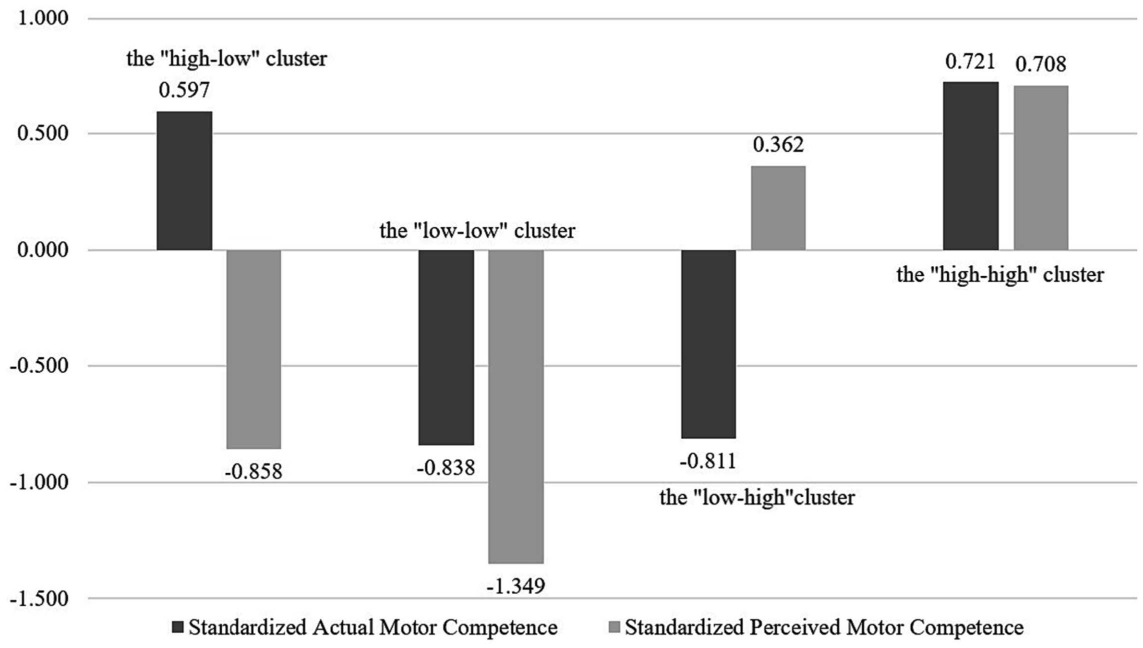

FIGURE 1
Four cluster solution based on standard scores for AMC and PMC.

TABLE 3 Mean scores, standard errors and cluster comparisons for the four clusters (*N* = 514).

Variables	Cluster				*F*	*p*
	Cluster1: high-low	Cluster 2: low-low	Cluster 3: low-high	Cluster 4: high-high		
	n = 100, 19.46%	*n* = 63, 12.26%	*n* = 151, 29.38%	*n* = 200; 38.91%		
Cluster dimensions (standard scores)						
Actual motor competence	0.597 (0.505)	−0.838 (0.582)	−0.811 (0.540)	0.722 (0.540)	323.276	<0.001
Perceived motor competence	−0.858 (0.544)	−1.349 (0.576)	0.362 (0.509)	0.708 (0.440)	410.583	<0.001
Cluster dimensions (raw scores)						
Actual motor competence	80.190 (4.735)	66.746 (5.448)	67.000 (5.062)	81.355 (8.575)	323.276	<0.001
Perceived motor competence	2.948 (0.268)	2.706 (0.283)	3.548 (0.250)	3.718 (0.216)	410.583	<0.001

Values in parentheses are standard errors.

motor experiences were constantly being enhanced and developed, progressively developing higher levels of AMC, and therefore being competent to engage in more PA. In addition, this study found that PMC of 6–7 years old children was significantly higher than that of 10–12 years old children. Previous literature showed that school-age children were in a period of rapid physical and mental development, and PMC would change rapidly with the increase of age (39). In early childhood, children's perception accuracy of their own competence was poor, and they often overestimated their own competence. However, with the growth of children's age and the continuous enrichment of personal experience, children's self-perception of competence would gradually converge with the real competence.

Based on the characteristics of children's MC, cluster analysis identified four groups of children. Two of the groups had corresponding levels of AMC and PMC, 12.26% of the children had relatively low levels of both AMC and PMC (the "low-low" cluster), and 38.91% of the children had relatively high AMC and PMC levels (the "high-high" cluster). Additionally, this study identified two groups of children with inconsistent levels of AMC and PMC, with some children (19.46%) having high levels of AMC but exhibiting low levels of PMC (the "high-low" cluster), and a larger portion of children (29.38%) showed relatively low AMC and high PMC (the "low-high" cluster). This was consistent with the results of a study of Belgian children aged 7–11 years, which also identified four MC-based profiles

TABLE 4 Mean scores, standard errors and cluster comparisons for the four clusters ($n = 514$): PA.

Variable	Cluster				F	p	Multiple comparisons (LSD)
	Cluster1: high-low (1)	Cluster 2: low-low (2)	Cluster 3: low-high (3)	Cluster 4: high-high (4)			
Physical activity	3.113 (0.658)	2.876 (0.781)	3.212 (0.905)	3.588 (0.825)	16.317	<0.001	(1)<(4) (2)<(3)<(4)

Values in parentheses are standard errors. All values are controlled for sex and age.

(22). Almost half of the children showed inconsistent levels of AMC and PMC, and one-third of the children overestimated their MC, suggesting that although children had more accurate cognitive and evaluative abilities in the middle and late stages than in the early stages (65), they still tended to overestimate their AMC.

The results of the study further indicated that there were differences in the PA levels of children with different MC profiles. Specifically, children in the "high-high" cluster had the highest level of PA, while children in the "low-low" cluster exhibited the lowest level of PA, which confirmed the hypothesis of the present study and was consistent with the results of existing studies (20, 35). The significant difference in PA levels between children with high AMC ("high-high" cluster) and children with low AMC (i.e., "low-low" cluster, "low-high" cluster) suggested that AMC was an important factor that influences children's participation in PA, highlighting the importance of promoting children's participation in sports and PA through the development of children's AMC (66). Bolger et al. (67) concluded that children with higher AMC were more likely to participate in organized sports activities, children could gain more knowledge about FMS from physical education teachers or coaches and promote their PA intensity. In addition, this study found that children with higher levels of PMC had higher levels of PA when their AMC levels remained consistent. This suggested that PMC also played an important role in facilitating children's PA, and that children needed to have a sense of belief in their competence to accomplish motor skills in order to be motivated to engage in PA. Competence Motivation Theory suggested that when individuals attempted to learn a motor skill, they derived "enjoyment" from learning it if they felt competent to do so, and that the recognition and approval of peers, teachers, and parents during the learning process accelerated the development of good PMC (2, 68). Once they had learned these motor skills, this PMC would motivate them to continue to participate in sport. For this reason, special attention needed to be paid to context-specific movement activities that were developmentally appropriate and that promoted the development of children's AMC and PMC, which could help to promote children's active participation in PA (69). While we focused on improving children's AMC through intervention programs and measures, we should also pay attention to the development of children's PMC. On the one hand, novel ways of PA, such as somatic games, could be introduced to arouse children's interest and mobilize their motivation; on the other hand, while shaping a relaxing and enjoyable physical education learning environment, reinforcement should be given to children to emphasize their successes, efforts and progress.

Nevertheless, it seemed important to highlight the limitations. First, although the sample size of this study was large and distributed across grades and urban and rural areas, only school-aged children in Beijing were selected as the target population, and the sampling should be expanded in the future to study the characteristics of children's MC and its relationship with PA in different areas, and future studies were required to further compare the performance of AMC and PMC and the relationship between AMC and PMC in children in rural and urban areas. Second, this study conducted a cross-sectional study, which provided a new perspective by adopting a person-centered approach, but it was unable to determine the causal relationship between children's AMC, PMC, and PA; therefore, future tracking studies should be conducted to determine the dynamic developmental trajectory among the three variables as children's age changes. Finally, the present study tested children's AMC using a well-established measurement tool and measured children's PMC using a scale corresponding to the TGMD-3 items, which reduced errors due to inconsistencies in the instrument items; however, this study used a self-report questionnaire, which had a certain degree of subjectivity, which leaded to the possibility that the results could have been overestimated or underestimated. Therefore, the use of more objective measurement tools and methods to collect data would be a future endeavor to continue the study, making the results more reliable.

5 Conclusion

The present study revealed the AMC and PMC characteristics of school children from Beijing City, as well as explored the differences in PA levels of children based on two different MC characteristics. The results of this study showed that there were some gender differences in children's AMC, with girls having better locomotor skills than boys, while boys performed better than girls in object control skills and overall AMC, but no gender differences were found in PMC and PA. In addition, AMC, PMC, and PA all had certain age characteristics that were consistent with the growth and development of children, AMC and PA improved to some extent with age, while children's PMC declined and their perception of MC became accurate. The present study identified four groups of children based on different MC profiles, and nearly half of the children showed inconsistent AMC and PMC, with children with high AMC having low PMC and children with low AMC having high PMC. Children with different MC characteristics had different levels of PA, to be specific, children with high AMC and high PMC showed higher levels of PA, which provided an intervention perspective for promoting active PA in children. Families, schools, and communities should collaborate to help children acquire good FMS at an early age, improve their levels of AMC, and develop good PMC and active lifestyles.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Written informed consent was obtained from the individual(s), and minor(s)' legal guardian/next of kin, for the publication of any potentially identifiable images or data included in this article.

Author contributions

HC: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft. RX: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft. LY: Investigation, Resources, Supervision, Visualization, Writing – review & editing. MM: Data collection, Formatting, Writing – review & editing. BH: Revision, Funding, Methodology, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Determinants promoting and hindering physical activity in primary school children in Germany: a qualitative study with students, teachers and parents

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Background: Determinants affecting children's physical activity (PA) at an early age are of particular interest to develop and strengthen strategies for increasing the levels of children's PA. A qualitative study was conducted to investigate the views of primary school-aged children, their teachers and parents regarding barriers and facilitators to engage in PA.

Methods: Focus groups were conducted separately with primary school children, parents and teachers in a city in Northern Germany between October 2021 and January 2022. The semi- structured focus groups with children and teachers took part in person within school, whereas the focus groups with parents took place online. Data were transcribed verbatim and analysed using thematic analysis. During analysis, the socio-ecological model was identified as useful to map the determinants mentioned and was consequently applied to organize the data.

Results: Teachers ($n = 10$), parents ($n = 18$) and children ($n = 46$) of five primary schools in Germany participated in the focus groups. Participants of the three groups identified similar barriers and facilitators of PA in primary school-aged children, ranging across all four layers of the socio-ecological model. The barriers encountered were the preferences of children for sedentary activities (individual characteristics), the preference of parents to control their child's actions (microsystem), a lack of financial resources from parents and long sitting times in class (mesosystem), and barriers related to rainy weather and Covid-19 restrictions (exosystem). Facilitators mentioned were the childrens' natural tendency to be active (individual characteristics), involvement and co-participation of parents or peers in engaging in PA, support provided by teachers and the school (microsystem), living in rural areas, having sufficient facilities and favorable weather conditions (exosystem).

Conclusion: A range of determinants promoting and hindering PA, ranging across all layers of the socio-ecological model were identified by children, parents and teachers in this study. These determinants need to be kept in mind when developing effective PA intervention programs for primary school-aged children. Future interventions should go beyond individual characteristics to also acknowledge the influence of childrens' social surrounding, including parents, peers and teachers, and the wider (school) environment.

KEYWORDS

physical activity, perspectives of children, primary schools, teachers, parents, socio-ecological model, qualitative research, focus groups

1 Introduction

According to the World Health Organisation (WHO), physical inactivity is the fourth leading population-based risk factor for global mortality (1). Regular physical activity (PA) during childhood has been shown to have multiple benefits for childrens' health, such as for improving their cardiorespiratory and cardiometabolic health and reducing their risk of adiposity and symptoms of depression (2). The WHO recommends children and adolescents to achieve at least 60 min of moderate- to vigorous-intensity of PA per day (3). Results of the German Health Interview and Examination Survey for Children and Adolescents 2014–2017 (KiGGS Wave 2) showed that only 22.4% of girls and 29.4% of boys aged three to seventeen meet the levels recommended by the WHO (4). These rates underline the importance of promoting PA among children in Germany.

Previous studies suggest that PA behaviours track from childhood to adolescence and adulthood (5). Therefore, it is important to promote PA at a young age. Data collected from children themselves is needed to understand the determinants of PA behaviours among children. In addition, involving teachers is important because schools have been identified as an important setting to promote PA (6) since children aged 6–10 years spend a considerable amount of time at school and potentially a large number of children can be reached through schools. Nonetheless, the home environment can also be considered as an important place for children to develop health behaviours (7). Consequently, the parents' perspective also plays an important role in the promotion of PA in children.

Several qualitative studies with parents, teachers or children on barriers and facilitators of PA have already been published (8–17). Previous qualitative studies investigated parent role modeling, parental support (8–11, 14–18), childrens' preference for being active (8–10, 15, 16, 19), organised activities and living in rural settings (8–10, 12, 13, 15–17, 20–22) as facilitators of PA in children. Important determinants that hinder PA identified in previous studies have been adverse weather conditions (8–13, 15, 16, 22, 23), costs associated with participating in PA (8, 9, 14, 16), lack of equipment (8, 12, 16), safety constraints (8–10, 13) and lack of parental time to help their children being active (8–10, 15, 16). Based on a focus group study with parents in Spain, children's PA is influenced not only by barriers and facilitators related to individual determinants, but also to contextual determinants related to friends, parents, siblings, schools and the children's environment. Unfortunatley, the perspectives of teachers and the children themselves were not included in the study (8). However, even though previous studies have already gathered knowledge on determinants promoting and hindering PA in children (10–13), to our knowledge, no focus group has explored the facilitators and barriers of PA for children in primary school by including the perspectives of teachers, parents and primary school children themselves in Germany concomitantly within one study. The aim of our study was to identify factors that promote and hinder children's PA by triangulating the views of primary school-aged children, their teachers and parents. In summary, our study allows for a direct comparison of the views of children, teachers and parents based on the same PA intervention, potentially disclosing unknown barriers and facilitators compared to previous studies.

2 Methods

2.1 Design

A qualitative study using focus groups was conducted with children, their parents and teachers to explore barriers and facilitators of PA in primary school children. This qualitative study was part of a larger German PA research project funded by the Ministry of Health in Germany (BMG): The ACTIvity PROmotion via Schools (ACTIPROS) project, aiming to promote PA in school children aged 6–10 years old by implementing a toolbox of evidence-based PA interventions (see also www.actipros.de). In a feasibility study, we applied and tested the toolbox approach with 12 evidence-based interventions to promote physical activity in children. The interventions included in the ACTIPROS toolbox were activities such as active breaks during and between school hours, physical education or active travel to school initiatives as well as interventions that include a combination of different components in the sense of a "whole school" approach (24).

2.2 Sample selection, recruitment, and ethics

This qualitative study is part of a pilot study involving 10 schools (5 intervention schools, 5 control schools) which was conducted to investigate the feasibility and acceptability of using the ACTIPROS toolbox approach for PA promotion (24). In Bremen, the education authority categorizes the school system using an annual index related to social indicators. The ACTIPROS intervention and control classes were matched by the area-level deprivation index to cover Bremen in all five ranks, ranging from 1 – highest social index, to 5 – lowest social index. In this pilot study, two classes at each intervention site were asked to implement the ACTIPROS toolbox over the course of one school year (Nov 2021 until July 2022). Classroom teachers of the 10 intervention classes involved in the pilot study were invited via email to participate in the focus groups. As a focus group of up to 10 participants provides sufficient speaking time for each and at the same time allows a certain group dynamic (25), a selection of 10 children maximum per school were invited to each children focus group by their classroom teachers. Additionally, all parents of participating children from the intervention group ($n = 217$) were further invited to take part in online focus group discussions. Further information on the recruitment and participants of the ACTIPROS study can be found elsewhere (24).

Prior to each focus group, information on the aim of the study and the approximate duration of the focus group were provided and all participants were informed that they could withdraw at any time without negative consequences. Pseudonyms were used throughout the report to preserve the anonymity of participants.

Classroom teachers of the intervention schools taking part in the ACTIPROS study were involved in the recruitment of children and parents. All classroom teachers were invited to a virtual meeting in which information about the purpose of the focus groups and process was provided. Instructions were given in that, e.g., the aim of the focus groups was to gain insight into diverse and different views on PA and that the selection of students and parents should try to contain a heterogenous sample. Five students aged 6–10 years and, separately, all parents of each class were invited to participate.

Ethical approval for this study was granted by Ethics Committee of the University of Bremen, Germany (reference: 2021–17). Parents of all participating students provided written informed consent for their children to take part in the research study. Oral consent was sought and recorded from parents and teachers who took part in the study.

2.3 Focus groups

The focus groups took place between October 2021 and January 2022. Separate focus groups were organized for teachers, parents and children to ensure that all groups could talk freely about their perspectives on determinants promoting and hindering students' PA. Between two and eight participants took part in each group to include a diversity of opinions and perspectives, and to facilitate optimal interaction between participants. All focus groups were conducted by one researcher (LS) with an assistant member of the research team present to take notes. Three topic guides with similar questions were used to direct the focus groups, appropriate to children and adults. The questions directed to children were related to the following issues: enjoyable activities during school and leisure time, active transport, PA opportunities and equipment and suggestions for improvement. The content of focus groups with teachers focused on PA teacher trainings, movement-related activities and excursions, determinants which may be important for the implementation of PA in primary schools and recommendations for sustainable promotion of PA. Parents' questions centred on children's movement offerings, family PA, parental participation and determent promoting and hindering their children's PA.

Focus groups with the children as well as classroom teachers from each of the school classes participating in the ACTIPROS study were conducted in person in a quiet room at the respective schools. The focus groups took place during the school day and a time was arranged in cooperation with the classroom teachers. The duration of the focus groups with children ranged from 29 to 50 min and the focus groups with teachers lasted 12–25 min.

Focus groups with parents of the participating students were conducted via virtual meetings using Zoom at a time and date arranged with parents'. The duration of the parent focus groups ranged from 26 to 40 min.

2.4 Data analysis

Focus groups were recorded with an encrypted audio recorder and transcribed verbatim. The available transcripts were initially cross-checked with the original recordings by a member of the research team (LS) and then anonymised. Afterwards, the anonymised transcripts were imported into MAXQDA (Version 20.4.1) to help organize and manage the data and facilitate data coding. The data were analysed using a combined technique of inductive and deductive thematic analysis for identifying themes. The transcripts were coded and first considered separately to get an overview of the perspectives of each participant group (i.e., children, parents and teachers). Similar codes were then grouped together into key themes. Two researchers (LS, HB) independently read a selection of the transcripts and met regularly to discuss the meaning of the codes and key themes generated.

Within the present study, triangulation occurred based on the data source as different groups of participant groups were involved. Whilst the overall methodology of data collection stayed the same throughout semi-structured focus groups, the format of data collection differed to best reach each participant group.

Data collection and analyses occured concurrently. Initially, the coding for each participant group was done seperately, and then all codes were compared and contrasted and integrated into one overall coding scheme. The coding scheme was then applied to all transcripts and it was noted which themes were identified by which participant group.

In the analysis stage, the socio-ecological model was identified as a suitable and fitting model to represent and organize the key themes identified (26). The social-ecological model provides a comprehensive framework for analysing multiple personal and environmental determinants influencing health behaviours (27). It includes 4 levels of environmental influence: (1) individual, (2) microsystem, (3) mesosystem and (4) exosystem (26). As such, all identified determinants were grouped to one of the four levels as per the socioecological model: individual characteristics (5 themes), microsystem (7 themes), mesosystem (6 themes) and exosystem (2 themes). Focus groups were conducted in German; all quotes used in this study were translated in English and were checked by two researchers (LS, HB) and then translated back into German to verify the accuracy of translation. Participant quotes are presented in parentheses to illustrate the respective themes. Quotations provided within this text are marked according to the focus group number (FG = focus group) and type of participant (C = Child; T = Teacher; P=Parent) (see Supplementary file 1).

3 Results

A total of 12 focus groups with 74 participants were conducted. Forty-six children participated in five focus groups, up to 10 children per focus group. Another five focus groups were conducted with 10 classroom teachers. Eighteen mothers of primary school children participated in two focus groups. Teachers of three schools located in a low socioeconomic status area, as indicated in the local deprivation index, stated that their students' parents were not interested in participating in a focus group and did not provide a reason for this.

The findings of this qualitative study were organized using the following levels of the socio-ecological model: individual

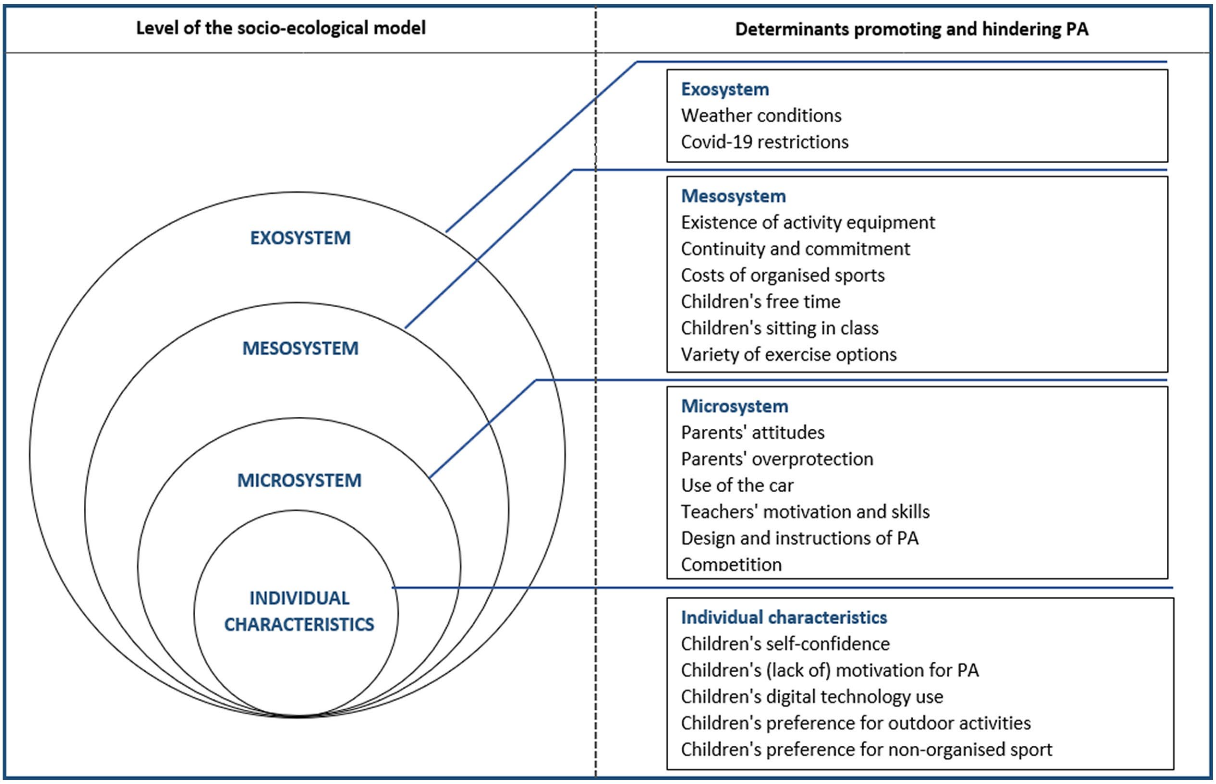

FIGURE 1
Determinants promoting and hindering PA based on focus groups consisting of children, teachers and parents by level of the socio-ecological model.

characteristics, microsystem, mesosystem and exosystem (Figure 1). The socio-ecological framework outlines four levels of interconnected layers within an ecology. The levels start with the individual and move in concentric circles outwards through the microsystem, mesosystem and exosystem. Bronfenbrenner's framework (27), with its four layers, serves to recognize that in any school setting, children and their PA are part of a larger whole that is influenced by formal and informal groupings and overarching systems. Nineteen overall determinants stated by teachers, parents and children were identified as barriers and/ or facilitators of PA (see Supplementary file 2).

3.1 Individual characteristics

Starting with the inner layer of the socio-ecological model, focussing on individual characteristics, five key determinants were referred to in the focus groups: children's level of self-confidence, children's (lack of) motivation for PA, children's digital technology use, children's preference for outdoor activities and children's preference for non-organized sport.

3.1.1 Children's self-confidence

According to some teachers, self-confidence is a facilitator of PA among children. While activities focused on children's strengths were seen to encourage children's engagement in activity, activities that exceed the children's competences were seen to have a demotivating effect on the children.

"Anything that encourages children to show their strengths is definitely advantageous." (FG5, T1).

3.1.2 Children's (lack of) motivation for PA

Most of the participants, both parents and teachers as well as the children themselves, stated that children have a natural inner urge to be physically active, they generally feel the need to move.

> *"They always want to keep moving, and even if they should already set up, half of them still keep playing because they want to be actively running around all the time."* (FG3, T1).

However, participants also stated that the motivation to be physically active varied among the children. According to many participating teachers, some children were not as motivated as other to be active, which was particularly evident in their lack of participation in physical education (PE) classes. Some children noted that sometimes they prefered sitting, as during lessons or on their way to school by car. Some parents also reported that their children did not express the need for activities of their own accord during leisure time or that they just prefer sedentary activities rather than being physically active.

> *"During class, it's also great when we sit."* (FG6, C1).
>
> *"My daughter goes to ballet once a week for an hour, and that's about it in terms of sports. She's not the most active child."* (FG11, P4).

When describing children that were not as active, this was put down to them "not feeling like it" or not "wanting it" by teachers.

> *"I think sports courses are chosen by those who have the desire for them anyway. So there are children here at school who go back to the sports club after school or take up other sports offers. And there are also children who do not because they do not have the desire for it."* (FG1, T2).

A few parents, teachers and children reported that badges in any form, e.g., stickers, certificates, checklists, medals, were seen to have a motivating effect on the children: *"Licenses, certificates and things like that are always very motivating at the elementary school age."* (FG1, T2).

3.1.3 Children's digital technology use

Some participants marked children's preference for digital technology use in their leisure time as a barrier to being physically active. Although one child mentioned exercising via a tablet, when asked what would hinder their movement, the children named a number of digital technologies as barriers to PA, for example mobile phones, tablets, televisions, video game consoles. A parental monitoring of children's digital technology consumption was regarded by children to possibly facilitate children's PA level: "*One can tell the parents: `Mom, hide my mobile phone.*'" (FG7, C11). A few parents equally referred to discussions with their children and being active rather than spending time on digital technologies. In addition, from a teacher's point of view, the low participation of children in sports clubs is seen to be related to increased media use of children.

> *"I have got this app on my mother's iPad: one can do sports with it."* (FG8, C3).
>
> *"Sitting in front of end devices for hours at a time […] is not exactly conducive to fitness."* (FG2, T2).
>
> *"And since this [PA] is a competitor to media, I'm a little critical of that."* (FG11, P4).

3.1.4 Children's preference for outdoor activities

Almost all children showed a clear preference for outdoor activities compared to indoor activities, both in school and during leisure time. Most parents shared the view that the children prefer outdoor activities.

> *"How you could move even more would be to go outside a lot and do a lot of gymnastics and play."* (FG 9, C1).

3.1.5 Children's preference for non-organized sports

Both within the school setting and during free time, the majority of children enjoy having free play time and prefer playing without adult guidelines. Some parents remarked that their children barely have any leisure time and opportunities for spontaneous leisure activities.

> *"They are allowed to play completely free at the beginning of physical education. They like that."* (FG3, T1).

3.2 Microsystem

Regarding the second layer of the socio-ecological model, representing the level of relationships and social interactions that a child has including his/her family, peers and teachers, the following six key themes were identified: parents' attitudes toward PA and related behaviours, use of the car, teachers' motivation and skills, design and instructions of PA and competition.

3.2.1 Parents' attitudes

Some teachers marked the children's home as an important environment for PA and reported various opportunities of parental involvement in PA (e.g., PA homework, school garden projects, fundraising runs).

While almost all participating parents overwhelmingly attached great importance to exercise and stated that they wanted to support their children in the best possible way in pursuing physical activities, they suspected that this may not be the case in all families: *""Now we are probably all parents who attach importance to this and look at what the children are doing. And others may possibly not care and say, 'Fine, then they'll just goof around the whole day.'. And then do not attach importance to the fact that there are certainly also games where one would have to move around."* (FG 12, P1).

However, according to some teachers, many parents were seen to not participate in activities such as school events, and teachers perceive this as an important barrier for children's uptake of PA. Possible reasons cited by teachers for this include parents' unwillingness, anxiety and convenience to accompany their children to organized activities and participate in activities. Furthermore, some teachers and all parents noted that while many parents were engaged, their work and other commitments did not allow them to participate in PA events themselves or to support their children in PA by accompanying them or picking them up.

> *"Sometimes one just do not feel like exercising, and then one just simply lays on the couch in front of the TV the whole Sunday. If one has not watched anything all week or something, then we do not do anything."* (FG 11, P2).
>
> *"[…] basically, to get the children to move, also besides the school, then, I think, it is with the parents. The parental work, it just does not work very well. I think that's the biggest obstacle."* (FG 2, T2).

3.2.2 Parents' overprotection

According to most children and teachers, many children were not allowed to walk to school without adult supervision. Teachers added that various activities, such as active transport to school and children's participation in club sports, were limited due to the lack of safety perceived by parents.

> *"They [parents] only think about their own child's safety, not that of the general public. 'I take my child to school safely by car. I do not see if I'm endangering others or not.`"* (FG3, T2).

> *"My mother does not allow me to walk [to school], I have yet to turn eight."* (FG9, C5).

3.2.3 Use of the car

Teachers reported that many parents take their child to school by car and referred to this as a two-fold problem: more cars on the school ground, which limits the safety of students walking to school. According to participating children, a lack of time, long distance to school and rainy weather often led to the use of car on the way to school.

> *"I take the car, (…) because it's faster, but sometimes I have to go there without the car."* (FG7, C9).
>
> *"I take the car. Because my house is so far away [from school]."* (FG10, C2).

3.2.4 Teachers' motivation and skills

Participating teachers viewed the support and engagement of teachers as an important facilitator for the promotion of children's PA.

In contrast, teachers with a low level of involvement in PA promotion could reduce the opportunities for the children to be physically active. Furthermore, a lack of skills and practice in educating PA may lead to less PA tasks provided by teachers.

> *"Of course, there are preferences among teachers and staff as well; they are not all as athletically predisposed as us two. There is probably less movement in the classroom."* (FG2, T2).
>
> *"I cannot really teach sports at all."* (FG3, T2).

3.2.5 Design and instructions of PA

As a determinant conducive to children's participation in PA, teachers further reflected upon the importance of an appealing design of activities and the element of choice. Children were seen to be fascinated by movement stories, music-accompanied activities and movement landscapes, such as multi-variant station training. Parents and children named numerous different types of exercise that the children did regularly or as club sports.

> *"I think when you have offerings that are particularly engaging, particularly when one kind of sets something up, movement landscapes, equipment, large equipment is always a huge fascination for the children."* (FG 4, T1).

Some children spoke positively about their participation in the design of PE classes (e.g., choosing activities/ games as a reward). Teachers also reflected that greater participation of children in the choice of PA activities would have a positive effect on levels of PA. The advantage of providing choices to children was also mentioned by a few parents, who explained how they let their children choose different activities in leisure time.

> *"And if it was a child's birthday, they often get to pick what we play that day. Also choosing something is great fun."* (FG10, C3).

3.2.6 Competition

Opinions varied on whether competition was considered as a facilitator or barrier in improving children's PA behavior. According to many teachers, children enjoy taking part in sports activities in a group and the thrill of winning in competitive activities. However, from a parental point of view, competitive sports were also perceived as a barrier, since the focus is on the child's talent instead of trying out different sports.

> *"So you now participate three times, and then you are told whether you have talent there or not,' and I always feel like that it shifts into this competitive mode really quickly."* (FG12, P1).

3.2.7 Influence of peers

Almost all children and teachers emphasized interactions in peers as a facilitator for children's PA. Many children reported going to school together as a group, with siblings or friends.

> *"Fun and games, they [children] meet with friends outside and get their exercise by wanting to play with others."* (FG4, T1).
>
> *"I have a running group. It's three guys from our class. And I always run up the hill with them."* (FG 10, C3).

3.3 Mesosystem

At level of the mesosystem exploring settings, such as schools and neighborhoods, the following six key aspects were identified: Existence of activity equipment, continuity and commitment, costs of organized sports, children's free time, children's sitting in class and variety of exercise options.

3.3.1 Existence of activity equipment

Most of the parents stated that no further equipment is necessarily needed for children to be active in nature: "*They can be super active outside, even without a single piece of playground equipment.*" (FG 11, P2). However, playing equipment were perceived to facilitate children's activity levels. A lack of resources within the school environment was perceived to inhibit children's PA opportunities.

3.3.2 Continuity and commitment

According to many participating teachers and parents, children require continuity and commitment regarding physical activities. Regular and fixed exercise times may be important, and exercise should be integrated into the everyday life of the children, both in school and leisure time.

> *"I think it's important that you keep trying, that you really pull it off continuously so that it's totally normal for the children. And not somehow like `Oh God I have to change again now', but no, it's everyday life."* (FG1, T1).

3.3.3 Costs of organized sports

A few teachers and parents shared the view that a lack of financial resources may also hinder children's participation in sports. By providing low-cost or free programmes that do not require any additional material, it can be ensured that all children have the opportunity to participate and try out different sports for themselves.

> *"The parents do not see the opportunity or cannot do it financially. Because it is always a cost factor if someone plays sports."* (FG12, P2).

> *"There are children who go to the sports club after school or participate in other sport offerings. And there are also children who do not do that because of money."* (FG 1, T2).

3.3.4 Children's sitting in class

According to a great number of children, sitting times in class are too long. A large proportion of the children explained that they were generally not allowed to move around in the classroom. From the teachers' perspective, pure sitting times can be reduced by offering lessons in which the children can alternate between sitting, lying down and walking.

> *"In class, we always sit."* (FG 8, C10).

> *"I work with the 'flexible seating' system in the classroom. They can choose their workstation and see if they want to work whilst sitting, lying down, standing up, or what suits them best." (FG1, T2).*

> *"…some children actually start moving around in their seats, we have these swivel chairs, they then start spinning around or some start lounging under the table, so they then look for possibilities to move around."* (FG1, T1).

3.3.5 Variety of exercise options

According to the majority of parents and teachers, providing a wide range of exercise opportunities at school, in after-lunch care, in sport clubs and as a vacation activity can be beneficial for children's PA. Most parents stated that organized exercise opportunities could be more differentiated in order to encourage their children to be physically active. A few parents remarked that for some specific sports that there were long waiting list (e.g., for swimming): "*I just tried again, for example, to get a place in this [name of course], where children can try out different sports, but I was told that the waiting lists are probably at least two years long.*" (FG 11, P3). Furthermore, some parents critically spoke about the after-school PA offers that they felt were not chosen appropriately because of less variety of content and time overlap with school lessons. Parents expressed the desire for various vacation camps and after-school activities organized by schools or activities that are timed to coincide with school hours, as well as taster courses offered by associations. Therefore, a broad spectrum of opportunities offered in terms of time and content of PA opportunities were seen to facilitate children's participation in PA.

> *"[…] it's helpful to have different offerings. So if I do not like balancing or running or anything else, just show somehow that sport can be very diverse."* (FG1, T2).

> *"We have a very large and well-known sports club here right next to the school. But I actually think that the sport offers for children could be even more differentiated. So my kids do not find anything there [at the sports club] straight away."* (FG11, P5).

3.3.6 Gardens, sport clubs and parks close to home

Both children as well as a few parents report that their own garden, basement, green spaces, playgrounds and other opportunities for movement in the residential environment are frequently and gladly used by the children for movement. A residential environment with exercise areas/green spaces provides opportunities for exercise. In addition, the children can walk unaccompanied. More distant opportunities for exercise are often an obstacle for parents, because they are connected with journeys. The residential environment also determines whether children actively make the journey to school.

> *"I think we are also very privileged, simply in terms of the living environment. So the kids, I think, all have the opportunity to get out relatively quickly, to get somewhere in nature. So we all have a hiking trail across the street more or less, so that's all relative that you can say, `There's an opportunity there, too.' So that is not reliant on driving there."* (FG 12, P1).

3.4 Exosystem

Two key aspects were referred to the level of the exosystem focusing on structures: weather-conditions and COVID-19 restrictions.

3.4.1 Weather conditions

When speaking about barriers to PA, many discussions also referred to the (bad) weather conditions. Bad weather was particularly often used as a reason to not engage in active travel to school. Most children and parents said they spend more time active outdoor when the weather is good like in summer and spring and more time being sedentary when it rains.

> *"I always come by bike, but if it's raining or something, my mom takes me to school by car."* (FG 7, C11).

3.4.2 COVID-19 restrictions

Several teachers, parents and children reported negative effects of Covid-19 restrictions on children's PA, such as sports classes not taking place and PA offerings at school being cut or canceled due to contact restrictions.

> *"If I now had Corona, I would not be able to go outside. And then, I do want to move around a lot, but if I had Corona now, I could not."* (FG 10, C1).

Looking across all levels of the socio-ecological framework, children, teachers and parents identified similar barriers and facilitators to PA for primary school children. Most determinants addressed pertained to the levels "Individual characteristics," "macrosystem," "mesosystem" and only two determinants were identified that related to the "exosystem."

4 Discussion

The aim of this study was to explore the individual, social and organizational determinants influencing children's activity behaviors, from the perspectives of children, parents and teachers. The results of this study show that according to all three groups PA of children aged six to 10 years is influenced by all levels of the socio-ecological model, namely individual characteristics, microsystem, mesosystem and exosystem. The promotion of PA may be facilitated by actions at a variety of levels across multiple domains, as both promoting and hindering determinants were mentioned at all levels. Below, the frequently reported determinants are discussed in relation to previous studies followed by implications for future research and potential interventions.

In relation to the individual characteristics and in line with previous studies (8, 9, 16, 19, 28), teachers, parents as well as children themselves considered children as very active and full of energy. However, this contradicts the findings that many children do not achieve the recommended minimum amount of daily PA (4). Although all subgroups perceived digital technology use as a determinant hindering children's PA, one participating child noted that digital technologies can improve children's PA by using an app to participate a digital sports programme. Oh et al. concluded in their review of digital interventions that there is great potential in digital platforms for health promotion in children (29). One study also showed that digital media may play a two-sided role when it comes to PA, enabling the promotion as well as presenting a barrier to PA (30). Although children and parents reported that outdoor activities are preferred by children, children themselves describe parents and teachers as not always allowing them to play outside, e.g., because of weather conditions or safety constraints. Since contact with green spaces has been shown to have positive effects on PA, the promotion of outdoor PA irrespective of certain weather conditions within the school setting as well as during leisure time, might lead to increased levels of children's PA (31).

When comparing the perspectives of parents, teachers and children in relation to individual determinants, it becomes clear that children have a natural motivation to be physically active. In all focus groups, children's preference for non-organized physical activities was mentioned. While all three groups noted hindering aspects of the use of digital technologies, a benefit was also mentioned from the children's perspective. The promoting aspect of outdoor activities was mentioned by parents and children but not by teachers. They, however, were the only ones to state the importance of children's self-confidence regarding their PA.

About the microsystem, and in line with previous studies (8, 32), the results of this study show that support, involvement and encouragement of parents, teachers, siblings and peers can have positive effects on childrens' PA levels. If parents have a positive attitude in supporting PA, children tend to become more physically active (21). However, parents prefering to control their child's actions were perceived as a barrier to PA by children and teachers. Suen et al. reported that safety concerns discouraged PA of young children (33). Therefore, future research should better explore the influence of parents' overprotection and its influence on childrens' habitual PA. In line with other studies, parents' use of the car was identified as hindering PA by children and teachers. Due to the short distance between the school and the home of the participating children in this study, it could be concluded that the perception of distances is a very subjective matter. Several studies have demonstrated that individual factors such as a child's age are crucial in relation to children's independent commuting (34, 35). The switch from parent-accompanied to independent commuting may be an important entry point for PA promotion of children that has been underutilized in Germany so far. A childlike and playful approach was perceived to be facilitating the PA of children. Activities including competitions were perceived as both, a hindrance and a benefit. Despite this, teachers and children perceived sitting times in class as a barrier of being physically active. Further studies confirm these findings by showing that children sitting time during school hours is longer compared with sitting times in non-school hours (36, 37).

All three groups perceived that children's closest social circle-peers and family members influence their PA behavior. Teachers also emphasized the promoting influence of teachers' motivation and skills. Only children and teachers mentioned parents' overprotection and use of the car as hindering determinants. All groups agreed on the promoting influence of a playful, child-friendly design of PA. Parents and teachers mentioned both facilitators and barriers regarding competitions in sports activities.

Regarding the mesosystem, a key facilitator was to provide children with various PA options. Variety included school-based and after-school programs, individual or team sports, competitive or non-competitive activities and exercise opportunities at different times. According to the parents and children, gardens, sport clubs and parks close to children's home facilitated PA. These results are consistent with a study (8) that showed household and neighborhood factors encouraged PA in children.

While all groups perceived the availability of play equipment and free playtime as promoting determinants for children's PA, teachers and parents also noted the influence of varied options of exercises as well as the cost and continuity of sports.

In relation to the exosystem, the results of this study are congruent with previous studies that confirm that bad weather conditions limit the level of PA of children and their time for outdoor play (8, 12, 16, 22, 23). In this respect, most of the children reported that they were not allowed to play outside during bad weather seasons. In line with other studies (8, 16, 18, 22, 23, 38, 39), our results reflect that bad weather conditions encourage the use of the car for transportation to school, even in urban areas where distances are short. A possible explanation for the low participation in active traveling to school in this study could be the urban conditions, such as large intersections or few opportunities to cross the road. The present study was conducted with children living in an urban area in Germany, where factors influencing active travel might differ from rural populations. Future research is needed to explore strategies to reduce the use of cars in bad weather. At the same time, it is important to explore whether or to what extent active transport is feasible and desirable for all children. As our results have shown, other approaches to increasing PA are desirable, such as providing a variety of physical activity options. Moreover, participants of all three subgroups perceived Covid-19 restrictions as a barrier to PA, such as needing to stay in quarantine. These findings are in line with a study by Kovacs and colleagues investigating the impact of the COVID-19 pandemic on PA in European children and adolescents aged 6–18 years old. Kovacs et al. suggested that children's PA level decreased dramatically during winter lockdown (40).

Regarding the exosystem, the Covid-19 restrictions were perceived by all three groups as a barrier of children's PA behavior. Children and parents also mentioned bad weather conditions as a hindering factor.

The results of the present study provide an in-depth view and several implications for research and practice from parents, teachers and children on determinants facilitating and hindering PA in children aged 6–10 years old. While teachers, parents and children identified the same facilitators and barriers, there were differences in their perceptions of these perceived determinants promoting and hindering PA in children. These findings suggest that there is a need to include different perspectives in future research when designing PA interventions. According to the results of this study, parental encouragement and support were perceived as facilitators of children's PA. Thus, including parents in the development and implementation of physical activities is needed. Moreover, peers and siblings should be involved in promoting children's PA as they seem to be a facilitating factor for children's participation in physical activities. Since children prefer outdoor activities, they should be offered the opportunity to be active outdoors regardless of any weather conditions. By introducing policies at schools that aim at ensuring that children can exercise outdoors during recess independent of the weather and offering them sufficient time for PA without instruction, PA could be improved in school-aged children. The design of active transport to school cannot be based on a "one size fits all" approach, but contextual determinants such as the children's living environment, the parents' need for safety, dealing with weather conditions, and scheduling should be considered. Traffic density often occurs around schools in Germany because parents drive their children to school for safety reasons (41). In order to promote active travel to school, the safety risks assumed by parents should therefore be reduced. Besides, most accidents on the way to school in Germany occur in cars being driven to school and not walking or cycling (42). Policy makers and traffic planners are still needed to promote active transport to school for children.

The strength of our study is that it adds to the available literature by exploring the facilitators and barriers of PA for children aged 6–10 years by including the perspectives of teachers, parents and children themselves. To date, qualitative research exploring this topic has predominantly focused on the perspectives of the teachers or the parents (8, 43), but also on parents and children (44, 45) separately. Confronting these three perspectives helped to triangulate the data and provided deeper understanding.

Several limitations will need to be acknolwedged. A first limitation of the study was the possibility of selection bias, because participants attended the focus group discussions voluntarily. The most motivated parents and teachers might have participated, whose children already might comply with current PA recommendations. In addition, there is the possibility of a selection bias because we limited the number of children to five participants per school class and these children were selected by the teachers with the aim of including heterogeneous perspectives. Furthermore, in the group of parents, focus group participants were entirely female. The experiences of fathers is therefore missing within the analysis. Despite concerted efforts to recruit a diverse range of parents, this was not achieved in the current study. Since, there is evidence relating to the role of the father in a child's development (46), it would be a valuable addition to the body of research to gain the fathers' perspective on factors that promote or hinder their children's physical activity. However, the child samples included both girls and boys of different age groups which provided a variety of perspectives. The focus groups and data analysis were conducted by the same researcher, which increases the risk of bias. However, focus groups were transcribed verbatim and additional researches were involved in both the focus groups and the data analysis.

5 Conclusion

There is consistent qualitative evidence that several determinants at various levels of the socio-ecological model influence children's PA behavior. Our results confirm children prefer non-organized and outdoor activities that involve active movement and play. However, the type of activities undertaken is strongly influenced by the attitudes and motivation of teachers and parents as well as siblings and peers.

PA should be promoted through a combination of intervention components, e.g., by using a socio-ecological framework focusing on the children, their relationships and environment. A comprehensive approach could include supporting PA regardless of actual weather conditions, involving teachers, peers and families, offering various opportunities of organized and non-organized activities in different settings and regulating the use of electronic devices. For the development and implementation of interventions in primary school setting, it is important to take into account the possible hindrances of PA explored in this study. Thus, strategies for regulating children's digital technology consumption, individual use of competitive situations among children, parental involvement in outdoor activities and active transport of children as well as strategies for physical activity even under pandemic conditions might be necessary.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the Bremen University Ethics Committee. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

LS: Writing – original draft, Data curation, Formal analysis, Methodology. MB: Writing – review & editing, Conceptualization, Project administration, Funding acquisition, Data curation. BB: Writing – review & editing, Project administration. HZ: Writing – review & editing, Funding acquisition. HB: Writing – review & editing, Methodology, Supervision.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2024.1280893/full#supplementary-material

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Physical activity interventions in European primary schools: a scoping review to create a framework for the design of tailored interventions in European countries

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Introduction: Schools provide a unique environment to facilitate physical activity for children. However, many school-based physical activity interventions have not been effective. We propose a new approach, which allows schools to tailor interventions to their specific context. This scoping review aimed to identify intervention components from previous school-based physical activity interventions to form the basis of a tailored approach in a European setting.

Methods: Joanna Briggs Institute guidelines for conducting scoping reviews were followed. European school-based intervention studies aimed at increasing physical activity in children aged 7–11 years published in English since 2015 were included. Databases searched were Ovid Medline, Embase, PsycINFO, Web of Science Social Sciences Citation Index, ERIC and British Education Index. Data was extracted on intervention components, context-related factors (geographical location, school size, child socioeconomic status and ethnicity), feasibility, acceptability and cost-effectiveness. A data-driven framework was developed to summarize the identified intervention components.

Results: 79 articles were included, constituting 45 intervention studies. We identified 177 intervention components, which were synthesized into a framework of 60 intervention component types across 11 activity opportunities: six within the school day, three within the extended school day and two within the wider school environment. Interventions most frequently targeted physical education (21%), active and outdoor learning (16%), active breaks (15%), and school-level environmewnt (12%). Of the intervention components, 41% were delivered by school staff, 31% by the research team, and 24% by external organizations. Only 19% of intervention studies reported geographical location and only 10% reported school size. Participant ethnicity and socioeconomic information was reported by 15% and 25%, respectively. Intervention acceptability was reported in 51% of studies, feasibility in 49%, and cost effectiveness in 2%.

Discussion: This review offers a first step in developing a future framework to help schools to develop context-specific, tailored interventions. However, there was a lack of reporting of contextual factors within the included studies, making it difficult to understand the role of context. Future research should seek to measure and report contextual factors, and to better understand the important aspects of context within school-based physical activity.

KEYWORDS

physical activity, children, school-based, primary schools, intervention components

Introduction

Physical activity has many positive effects on physical and mental health outcomes during childhood, such as improved cardiorespiratory health and fitness and reduced depressive symptoms, as well as improved cognitive function and academic performance (1, 2). However, a large number of children do not meet the World Health Organization (WHO) recommended average of 60 minutes of moderate-to-vigorous physical activity (MVPA) per day (1, 2), with recent accelerometer data suggesting that only 41% of 10–11 year old children meet the recommendation (3, 4). As we emerge from the COVID-19 pandemic, the way in which children are physically active has changed, with fewer children engaging in unstructured forms of physical activity, such as active play, and an increased dependence on structured activities, such as active school clubs (5–7). As girls and children from lower socio-economic groups have greater challenges in engaging in structured activities, these groups may be at risk of lower than their pre-pandemic levels of physical activity (5–8).

Schools can provide an environment in which physical activity can be equitably promoted (9, 10). Research shows that 13% of variability in weekday MVPA in primary school children on average can be attributable to school-level factors, almost double that of individual factors (11, 12). Therefore, schools can provide an important role in promoting physical activity, especially during the pre-adolescent years (aged 7–11) where physical activity has shown to decline with age (13). However, the majority of school-based physical activity interventions are either ineffective at increasing average MVPA or only yield small improvements (14–16). We have argued that one of the main reasons for this is the lack of focus on school context when designing, implementing, and evaluating school-based physical activity interventions (17). That is, the factors that influence schools as a setting for physical activity interventions (such as cultural, social, economic, environmental), as well as the factors influencing those delivering and receiving the physical activity intervention (such as demographic, socioeconomic) (17). School context can vary significantly from one school to another and potentially influences whether an intervention is successful. Therefore, school-based physical activity interventions that have been deemed "ineffective" as a one-size-fits-all approach in previous research may still offer promising ways to promote children's physical activity if the intervention components are considered separately and implemented and possibly combined within the appropriate school context. We therefore argue for the rethinking of school-based physical activity intervention studies to focus on context and the need for adaptable interventions that build on what is currently offered by schools (17).

We propose a new flexible school-based physical activity portfolio intervention approach to be delivered in European primary schools (18). This will involve schools selecting intervention components from a framework of components identified from previous studies to create their own school-specific portfolio. The intervention components are defined as the individual elements making up an intervention, while the framework is the resource which collates and presents these components for schools to choose from. The school-specific portfolio is then defined as the combination of intervention components selected by each individual school to meet the local contextual needs of the setting, facilities, priorities, culture, and ethos. The portfolio intervention approach is thus based on the idea that a selection of intervention components allows for a bespoke program for each school.

Recently, tailored interventions and whole school approaches have been developed, which recognize the need for school-specific approaches and alternative ways to effectively promote children's physical activity. Two recent examples include the Creating Active Schools (CAS) Framework (19–21) and the ACTivity PROmotion via Schools (ACTIPROS) 'toolbox' (22) which both provide approaches to work alongside schools to co-design or select physical activity interventions and/or policies that are tailored to school needs. The CAS Framework was developed via stakeholder engagement workshops to highlight opportunities for physical activity within the extended school day and provides a framework for co-designing physical activity policies and interventions with schools, to ensure school ownership and sustainability (19–21). Although, this stakeholder engagement approach has merit in identifying physical activity opportunities, the CAS Framework did not systematically review the published literature, which could also provide useful insight into how best to increase children's physical activity. The ACTIPROS 'toolbox' is an intervention approach whereby schools select from a number of previously identified evidence-based interventions (22). The toolbox was created by systematically identifying previous randomized controlled trials of school-based interventions found to be effective in increasing physical activity and/or cardiorespiratory fitness among 6-11-year-old children (23), which were then mapped onto the WHO Health Promoting Schools Framework (a framework associated with positive health effects when incorporated into intervention development) (24). However, the inclusion of effective interventions only may have limited the number of potentially relevant studies to be included to inform future interventions to increase children's physical activity, as interventions reported as "ineffective" may have effectiveness in certain contexts. In addition, the inclusion of RCTs only may have also limited inclusion of relevant studies, as there may be important learning from non-randomized intervention studies. It is important to highlight here that while we think that these previous approaches have a lot of merit there is potentially even greater benefit from allowing schools to build an intervention at the component level (i.e., the elements making up the whole intervention), rather than at the higher 'complete intervention' level. Yet, there is a lack of available literature related to individual intervention components that is needed to inform our context-specific tailored intervention approach, and it is this gap that we sought to address in this scoping review.

The primary aim of this scoping review was to identify existing physical activity intervention components that could form a portfolio of intervention components for delivery in European primary school settings. We limited our search to studies from 2015 that aimed to increase physical activity among children aged 7–11 years to ensure the most current research was captured. Similarly, as we are focused on components that could be combined to form data-driven portfolios for delivery in a European setting, we limited our search to studies in European schools, as school contexts in other countries, such as school structure, provision, facilities, and physical environment, are likely to differ. Our aims aligned with the rationale for conducting a scoping review, as the interest was in identifying intervention components, rather than assessing efficacy (25). In addition, because our framework will allow schools to build their own tailored school-specific portfolio based on their individual school context, the included intervention studies did not have to report effectiveness or have been reported to be effective at increasing physical activity to form part of our inclusion criteria for the framework. Our secondary aims were to identify if there was evidence of feasibility or acceptability for each component and to identify the resources likely required to implement each component.

Methods

This review was conducted in accordance with the guidance for conducting scoping reviews as outlined by the Joanna Briggs Institute (JBI) guidelines (26, 27) and the checklist for Preferred Reporting for Systematic Review and Meta-analyses (PRISMA)—extension for Scoping Reviews (28, 29) (Supplementary Table 1). The protocol was published on the Open Science Framework (OSF | PASSPORT) (18) on 31st March 2023.

Search strategy

A comprehensive search strategy was developed by SD (information specialist), with input from RJ and AP. Search terms were discussed and developed for three concepts: school children, physical activity, and school-based interventions. A study design filter was added so that only experimental studies were identified. Limits were also carefully applied to screen out studies that would definitely not meet our inclusion criteria. The databases Ovid Medline, Embase, PsycINFO, Web of Science Social Science Citation Index, ERIC and British Education Index were searched. Supplementary Table 2 presents the full Medline search strategy. The search strategy was tested by AP and refined by SD. Searches were conducted between April and June 2023.

Study selection

Table 1 presents the inclusion and exclusion criteria, defined in terms of Population, Concept, Context, and type of publication, in line with scoping review protocol guidance (26). Pilot screening was conducted by AP and discussed with the research team to ensure the eligibility criteria were as comprehensive as possible. Studies of interventions lasting less than 4 weeks were excluded to focus the review on interventions with the potential to make sustainable changes to children's physical activity levels. Additional exclusion criteria were added after pilot screening, which were not specified in the protocol. These were studies not targeting the provision or knowledge of physical activity (e.g., smartphone bans) and studies focused on use of technology (e.g., apps, virtual reality) because they did not align with our aims of identifying intervention components to

TABLE 1 Eligibility criteria.

Terms	Eligibility criteria	
	Inclusion criteria	Exclusion criteria
Population	Older primary school aged children (7–11 years) attending state funded schools Schools in Europe	Special or private schools Children with chronic conditions (including overweight and obesity) or learning difficulties Schools outside of Europe
Concept	Interventions aiming to increase children's moderate-to-vigorous physical activity (MVPA)	Interventions aiming to increase MVPA in combination with other health behaviors (e.g., healthy eating) Intervention lasting less than 4 weeks. Studies in which intervention components could not be extracted due to lack of detail.
Context	Interventions targeting physical activity during school term time within the extended school day or across the wider school environment (e.g., within school curriculum, school break times, travel to school, before and after school clubs, homework).	Interventions conducted outside of the extended school day (e.g., in school holidays or the use of school facilities for evening community groups) Interventions that did not directly target the provision or knowledge of physical activity (e.g., smartphone bans) Interventions focused on eHealth or use of technology (e.g., apps, virtual reality, electronic tablets)
Type of publication	Peer-reviewed studies of experimental design (e.g., randomized controlled trials, between-subject, quasi-experimental)	Student theses, conference abstracts, editorials, opinion pieces, reviews, protocols, commentaries Articles not published in English

inform a portfolio intervention approach to directly target physical activity in children, implementable across a range of schools.

SD imported titles and abstracts into the reference manager Endnote 20 (30) and removed duplicates. AP uploaded and screened all titles and abstracts in Rayyan (31) and RW independently screened 25% (32). All articles that potentially met the inclusion criteria were included for full-text screening. The full text of articles was then screened against the eligibility criteria by RW, with AP independently screening 25% (32). Where full text articles could not be obtained, authors were contacted. Screening discrepancies were discussed and resolved by AP and RW. The reference lists of all included articles were screened by RW (with AP independently screening 25%) to identify additional studies.

Data extraction

A standardized Excel spreadsheet was created to extract data. Data extraction was piloted by RW and discussed with the research team, leading to revisions to the original data extraction form. These revisions included extracting data at the study level rather than the intervention component level to align with how study findings were reported (e.g., feasibility and acceptability were reported for the intervention as a whole rather than for the intervention components separately). Due to the lack of data on specific barriers and facilitators to implementation in most studies, we instead extracted data where authors had made suggestions to change or improve the studies. RW independently extracted the data from all studies and AP conducted a 25% data check. Data were extracted by intervention study, drawing from all associated articles (i.e., one intervention may have been associated with a pilot or feasibility trial, full trial, qualitative evaluation and/or process evaluation). Feasibility and acceptability were reported using results from associated qualitative and process evaluations if not reported in the full trial study. We extracted data on intervention characteristics (e.g., country of implementation, intervention description, the number of intervention components included, who delivered the intervention components); study characteristics (e.g., study design, duration of study); study populations (e.g., sample size, gender, ethnicity and socioeconomic status of children); and relevant study findings (e.g., evidence of feasibility, acceptability, cost-effectiveness). The data extraction form is presented in Supplementary Data File 1. Intervention characteristics, study characteristics, study populations and relevant study findings were charted and narratively synthesized in the results section. In line with scoping review guidance, we did not appraise the methodology quality of studies (26).

Framework development

Data were synthesized into a framework of intervention components. Figure 1 presents a flowchart, which provides an overview of the framework development process. An iterative data-driven approach to framework development was taken via discussions and consensus meetings with the research team, including subject experts and practice-based professionals. Using the data extraction form (Supplementary Data File 1), RW identified the unique intervention components across all interventions. RW then curated a list of intervention components types, which summarized the unique intervention components (e.g., instruction manuals and activity cards were summarized as 'Resources for teachers'). The intervention component types were then mapped onto an 'Activity Opportunity', which was used to highlight which

FIGURE 1
Flow chart of framework development.

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intervention components have been previously used to promote certain physical activity opportunities within schools. The labels and definitions of the activity opportunities were developed using the intervention descriptions in the data extraction form (e.g., the Breaktime activity opportunity was developed from descriptions relating to interventions implemented within school break and lunch times). The activity opportunities were then mapped onto three overarching headings: Within school day; Within extended school day; and Wider school environment, to highlight where in the school system the activity opportunity had been implemented. The intervention component types were color coded to show where the same or similar intervention component types appeared across multiple activity opportunities. Supplementary Data File 2 presents the shortlist of intervention components, highlighting how the unique intervention components were summarized into the higher-level categories described above. Throughout the framework development process, the research team discussed and refined the higher-level categories to ensure clarity. The shortlist was then used to create an illustrative diagram of the framework (Figure 2). The diagram was discussed, drafted and refined by the research team. To increase the external validity of the framework, it was then sent to practice-based professionals, including a multi-academy trust PE strategic lead, a classroom teacher, and a primary education and physical literacy lead at a national children's physical activity charity for feedback on its appearance and clarity. The framework diagram was further revised after the feedback, which for example included adding additional sub-headings, and editing the language of certain headings.

Results

We identified 5,883 articles, of which 1,713 were duplicate records. Subsequently, 4,170 were screened at title and abstract level. Of these, 517 articles were screened at full text level, resulting in 79 articles constituting 45 intervention studies (33–112). Figure 3 displays a PRIMSA diagram illustrating detailed information related to screening and inclusion. The detailed data extraction form can be seen in Supplementary Data File 1.

Intervention characteristics

Table 2 displays the characteristics of the 45 included interventions. Interventions were identified from 11 countries, with interventions implemented in the UK being most common ($n = 18$, 40%). We identified 177 individual intervention components, with between two and five intervention components per intervention being most common ($n = 32$, 71%). Within the 45 interventions, 11 opportunities for physical activity were targeted, with the most frequently occurring being the PE curriculum ($n = 13$, 21%), active and outdoor learning ($n = 10$, 16%), active breaks ($n = 9$, 15%), and school-level environment ($n = 7$, 12%). Members of school staff delivered 72 (41%) of the identified intervention component(s), while the research team and external organizations delivered 54 (31%) and 43 (24%), respectively. The majority of interventions lasted 1–3 months ($n = 22$, 49%), with 16 interventions (36%) lasting longer than 3 months.

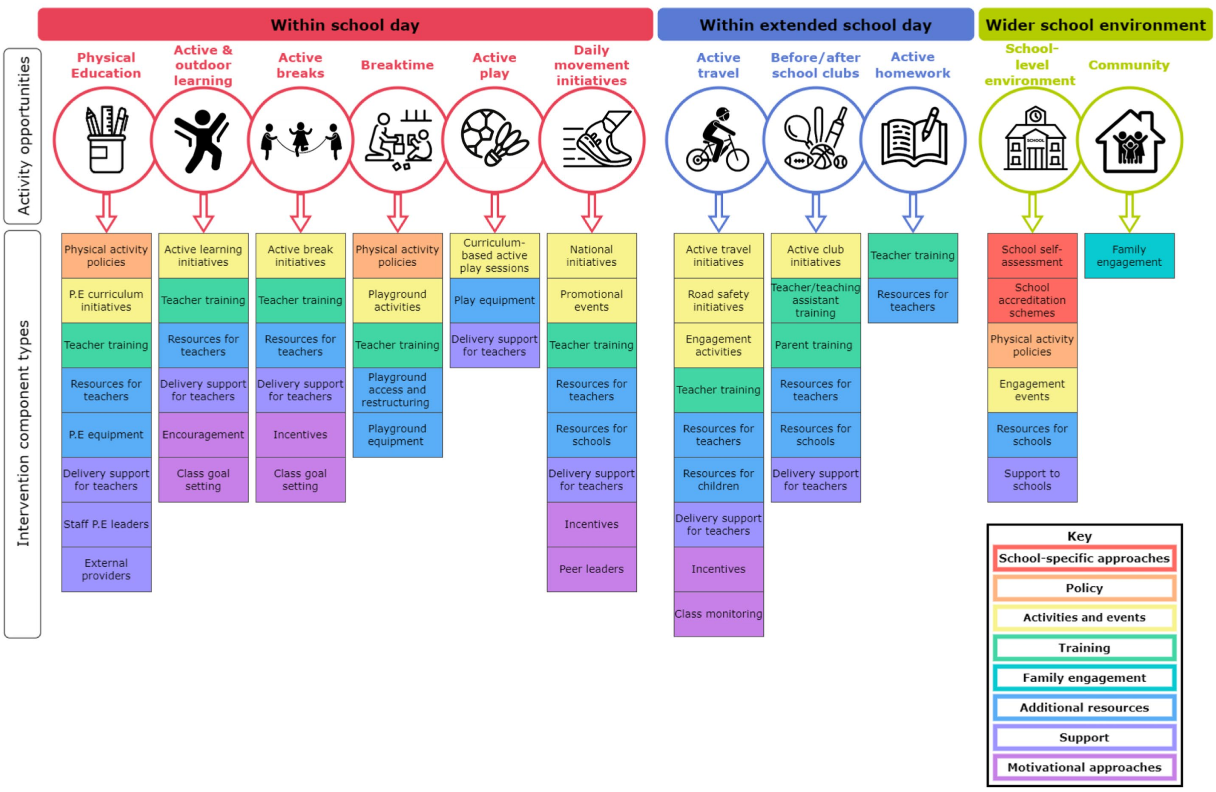

FIGURE 2
Framework of intervention components.

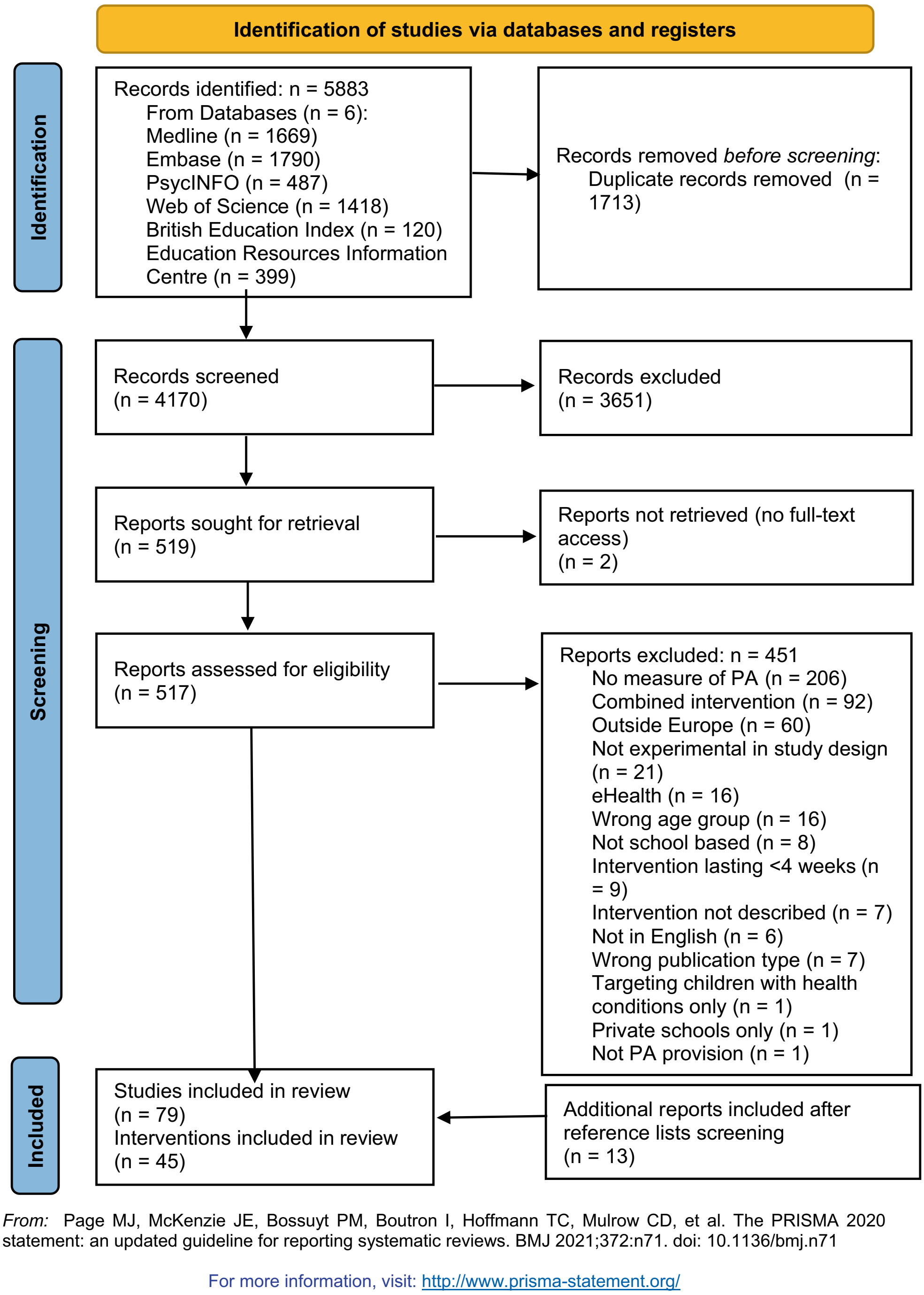

FIGURE 3
Prisma flow diagram.

Intervention components framework

The intervention components framework is displayed in Figure 2. The 177 individual components identified comprised 100 unique intervention components that were then grouped into 60 broader component types (Supplementary Data File 2). For example, workshops/seminars, CPD opportunities and on the job training for teachers were grouped into "teacher training." These component types were then mapped to the 11 opportunities to increase physical activity, which are displayed and defined in Table 3. Six activity opportunities were grouped within the school day, those that targeted opportunities during school hours; three within the extended school day, those that targeted opportunities outside of school hours but were linked to the school day; and two within the wider school environment, those that influenced the broader environment or community to promote children's physical activity. The 60 broader intervention component types were then put into eight categories: (1) activities and events (yellow; 20 unique components); (2) training (green; 13 unique

TABLE 2 Intervention characteristics.

	Number of studies	%
Country[a]		
UK	18	40.0%
Spain	5	11.1%
Italy	4	8.9%
Ireland	4	8.9%
Finland	3	6.7%
Denmark	3	6.7%
France	2	4.4%
The Netherlands	2	4.4%
Norway	2	4.4%
Germany	1	2.2%
Austria	1	2.2%
Activity opportunities[b]		
PE curriculum	13	21.3%
Active & outdoor learning	10	16.4%
Active breaks	9	14.8%
School-level environment	7	11.5%
Breaktime	6	9.8%
Active travel	5	8.2%
Community	3	4.9%
Daily movement initiatives	3	4.9%
Before/after school clubs	2	3.3%
Active play	2	3.3%
Active homework	2	3.3%
Number of intervention components[a]		
1	4	8.9%
2–3	20	44.4%
4–5	12	26.7%
6–7	4	8.9%
8–9	5	11.1%
Who delivered the intervention components[c]		
School staff	72	40.7%
Research team	54	30.5%
External organizations	43	24.3%
Pupils	1	0.6%
Not specified	18	10.2%
Intervention duration[a]		
1–3 months	22	48.9%
4–6 months	5	11.1%
7–9 months	4	8.9%
10–12 months	5	11.1%
> 1 Year	2	4.4%
Not specified	3	6.7%
No specific duration	4	8.9%

[a]Percentage calculated from the total number of included interventions (N = 45).
[b]Percentage calculated from the total number of intervention opportunities identified across all studies (note: interventions could include more than one intervention opportunity) (N = 61).
[c]Percentage calculated from the total number of intervention components (N = 177). Note that some components were delivered by multiple people (i.e. research team and school staff).

components); (3) additional resources (blue; 29 unique components); (4) support (purple; 14 unique components); (5) motivational approaches (pink; 10 unique components); (6) policy (orange; 5 unique components); (7) school-specific approaches (red; 6 unique components); and (8) family (teal; 3 unique components). As an illustrative example, an intervention component that provided instruction manuals to deliver active learning was categorized as "resources for teachers" and color coded in blue to represent its relationship with other components that provided "additional resources," which was then displayed under the opportunity "active and outdoor learning" within the larger group "within school day." The number of components per opportunity for physical activity ranged from three (community) to 15 (Physical Education).

Study design and contextual factors

Information related to study design is displayed in Table 4. We identified three types of experimental design, with most studies being quasi-experimental (n = 30, 63%). Baseline sample sizes within the pilot/feasibility studies ranged from 15 to 319 in the experimental groups and 14–165 in control groups. Within the main trials, baseline experimental group sample sizes ranged from 38 to 2,563 and control groups from 22 to 1,343. Mixed methods were employed by 17 (38%) interventions and 6 (13%) had a follow up measure beyond the post-intervention measure.

Table 5 displays contextual factors reported by intervention pilot/feasibility and main trial evaluations. Few studies reported contextual factors, such as geographical location (n = 9, 19%) or school size (n = 5, 10%). Seven studies (15%) reported participant ethnicity and 12 reported participant socioeconomic information (25%). Acceptability was reported in 23 (51%) studies, feasibility in 22 (49%), and cost effectiveness in one (2%).

Discussion

This scoping review has provided a novel synthesis of intervention components that have been reported in European primary school-based physical activity interventions since 2015. We identified 177 individual intervention components that comprised 100 unique components that were then grouped into 60 component types. These components targeted 11 opportunities to increase physical activity, which were categorized into three overarching groups: within the school day; within extended school day; and wider school environment. This information was illustrated in our framework of intervention components (Figure 2). This work forms the basis for creating a portfolio of intervention components that will be used to develop tailored, context-specific school-based physical activity interventions.

The most common opportunities for physical activity targeted by intervention components were PE, active breaks, and active and outdoor learning. This finding aligns with a systematic review and meta-analysis of multi-component school-based physical activity interventions, which identified PE and physical activity during the school day (including active breaks and active learning) as the most common intervention target areas (16). Although a positive trend for the effects of classroom active breaks and active learning has been

TABLE 3 Activity opportunities and definitions.

	Activity opportunity	Definition
1	PE curriculum	Interventions that made changes to the mandatory school PE curriculum to promote physical activity
2	Active & outdoor learning	Interventions that combined physical activity with non-PE curriculum academic learning objectives to facilitate learning while moving
3	Active breaks	Interventions that used short duration physical activities within the classroom as a break from academic learning
4	Breaktime	Interventions that changed the playground environment to promote physical activity at breaktimes
5	Active play	Interventions that targeted non-breaktime active play (i.e., curriculum time play sessions)
6	Daily movement initiatives	Non-PE curricular programs that regularly encourage children to walk or run over set distances or times, usually taking place outdoors
7	Active travel	Interventions that targeted active modes of travel to and from school (i.e., cycling, walking)
8	Before/after school clubs	Interventions that increased or changed before/after school club provision in order to promote physical activity
9	Active homework	Interventions that used homework with active elements to promote physical activity
10	School-level environment	Interventions that targeted elements of the broader school and its structures to promote physical activity
11	Community	Interventions that drew upon community influences (i.e., the family) to promote physical activity among pupils

TABLE 4 Study designs.

	Number of studies	%
Experimental design[a]		
Quasi-experimental	30	62.5%
Randomized controlled trial	15	31.3%
Natural experiment	3	6.3%
Type of intervention study[a]		
Pilot/feasibility study	16	33.3%
Main trial	32	66.7%
Studies which included both	3	6.3%
Intervention evaluation methods[b]		
Quantitative only	28	62.2%
Mixed methods	17	37.8%
Follow up beyond post-intervention[a]		
No follow up	42	87.5%
1–3 months	2	4.2%
4–6 months	3	6.3%
> 6 months	1	2.1%
Additional evaluations		
Reported intervention acceptability [b]	23	51.1%
Reported intervention feasibility [b]	25	55.6%
Reported cost effectiveness [b]	1	2.2%

[a]Percentage calculated from the total number of included pilot/feasibility and main trials (N = 48). [b]Percentage calculated from the total number of included interventions (N = 45).

TABLE 5 Study contextual factors.

	Number of studies	%
School characteristics		
Reported geographical location	9	18.8%
Reported school size	5	10.4%
Participant characteristics		
Reported participant socioeconomic characteristics	12	25.0%
Reported participant ethnicity	7	14.6%

suggested in the literature, it is challenging to draw conclusions due to low study quality and variability of study designs (113–115). Interventions that target PE have shown to consistently increase in-session physical activity (116–118); however, their impact on whole day physical activity is less clear, with one review finding little positive impact on leisure time physical activity (117). This may be due to compensatory behavior whereby increases in physical activity during one period of the day results in declines in another period (14), emphasizing the need for whole day physical activity measures. Yet, to date, school-based interventions have shown to have a small or no effect on whole day MVPA (14–16). It is clear then that the challenge in increasing MVPA among children requires innovative approaches.

Our results are broadly consistent with a recent scoping review that identified and mapped the characteristics of interventions that sought to increase physical activity or cardiorespiratory fitness among children to the Health Promoting Schools (HPS) framework (23). Aligning with our review, most (58%) interventions centered on health skills and education (i.e., teacher training and materials) and the implementation of active learning, in-class exercises, and improvements to PE, whereas, only 7% of interventions were centered on healthy school policies (23). Although we adopted a data-driven rather than stakeholder-informed approach, the opportunities identified in our review also align with those identified in the Creating Active Schools (CAS) framework (19–21) that include events/visits, break/lunch (recess), PE, curricular lesson, before/afterschool clubs, active travel, and family/community (19–21). Our review provides detailed information related to specific intervention components that can be used to increase physical activity via the opportunities noted in the CAS framework, as well as additional detail to some of the specific opportunities within the CAS opportunities, such as curricular (non-PE) lessons (e.g., active homework, active breaks, daily movement initiatives, and active and outdoor learning). As a result, practitioners may find this information helpful when developing specific approaches.

We have recently proposed a new context-specific approach for school-based physical activity intervention design that emphasizes the varying needs of schools and the subsequent importance of a tailored approach (17). Between-school variability, attributable to unmeasured school factors, has shown to account for nearly double the amount of variation as individual factors (11, 12). Yet, among the studies included in this review, few report descriptive information that can help to understand context, such as geographical location, socioeconomic characteristics, ethnicity, and school size. While this is certainly not an exhaustive list, or even a sufficient level of detail to understand the complexity of school contexts, it reflects what we view as a lack of consideration for contextual factors that are likely to affect intervention effectiveness (17). Collecting relevant data to identify and explore context variation across schools is important to evaluate differential intervention effects, allowing context-specific features to be understood that can be harnessed to promote physical activity. Yet, the aspects of school context that are most important in relation to physical activity is relatively unknown, which makes collecting relevant contextual information challenging. It is therefore important that future research explores school context and its features that influence physical activity.

In our original aim outlined in this scoping review's protocol (18), we intended to extract detailed information related to the intervention components, including who delivered it, who it was targeted at, resources required, and its duration and frequency. It was our intention that these could subsequently be replicated as part of a portfolio of intervention components that could be developed for individual schools. Yet, it became apparent during extraction that the level of detail needed to be able to replicate components was insufficient. Using teacher training as an example, studies would commonly state the duration and format of the training (i.e., a 1 h workshop), but less often reported the contents of the training sessions being delivered. As a result, researchers and practitioners would be unable to replicate the intervention components reported in these studies. In addition, we were unable to extract resources (e.g., budget, space, number of staff) required to deliver intervention components due to insufficient reporting. This is a well-recognized problem with, for example, a systematic review showing that only 39% of non-pharmaceutical interventions, which included physical activity interventions were adequately described, with missing information related to intervention materials being the most common (47% of studies provided intervention materials) (119). This scoping review adds to this finding and may indicate that inadequate intervention description may be a prevailing issue in physical activity research and steps to improve intervention descriptions might be needed; however, further research to explore this topic in depth on a broader range of studies is needed. Researchers may find the template for intervention description and replication (TIDieR) checklist and guide a useful resource for ensuring interventions are adequately described and reported (120). This would enable researchers to effectively build from the work of others in the field.

Nearly a third (31%) of studies identified in this review were randomized controlled trials (RCTs). These are widely considered the "gold standard" for evaluating interventions (14–16). However, researchers should consider the limitations of RCTs when trying to understand how effectiveness depends on variation between contexts (17). For example, a large number of schools is required to capture the range of contexts in both intervention and control groups to ensure randomization adequately balances contextual differences, which is often not feasible within real-world research that is limited in resources and scope. We have suggested that a cohort-based stepped wedge design could provide an alternative, pragmatic design that allows each school to act as its own control, thus reducing the number of schools needed while maximizing the information available on factors associated with the intervention (17). As such, we suggest that researchers would benefit from considering alternative designs to the RCT in future research.

The cost of implementing school-based interventions varies considerably. For example, in this review we identified an intervention that conducted major playground remodeling (41), which likely comes at relatively greater costs than other interventions, such as changing the way in which PE is taught (46, 47, 75). Cost-effectiveness is therefore an important detail needed to evaluate the effectiveness of physical activity interventions so that informed decisions can be made related to the best use of limited resources. Yet, only one intervention in this review included an evaluation of cost-effectiveness. Including an assessment of cost-effectiveness in future intervention evaluations, where appropriate, is needed to provide additional beneficial information for decision makers and future implementation.

The majority of intervention components identified in this review were delivered by school staff. While a member of school staff may be conveniently placed to deliver an intervention component and more cost-effective to schools than external providers, a lack of time and resources to enable school staff to deliver quality physical activity is a consistent issue identified in the literature (121–123). This issue may have been further exacerbated following the COVID-19 pandemic, where the impact of missed education is evident (124) and schools feel pressured with the need to "catch up" on missed learning while managing the varying post-pandemic needs of each child (125). Therefore, interventions that draw on over-pressured school staff and resources may therefore risk adding further pressure to strained school systems, leading to the intervention not being implemented as intended. This issue was demonstrated pre-pandemic in the process analysis of an intervention included in this review where releasing school staff for training was a key barrier in some schools (54). These systemic pressures within school systems need to be addressed to enable physical activity to be prioritized alongside academic studies within the curriculum. However, researchers and practitioners often have little influence to change these systems and are therefore limited to implementing school-based physical activity interventions within the existing school systems. Systemic pressures likely vary between schools and depend on a number of contextual factors, including school culture, demographics, and community influences. For this reason, context is important, and allowing each school to reflect on their current provision and build intervention components into their specific context, with consideration for their available resources, is vital to promoting physical activity within strained school systems.

The second most common implementer of intervention components was the research team. While these individuals hold expertise in their subject area, this may create delivery agent bias when interventions are scaled up and implemented more widely (126). For example, if the research team are delivering teacher training, when the intervention is scaled up, this training may need to be conducted by a person who does not have the same level of in-depth knowledge or experience as the research team. As a result, the training may be of lower quality and have a less impactful effect on physical activity outcomes. Thus, it would be beneficial to consider the implications of the research team delivering intervention components to ensure that delivery agent bias is minimized when interventions are scaled up. Components that were delivered by the research team also included materials, such as training manuals or guidance. For these materials, researchers may find Patient and Public Involvement (127), or a deeper process of collaboration, a useful means of ensuring that these materials are appropriate for the target population.

The new framework that has been created based on the results of this review does not provide an exhaustive list of intervention components that can be implemented in schools to increase physical activity, but constitute those identified within a specific period of time and population, almost all of which were designed and developed by a research team. This means some potential components and target areas may be missing. For example, through our work with schools, we have seen the implementation of a range of strategies to increase pupil physical activity, such as award ceremonies, t-shirts and other materials to promote school ethos, playground buddy systems, and inspirational school trips to watch sport competitions. Although such interventions are not reported in the academic literature, it is vital that we acknowledge the experientially-informed knowledge of school staff and how these have performed in their specific contexts. Our future research therefore aims to co-design a portfolio of intervention components by synthesizing strategies and interventions developed by both researchers and schools. We envision that this will be completed via workshops and working groups with key stakeholders surrounding children's school-based physical activity, such as teachers, school senior leadership team members, school governors, and pupils.

Following the co-design workshops, the framework of intervention components will help to facilitate the development of tailored interventions based on the context-specific needs of individual schools. However, there still exists a need to map these components to specific contextual factors. For example, if time and resources are scarce within schools (125), components that require little of each may be appropriate. As discussed above, little is known about primary school contexts and the factors that are most influential to promoting pupil physical activity. Therefore, future work will be needed to combine the framework of intervention components once contextual factors are better understood before it can implemented. It is also important that research is conducted to test the intervention's efficacy in encouraging children's physical activity within primary school before it is widely implemented. This work is currently being undertaken as part of the PASSPORT project and will be available once completed and peer-reviewed.

Strengths and limitations

By mapping the intervention components used in previous European school-based physical activity interventions for children aged 7 to 11 years, this scoping review has provided an initial framework for future intervention development. The resulting framework was data-driven and received input from practice-based professionals to ensure its external validity. The scoping review search strategy was developed by an information specialist and a range of experimental study designs, including natural experiments and quasi-experimental studies were included. In addition, responding to our research highlighting the problematic dismissal of interventions when they do not scale up across contexts or fail to deliver on narrow outcome measures (17), in this scoping review we did not limit our search to interventions found to be effective or successful. However, it is important to highlight the limitations of our scoping review. As highlighted in the discussion, we were unable to extract detailed information about acceptability, feasibility and resource use associated with individual intervention components as we had originally aimed to, due to the lack of reporting across the included studies. We only included studies aiming to increase MVPA and excluded studies exclusively focused on light physical activity, sedentary time or other related health outcomes. Furthermore, we only included studies conducted in European schools and published after 2015 to ensure the intervention components identified were the most relevant for the development of future school-based physical activity interventions in Europe. However, it is possible that studies from other countries, published before 2015 could have provided additional unique components, which could be relevant to European schools. We highlight in the results that 40% of interventions were conducted in the United Kingdom, which may be a reflection of the varying research priorities between countries and there may be interventions published in other languages that were not included in this review. In addition, while we aimed to develop a framework that can be applied across Europe, due to the large number of UK-based interventions, it is warranted to first test the framework in these contexts. Finally, our review was limited to peer-reviewed publications.

Conclusion

This scoping review has added novel information related to specific intervention components that can be used as a first step in developing a future framework, allowing schools to develop context-specific, tailored interventions to promote children's physical activity in Europe. This framework addresses a gap in the literature by providing a level of detail at the intervention component level, which is needed to tailor interventions to current school contexts to maximize their capability to promote physical activity. It is important that experientially-informed knowledge is synthesized and included in this framework and co-design workshops with key stakeholders is an important next step in its development. Importantly, we also observed a lack of reporting of contextual factors and cost-effectiveness within the studies included in this review. Future research would benefit from considering these in the design and reporting of school-based physical activity interventions.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

AP: Conceptualization, Data curation, Methodology, Project administration, Writing – original draft, Writing – review & editing. RW: Conceptualization, Data curation, Methodology, Project administration, Writing – original draft, Writing – review & editing.

DH: Conceptualization, Project administration, Writing – review & editing. RS: Conceptualization, Funding acquisition, Methodology, Writing – review & editing. SD: Methodology, Writing – review & editing. SI: Conceptualization, Writing – review & editing. FV: Conceptualization, Writing – review & editing. RJ: Conceptualization, Funding acquisition, Methodology, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The handling editor JS declared a past collaboration with the author RJ.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2024.1321167/full#supplementary-material

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School-based promotion of physical literacy: a scoping review

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Introduction: The role of physical activity in children's healthy development is undisputed, with school-based interventions being seen as a priority. The promotion of physical literacy (PL) seems to be promising due to its holistic approach, combining physical, cognitive, and affective domains. To develop recommendations for possible measures, we compiled existing literature on existing school-based PL interventions.

Methods: Five databases (MEDLINE, Web of Science, SPORTDiscus, ERIC, and PsycInfo) were searched between July 6 and July 10, 2023, by combining the terms "physical literacy," "school," "program," "workshop," "intervention," and "curriculum" as well as a manual search. Records were screened in a two-stage process by two independent authors using *a priori* criteria. Eligible studies concerned PL interventions in the school context. The included records were sorted according to school type/population, structure, content, PL domains addressed, and evaluation.

Results: In total, 706 articles were found through the database search and an additional 28 articles through the manual search. After removing duplicates, 502 publications remained, which were screened by title and abstract, leaving 82 full texts. These were cut down to 37 articles describing 31 different programs (19 in primary schools, eight in secondary schools, one in both primary and secondary schools, and three unspecified). Most interventions were conducted during physical education classes (n=12). All three PL domains were addressed by five interventions, while 11 interventions solely concerned the physical domain. In addition, 21 interventions evaluated their effects on PL. Most evaluations showed small to moderate but inconsistent effects on several PL-related constructs (e.g., self-efficacy, motivation, movement skills). Interventions incorporating all three domains reported positive effects on physical competence and enjoyment.

Discussion: Although there is a growing body of data related to school-based PL promotion, their effects and practical application remains relatively underdeveloped: study designs, study quality, PL assessments, and results are heterogeneous. Corresponding research adhering to the holistic approach of PL will be crucial in clarifying the potential lifelong role of PL in promoting physical activity, increasing health and well-being and to actually enable development of recommendations for action.

KEYWORDS

physical literacy, school-based interventions, children, physical activity promotion, health promotion

1 Introduction

Physical activity and exercise play a central role in the healthy physical, psychosocial, cognitive, and emotional development of children and adolescents (1–3). However, school-aged children tend to engage in sedentary behavior and excessive use of audiovisual media. Steene-Johannessen et al. (4) integrated 30 studies conducted between 1997 and 2014 into a systematic review that used accelerometry to measure physical activity levels and sedentary behavior in children aged 2–9.9 years and adolescents aged 10–18 years. Notably, only 29% of the children and adolescents were classified as being sufficiently physically active. Boys were more active in all age categories. The beginning of the age-related decrease in or leveling off of physical activity and the increase in sedentary behavior seemed to occur roughly at the age of 6–7 years. The COVID-19 pandemic significantly worsened this trend, leading to a reduction in children's physical activity of between 11 and 91 min a day (5).

Due to the numerous negative consequences associated with physical inactivity, such as motor deficits, obesity, and weight gain, effective counter measures are warranted. In this context, schools emerge as an ideal setting: the fact that young people spend a significant proportion of their time in schools and actively participate in school activities makes them a strategic and accessible setting for targeted interventions (6). However, although a range of measures has been introduced in schools to promote physical activity and reduce sedentary behavior (7–9), there is still no gold standard for effective interventions. Following a systematic Cochrane review including 89 studies, representing data from 66,752 study participants, the increase in the time spent engaging in moderate to vigorous physical activity through school-based physical activity intervention is small to non-existent (mean difference = 0.73 min/day; 95% confidence interval = 0.16–1.30 min/day). The authors emphasize that considering the diversity of effects, the potential for bias, and the generally modest magnitude of effect, the results should be interpreted cautiously (10).

Factors influencing participation in physical activity are multicomponent encompassing social environment and intrapersonal level, among others (11). Therefore, there is a need to implement more comprehensive strategies targeting daily life and living environments as well as additional factors such as the intrinsic motivation and self-efficacy of children and adolescents to initiate and maintain an active or healthy lifestyle. A promising approach in this context is the holistic concept of physical literacy (PL) developed by Whitehead (12, 13). Within this concept a cognitive domain (knowledge and understanding of the physical and psychological effects of sports and exercise), an affective domain (integrating various constructs like motivation and exercise-related self-efficacy and self-confidence), and a physical domain (movement, sports participation, motor skills, and basic movement skills) was summarized. According to her, these domains are interrelated and form the basis of a lifelong active lifestyle (14). A cross-sectional Danish study explored the associations between adolescents' PL and their emotional and social well-being and whether these associations are mediated by sports and exercise participation. Positive associations were observed between PL, well-being, and exercise participation (15). Additionally, Carl et al. (16) described positive effects of PL interventions on individual domains as well as on physical activity behavior. However, this review mainly analyzed the effects on the PL or their individual domains and did not relate them to the respective setting or the intervention content. Given that appropriate measures in schools can significantly contribute to lifelong physical activity, a more in-depth analysis of such interventions within the school setting is essential to develop appropriate recommendations. Therefore, we conducted a scoping review to answer the following questions: What theoretical PL concepts are school-based PL interventions based on? How are PL interventions implemented in everyday school life, in terms of program length, frequency, and duration of individual units? Which assessment instruments were used to measure the effects of the interventions on PL? What effects do school-based PL interventions have on PL outcomes?

2 Methods

This scoping review was conducted according to the methodological framework elaborated by Arksey and O'Malley (17). This article is based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRIMSA-ScR) (18).

The search strategy was based on Whitehead's (12) definition and the three domains of PL. The cognitive domain incorporated knowledge and understanding of the changes in the body and psyche due to movement. The affective domain covered the areas of motivation, self-efficacy, and self-confidence. The physical domain encompassed motor skills, movement behavior, and basic movement skills.

All school types were addressed: primary, secondary, and high school. The distinction between primary and secondary school was defined by the school system of the country of origin of the intervention. Secondary schools were defined as any school with an International Standard Classification of Education (ISCED) level-3 qualification (19) at the maximum, which includes, for example, American High Schools.

2.1 Search strategy and selection process

The following five databases were searched for articles published by July 6, 2023: MEDLINE (via PubMed), Web of Science, SPORTDiscus, ERIC, and PsycInfo. The search was conducted by combining the terms "physical literacy," "school," "program," "workshop," "intervention," and "curriculum." Details on the specific search strategies used on each database can be found in the appendix (Supplementary Table S1). In addition, the reference lists of systematic literature reviews were searched to identify relevant publications. If study protocols were included, a search was conducted for the published results of the study. Where possible, inaccessible full texts were requested from the corresponding author by email three times.

Publications were included if the following *a priori* criteria were met: (i) a PL intervention/program/workshop/curriculum implementation (hereafter referred to as an intervention) or an intervention designated as such was used; (ii) the intervention targeted school children, or the effects of the intervention on school children were examined; (iii) the intervention took place in a school context; and (iv) the publication was written in English or German. Publications were excluded if (i) the PL intervention was aimed at kindergarten children, preschool children, university students, school staff, or parents; (ii) the PL intervention did not take place in a school context; (iii) the publication was a conference paper or scientific poster or was not written in English or German.

Studies were selected using the online program Rayyan (20). Duplicates were first removed automatically and then manually. Two authors (M.G. and L.K.) independently and blindly screened the identified publications against the inclusion and exclusion criteria in two steps: (i) title and abstract screening and (ii) full-text screening. Disagreements were discussed at the end of each step. If no consensus could be reached, a third author (C.J.) decided.

The search and selection processes were documented in a PRIMSA flow chart (Figure 1) (21).

2.2 Data extraction

A standardized extraction table was developed *a priori* and was initially tested for applicability and completeness using five publications. This pilot test demonstrated that the extraction table

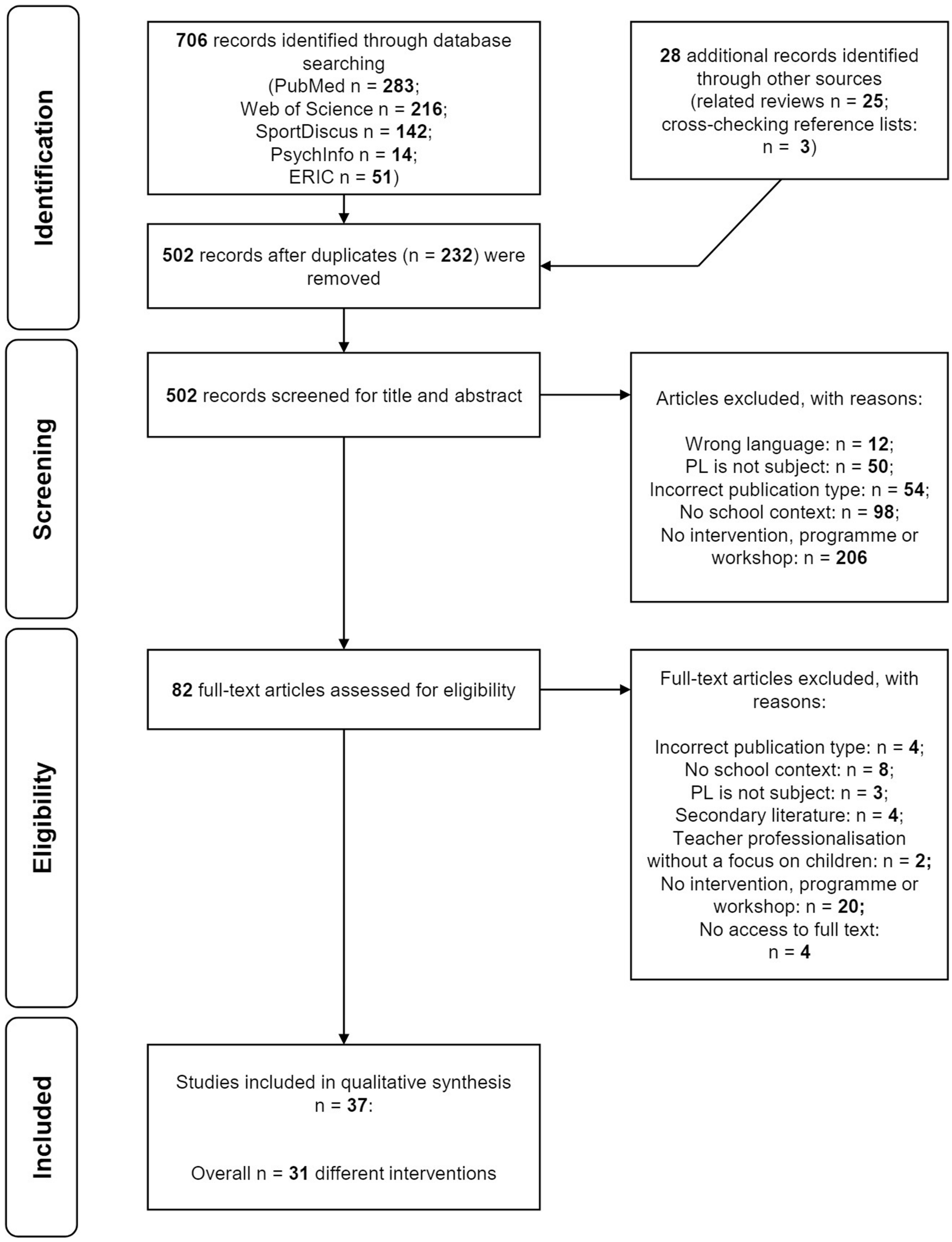

FIGURE 1
PRISMA flow diagram presenting the process of study selection.

could capture basic publication data, intervention classification and description data, evaluation results, and evaluation classification data. A complete list of the extracted data items can be found in the appendix (Supplementary Table S2).

2.3 Synthesis

The implementation of PL into the school routine was recorded based on the time of everyday school life when the intervention was conducted (after school, physical education (PE), multi-component, other) and the type of school (primary and secondary school). The structure was assessed by length (in weeks), frequency (in sessions/week), and duration (in minutes/unit).

The realization of the three PL domains in each intervention was assessed using the following criteria. The criteria for the affective and cognitive domains were considered to be fulfilled as soon as they were mentioned or described in the intervention description; example for fulfilled affective domain: "[…] by engaging the students in an experience that would provide individual challenges, also known as positive challenges, they would concurrently develop aspects of the affective domain of physical literacy. Not only would students experience these optimal challenges, but in doing so they could develop feelings of positive affect such as fun and enjoyment, which would foster motivation," (22); example for fulfilled cognitive domain: "The cognitive aspect of the psychological domain was specifically worked on in the circuits through understanding movements and using feedback and knowledge of results to improve," (22). The physical domain criterion was fulfilled if at least one additional physical activity session took place (e.g., active breaks) or a new concept was implemented in regular PE lessons (e.g., the SAMPLE-PE intervention by Rudd et al. (23): Children explored objects in the PE hall. Activities with changing constraints were played. No demonstration and feedback were provided. Instead, children reflected using questioning strategies or observed their peers. Questioning fostered an external focus of attention). Conversely, carrying out regular PE lessons did not fulfill the physical domain criterion.

Additionally, to be able to consider the effectiveness of the interventions on PL outcomes, study designs, assessment instruments, and reported results were obtained, if available.

3 Results

3.1 Literature search and study characteristics

The search of the online databases returned 706 articles, with another 28 articles identified through manual searching (see Figure 1). After duplicates were removed, the titles and abstracts of the remaining 502 sources were screened. In the next step, the full text of 82 articles was assessed for eligibility. In total, 37 articles describing 31 different interventions met the inclusion criteria.

Eight interventions were conducted in Canada, seven in the United States, three each in Germany and Wales, two in Hong Kong, and one each in Australia, England, Ireland, Scotland, Slovakia, Spain, and Turkey. For one intervention, the country of origin could not be determined.

3.2 Underlying theoretical physical literacy concepts within the interventions

All of the interventions identified in this study ($n = 31$) referred to a PL model. Most frequently, Whitehead (12, 13, 24) was cited when deriving a definition ($n = 14$). The definition of the International Physical Literacy Association (IPLA), which is closely connected to the perspective of Whitehead, was referred to seven times: "Physical literacy can be described as the motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engagement in physical activities for life" (25). Canada's Consensus Statement, which aligns with the definition established by the IPLA, was described once (26). A review by Edwards et al. (27) was mentioned twice; it presents a summary of existing PL definitions, with the main result that approximately half of the approaches are based on a monist/holistic PL perspective. The definition proposed by the Aspen Institute was also mentioned twice: "Physical Literacy is the Ability, Confidence, and desire to be Physically Active for Life" (28). One intervention presented its own definition: "Physical literacy is a part of the ontogenetic development of the individual […]. A physically literate person should have adequate motor abilities, skills, and knowledge, including a positive attitude to physical activities, and is able to take responsibility for his own health" (29). In four instances, no specific details were provided regarding the definition applied in the intervention.

In relation to the theoretical construct PL five interventions focused all three domains. Two domains were addressed by 15 measures each (physical and affective: $n = 9$; physical and cognitive: $n = 5$; affective and cognitive: $n = 1$). The physical domain alone was addressed by eleven interventions.

3.3 Physical literacy assessments

Overall, 21 interventions were evaluated in terms of isolated PL domains (Tables 1–4). The effects on PL as an overarching construct were assessed five times, using the Canadian Assessment of Physical Literacy ($n = 1$), the second version of this assessment ($n = 3$), and the Passport for Life tool ($n = 1$). PL self-perception was evaluated using the Physical Literacy Assessment for Youth Self (PLAYself) questionnaire ($n = 3$).

In 13 interventions, the effects on the physical domain were assessed via motor test batteries: motor skills (TGMD-2: $n = 4$; TGMD-3: $n = 2$), physical competence (PLAYbasic: $n = 2$; PLAYfun: $n = 3$), aerobic capacity (PACER: $n = 1$), and basic motor competencies (MOBAK: $n = 1$). In eight interventions, the effects on the affective domain were assessed with constructs such as motivation (Leuven Involvement Scale for Young Children: $n = 1$; Behavioural Regulation in Exercise: $n = 1$; subscale from adapted behavioral regulation and psychological need satisfaction scales: $n = 1$; self-developed: $n = 1$), confidence (Pictorial Scale of Perceived Competence and Social Acceptance: $n = 1$), self-efficacy (Children's Self-Perception of Adequacy in and Predilection for Physical Activity: $n = 1$; Perceived Physical Ability Scale for Children: $n = 1$), self-concept (Physical Self-Description Questionnaire-Short Version: $n = 1$), perceived competence (subscale from adapted behavioral regulation and psychological need satisfaction scales: $n = 1$), and self-perception (PLAYself: $n = 4$). In two interventions, the effects on the cognitive domain were assessed using multiple-choice questionnaires about

TABLE 1 Identified interventions conducted during physical education lessons.

Author, year: Project	Country	Participants			Intervention characteristics			Structure of intervention	Content of intervention				Study design	Construct: instrument	Results
		N	Age (mean ± SD) [years]	Female [%]	Length [wk]	Frequency [PLS/wk]	Duration [min/ PLS]		Description	Cognitive	Affective	Physical			
Primary school															
Borzikova et al. (2020)	Slovakia	84	6.8 ± 0.4	–	24	1.25	60–72	One session included 6 physical activities or movement games. Intervention sessions were additional to standard PE.	Physical exercises and activities with non-traditional equipment and psychomotor games.	No	No	Yes	RCT	Basic motor competencies: MOBAK ("Motorische Basiskompetenz").	Basic motor competencies: post-intervention IG favored, $p < 0.01$ (unpaired t-test, IG 11.95 ± 2.09, CG 7.20 ± 2.72).
Coyne et al. (2018): Athletics Canada's Grassroots RJTW Program	Canada	310	10.5 ± 1.0 Range: 7–12	50.3	10	2	40	Running, jumping, and throwing programs of 3 weeks each.	Track-and field-inspired games, activities, and skill challenges.	No	No	Yes	Non-controlled study	PL: Canadian Assessment of Physical Literacy	PL: pre-post-intervention time effect IG, $p < 0.001$, Cohen's $d = 0.303$ (paired t-test, pre intervention 61.7 ± 10.4, post intervention 65.0 ± 11.4).
Deutsch et al. (2022): Best Warm-up Activities	USA	75	9.0 ± 1.0	60.0	4	1.5	30	15 min one "physical-best" or traditional warm-up + 15 min activity games.	"Physical-best" warm-up: (i) Jumping Frenzy: stations with instruction cards for various jump rope activities and stretches. At each rest station, children self-assess what activities were most intense and beneficial to physical health. (ii) Artery Avengers: fill an opponent's hula hoop (arteries) with yarn balls (fat from food) while keeping their hula hoop empty. (iii) Clean the Beach: collecting beanbags (trash) and placing them in hula hoops (trash can) using various locomotor movements (walking on all fours, tiptoes, hopping on one foot). After the activity is over, students identify which body parts' muscular strength was developed by each locomotor movement.	Yes	No	Yes	Quasi-experimental controlled intervention trial.	Health-related knowledge: multiple choice questionnaire.	Health-related knowledge: pre-post-intervention time effect, $p = 0.02$, small effect (repeated measure ANOVA).
Johnstone et al. (2017): Go2Play active play	Scotland	189	7.0 ± 1.1	56.1	20	2	60	One session: 30 min of structured games and 30 min of free play.	The first half of the session was fun, inclusive, and active games focused on improving a specific FMS area. Each session concentrated on one FMS area so that a broad range of skills was covered over the intervention period. The second half was free play, which allowed children to practice what they learned in the first half of the session and/or to create and play their own games using a variety of traditional equipment, such as balls, beanbags, cones, hoops, etc.	No	Yes	Yes	Quasi-experimental controlled intervention trial.	Motor skills: Test of Gross Motor Development (TGMD-2).	Motor skills: time*group effect IG favored, $p < 0.04$, pre-post-intervention time effect IG, $p < 0.01$ (repeated measure ANOVA).
Kriellaares et al. (2019): Circus Arts Instruction in Physical Education (CAI-PE)	Canada	211	10.1 ± 0.8	55	20 (a), 52 (b), 10 (c) (d.o.s)	2 (a), 3 (b), 1 (c) (d.o.s)	60 (a, b), 50 (c) (d.o.s)	–	Wide range of circus disciplines from the five major circus families (clowning, manipulation, equilibriums, aerials, and acrobatics). Artistic movement expression, technical variations in expression, and choice of progressions were fostered to encourage self-challenges and ownership of movement.	No	Yes	Yes	Quasi-experimental controlled intervention trial.	No evaluation of PL outcomes.	

(Continued)

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TABLE 1 (Continued)

Author, year: Project	Country	Participants			Intervention characteristics			Structure of intervention	Content of intervention				Study design	Construct: instrument	Results
		N	Age (mean ± SD) [years]	Female [%]	Length [wk]	Frequency [PLS/wk]	Duration [min/PLS]		Description	Cognitive	Affective	Physical			
Rudd et al. (2020) and Crotti et al. (2021): SAMPLE-PE	England	360	5.9 ± 0.3	55	15	2	60	Three 5-week phases: dance, gymnastics, ball sports.	At the beginning of each lesson, coaches invited children to explore the PE hall and the different objects within the environment. The lesson continued with activities representative of game, sport, or performance situations where coaches introduced variability by changing constraints. Coaches did not provide demonstrations or feedback during activities. Alternatively, they invited children to reflect using questioning strategies or to observe their peers. Coaches also used questioning to foster an external focus of attention in the child to infuse variability in the task and channel children's learning.	No	Yes	Yes	Protocol	No data available	
Stoddart et al. (2021): PLitPE	Canada	131	9.7 ± 0.6	49.6	9	3	25	Two sets of circuit stations on two separate days (Circuit 1: 8 skills; Circuit 2: 6 skills), with a third day specifically focused on locomotor patterns (e.g., skip, gallop, crossovers).	Each station had a laminated poster that provided an image, performance cues for the movements, and instructions for the task. Students were provided with choices that enabled them to modify activities based on their own skill level and desired challenge. The remainder of the PE class was spent teaching content working towards other curricular outcomes. Depending on what the teachers had previously covered in the curriculum, during the second half of class, teachers taught content such as dance, flag football, track and field, and other topics. The circuits were adapted when possible to allow for transfer.	Yes	Yes	Yes	Quasi-experimental controlled intervention trial	PL self-perception: PLAYself. Physical competence: PLAYfun	PL self-perception: no significant pre-post-intervention time effects, post-intervention IG favored in one subscale, $p < 0.039$ (unpaired t-test, IG 423.9 ± 89.5, CG 390.1 ± 87.6) Physical competence: pre-post-intervention time effect IG, $p < 0.001$, Cohen's $d = 0.88$ (paired t-test, pre intervention 42.3, post intervention 49.4), post-intervention IG favored, $p < 0.001$, Cohen's $d = 1.04$ (unpaired t-test, IG 49.4 ± 7.1, CG 40.0 ± 2.9).
Wainwright et al. (2018): Foundation Phase	Wales	49	Range: 5–6	55.1	44	–	–	–	The Foundation Phase is a play-based, holistic, child-centered approach to education for children aged 3 to 7, underpinned by childhood well-being. Curriculum documentation advocates the use of indoor and outdoor spaces that are exciting, fun, stimulating, and safe and promote discovery and independence. The "use of the outdoors for learning" is one of four key features of the Foundation Phase, along with "play and active learning," "child-initiated learning," and "focused adult-led sessions."	No	Yes	Yes	Quasi-experimental controlled intervention trial	Motor skills: Test of Gross Motor Development, second edition (TGMD-2). Confidence: Pictorial Scale of Perceived Competence and Social Acceptance (PSPCSA). Motivation: Leuven Involvement Scale for Young Children (LIS-YC).	Motor skills: time effect, $p < 0.001$, $\eta^2 = 0.66$ (repeated measures ANOVA) Confidence: pre-post-intervention time effect, $p = 0.016$ (paired t-test) Motivation: no description of calculation for intervention effects.
Wainwright et al. (2019): Foundation Phase	Wales	164	5.5 ± 0.6	–	8	2	45							Motor skills: Test of Gross Motor Development, version 3 (TGMD-3)	Motor skills: Pre-post-intervention percentage change IG favored, $p < 0.001$ (unpaired t-test, IG 35% ± 19%, CG 2% ± 25%)

(Continued)

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TABLE 1 (Continued)

Author, year: Project	Country	Participants			Intervention characteristics			Structure of intervention	Content of intervention				Study design	Construct: instrument	Results
		N	Age (mean ± SD) [years]	Female [%]	Length [wk]	Frequency [PLS/wk]	Duration [min/PLS]		Description	Cognitive	Affective	Physical			
Secondary school															
Alagul et al. (2012)	Turkey	25	-	-	4	-	80	40 min of salsa and 40 min of PL.	Physical moves of salsa dance were practiced, such as fundamental steps, moving figures, and paired choreography. PL involved abilities like reading, writing, speaking, and listening practices.	No	No	Yes	Qualitative study	No PL evaluation	
Liu and Chen (2021)	USA	226	12.2 ± 0.7	53.3	8	0.5	20–30	One session: (i) motivational module, (ii) informational module.	High-and low-performing PL students were separated during workshops. The activities to implement the motivational module included instruction, communication, and encouragement, where pedagogical skills were used to facilitate student engagement. To complete the series of activities during the motivational module, the student participants (a) shared with others their fun experiences, challenges/barriers, and social experiences related to physical activities, (b) received encouragement to participate in physical activities where they can seek fun, (c) worked together to provide possible solutions for others to overcome difficulties in performing these activities, and (d) received strategies for better socializing with others. The informational module was subsequently delivered with instruction and demonstration concerning the knowledge of health-related fitness and PA, tips to improve movement skills, health-related fitness, and behavioral strategies.	Yes	Yes	No	Non-controlled study	PL: Canadian Assessment of Physical Literacy-2 (CAPL-2)	PL subscales: time*group effect (groups of high- vs. low-performing PL levels) for the subscale Behavioral domain, $p < 0.01$, $\eta^2 = 0.36$ (ANCOVA)
Strobl et al. (2020)	Germany	233	14.66 ± 1.27	54.94	52	–	–	(i) Teachers participated in a participatory planning process to conceptualize evidence-based PE lessons; (ii) they then implement these lessons in physical education.	The learning outcomes should follow a holistic understanding of health and fitness: psychosocial aspects, short-and long-term benefits of physical activity for the improvement of physical fitness at school as well as in their spare time, activity-related behavior in terms of risk factors, injuries and illnesses, and knowledge and understanding of how social and mental well-being are interrelated with physical activity.	Yes	No	Yes	Quasi-experimental controlled intervention trial.	Health-related knowledge and understanding: multiple choice questionnaire.	Health-related knowledge and understanding: post-intervention IG favored, $p < 0.001$, $\eta^2 = 0.066$ (ANCOVA adjusted for type of school, sex, baseline).
Haible et al. (2019) and Rosenstiel et al. (2022): Promotion of physical activity-related health competence in PE (GEKOS)	Germany	841	14.20 ± 0.51	51.13	6	1	90	-	The special feature of the GEKOS intervention is the combination of its methodical approach to addressing knowledge, skills, abilities, and motivation and its content focus on health and fitness. The lessons emphasized health and fitness, both theoretically and practically, using the two main topics of perception of physical load and control of physical load and physical training. The individual lessons focused on content that included (1) the perception of physiological responses to PA, (2) the perception and measurement of heart rate, (3) the perception and measurement of perceived exertion, (4/5) health-related fitness (strength training and cardiovascular endurance), and (6) the application of skills and knowledge.	Yes	No	Yes	RCT	PL evaluation planned	

d.o.s, depending on school; min, minutes; IG, intervention group, PA, physical activity; PE, physical education; PL, physical literacy; PLS, physical literacy session; SD, standard deviation; wk, week.

health-related knowledge. No information about validation was obtained for one questionnaire, and the other was validated in-house.

3.4 Implementation in physical education lessons

Of the identified interventions, 12 were implemented during PE lessons, they are presented in Table 1 (22, 23, 29, 31–42).

3.4.1 Structure, domains, and effects in physical education: primary school

Eight interventions were conducted during PE lessons at primary schools (22, 23, 29, 32–34, 36, 37, 41, 42) with a number of participants ranging from 49 to 360, a mean age between 5.5 and 10.5 years, and proportion of female participants of 49.6–60%. The length of the intervention varied between 4 and 52 weeks. The frequency of PL sessions ranged between 1 and 3 sessions per week. The duration of one PL session ranged from 30 to 72 min.

Only one intervention addressed all three domains (22), while five interventions targeted two. Specifically, four covered the affective and physical domains (23, 36, 37, 41, 42), and one the cognitive and physical domains (34). The other three interventions focused solely on the physical domain during PE (29, 32).

Six interventions were evaluated. The PLitPE intervention demonstrated large positive effects on physical competencies compared to the control group ($p < 0.001$, Cohen's $d = 1.04$). It focused on all three domains through the practice of movement skills using a playful approach. Additionally, knowledge about movement terminology was obtained to address the cognitive domain (22). Interventions targeting one or two PL domains showed various small to moderate positive effects on health-related knowledge, motor skills, and confidence levels compared to the pre-intervention assessments (Table 1) (29, 34, 36, 41, 42).

3.4.2 Structure, domains, and effects in physical education: secondary school

Four interventions were conducted at secondary schools (31, 38, 40), with between 25 and 841 participants, a mean age range from 12.2 to around 14.7 years, and a proportion of female of 51.1–54.9%. The lengths of the interventions were 4, 6, 8, and 52 weeks. The frequency of PL sessions was 0.5 and 1 session per week (missing information for two interventions). The duration of one PL session varied between 20 and 90 min.

No intervention included all domains. Three interventions addressed two domains: two covered the cognitive and physical domains (35, 39, 40), one the affective and cognitive domains (38), and the remaining intervention only focused on the physical domain (31).

Two interventions were evaluated. A medium-sized positive effect ($p < 0.001$, $\eta^2 = 0.066$) on health-related knowledge and understanding compared to the control group was found for an intervention addressing the cognitive and physical domain through lessons implemented specially to address health-related knowledge and understanding. One example of this was that pupils carried out research on swimming-specific strength training in preparation for swimming classes. They presented and carried out their findings in class (40). The effects of another intervention were evaluated in a non-controlled study and are shown in Table 1.

3.5 Implemented as other school-based approaches

Other school-based approaches included qualifications of teachers and the implementation of content during lessons [$n = 2$; (30, 43)], break-time activities [$n = 1$; (44)], and a summer-school program [$n = 1$; (45)]. The setting for one approach was not further described but took place during school time (Table 2) (46). The intervention by Sum et al. (30) was carried out in primary and secondary schools and is therefore mentioned in both of the next two sections.

3.5.1 Structure, domains, and effects in other school-based approaches: primary school

Of these five interventions, four were conducted at primary schools (30, 43, 44, 46). The number of participants ranged from 57 to 551. Among the two interventions with available data, the mean age was 7.8 and 10.3 years. The percentages of female participants were 45.8 and 50.9%. The length of the primary school interventions ranged from 4 to 32 weeks. The PL sessions took place between one and seven times a week, with each session lasting between 15 and 60 min.

One intervention addressed all three PL domains (43). Of the remaining three interventions, two targeted two domains: one the affective and physical domains (44) and the other the cognitive and physical domains (30). One intervention focused solely on the physical domain (46).

Three interventions were evaluated. Positive significant effects on an overall PL score compared to the control group were reported for the "active breaks" intervention ($p = 0.017$). It addressed the affective and physical domains by getting children to engage in game-based physical activity during their breaks (44). Notably, the "Job embedded professional development" intervention addressing all three domains reported a positive effect on only one of five physical competence items compared to the control group (motor skill overhand throw, $p < 0.05$) (43). Further effects are presented in Table 2.

3.5.2 Structure, domains, and effects in other school-based approaches: secondary school

Two interventions were implemented at a secondary school (30, 45). While data is missing for one intervention, the other had 57 participants, with an age range from 11 to 14 years and 56.5% of female participants. The lengths of the interventions were 6 and 32 weeks, with an average of 1.3 and 1.6 sessions per week. In the intervention with 1.6 sessions per week, each session lasted 60 min.

Both interventions addressed two PL domains: one the affective and physical domains (45) and the other the cognitive and physical domains (30). Only one intervention was evaluated, displaying significantly positive effects on one subscale of the motivation to exercise compared to the pre-intervention assessment. There were no effects on physical self-efficacy compared to the pre-intervention assessment and the control group (45).

3.6 Implemented as after-school programs

Seven interventions were conducted as after-school programs (Table 3) (47–56).

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TABLE 2 Other identified interventions.

Author, year: project	Country	Implementation	Participants			Intervention characteristics			Structure of intervention	Content of intervention				Study design	Construct: Instrument	Results
			N	Age (mean ± SD) [years]	Female [%]	Length [wk]	Frequency [PLS/wk]	Duration [min/PLS]		Description	Cognitive	Affective	Physical			
Primary school																
Eveland-Sayers et al. (2022)	United States	During school time	92	–	–	6	1	30	One session: warm-up (6 min), jumping (15 min), throwing (8 min), homework (1 min).	Movement skills focused on locomotor skills (running mechanics, various skips, shuffling, carioca/grapevine, running pace, starts, hurdles, broad jump, hops, bounding, proper landing, and balance) and ballistic skills (throwing). Homework included practicing, physical challenges (e.g., cross-legged sit-to-stand without hands on the ground), bodyweight exercises (e.g., pushups, squats), and stretching.	No	No	Yes	Non-controlled study	Self-efficacy for physical activity: Children's Self-Perception of Adequacy in and Predilection for Physical Activity (CSAPPA).	Self-efficacy for physical activity: time*group interactions favored children with higher BMI, $p = 0.03$, $\eta^2 = 0.097$ (ANCOVA).
Wright et al. (2020): Job Embedded Professional Development (JEPD)	Canada	Professional development/PE	551 Pupils 15 Teachers	IG 7.9 ± 1.7; Range: 4.7–10.8 CG 7.6 ± 1.6; Range: 4.8–11.0 Teachers: Range: 25–44.	Pupils: 45.8; Teachers: 87.0.	10	1	30	–	Games and activities that developed competence in movement skills and built confidence, motivation, and knowledge of physical activity in the children. The activities and skills covered included teaching cues for running, jumping, throwing, and catching, as well as other movements such as galloping, hopping, striking, and dribbling.	Yes	Yes	Yes	Quasi-experimental controlled intervention trial	Physical competence: PLAYbasic	Physical competence: time*group effect IG favored for one item, $p < 0.05$; pre-post-intervention time effect IG for all five items, $p < 0.05$ (repeated measure ANOVA).
Mendoza-Muñoz et al. (2022): Active breaks (AB)	Spain	Breaks	57	10.3 ± 0.4 Range: 8–12	50.9	4	7	15	One session: warm-up (2–3 min), games and activities (15 min), cool-down (2–3 min).	Warm-up: meeting-time and mobility exercises. Cooperative and competitive games (catch the flag, rock paper scissors, dodge ball, fox hospital, card games) with meeting-time and mobility exercises of increasing difficulty. Cool-down: relaxation exercises, time for sharing experiences.	No	Yes	Yes	Quasi-experimental controlled intervention trial.	PL: Canadian Assessment of Physical Literacy-2.	PL: pre-post-intervention time effect IG, $p < 0.001$, (ANOVA, pre intervention 61.19 ± 11.96, post intervention 68.30 ± 10.85); post-intervention IG favored, $p < 0.017$ (ANOVA, IG 68.30 ± 10.85, CG 60.72 ± 11.90).
*Sum et al. (2018): Physical Education Continuing Professional Development (PE-CPD)	Hong Kong	Professional development	–	–	–	32	1.6	60	PE lessons taught by teachers who participated in the physical education continuing professional development intervention.	Teaching and learning domain (24 h): pedagogical workshop of fundamental movement, Teaching Games for Understanding (TGfU), and sports education; PE homework; using IT in PE. Student development domain (8 h): seminar on understanding students' diverse needs; workshops and sharing session on planning and organization of student development sports activities. School development domain (6 h): exemplary sharing of home–school collaboration on parent-related school activities; roles of PE and sports as promoting factors of the school culture and school image. Professional relationships and services domain (12 h): workplace learning through action research; institutional learning to facilitate understanding of research findings and best practices.	Yes	No	Yes	Protocol	PL evaluation planned	

(Continued)

TABLE 2 (Continued)

Author, year: project	Country	Implementation	Participants			Intervention characteristics			Structure of intervention	Content of intervention				Study design	Construct: Instrument	Results
			N	Age (mean ± SD) [years]	Female [%]	Length [wk]	Frequency [PLS/wk]	Duration [min/PLS]		Description	Cognitive	Affective	Physical			
Secondary school																
Pullen et al. (2020)	Wales	Summer school	46	Range: 11–14	56.5	6	1.3	–	–	Strength-and conditioning-based activities for athletic motor skill competencies: to stimulate strength adaptations, resistance was provided using body weight, resistance bands, or medicine balls. Basic resistance training equipment was incorporated into games, challenges, or short periods of teaching to learn techniques. Games and challenges utilized an individualized, constraint-led approach by manipulating task and environmental constraints. Many exercises were integrated into games to make the intervention enjoyable and engaging for the pupils.	No	Yes	Yes	Quasi-experimental controlled intervention trial	Motivation to exercise: behavioral regulation in exercise. Physical self-efficacy: Perceived Physical Ability Scale for Children	Motivation to exercise: pre-post-intervention time effect male IG in one subscale, $p < 0.05$ (paired and unpaired *t*-test, Mann–Whitney *U*-test); Physical self-efficacy: No significant results for IG (paired and unpaired *t*-test, Mann–Whitney *U* test).
*Sum et al. (2018): Physical education continuing professional development (PE-CPD)	Hong Kong	Professional development	–	–	–	32	1.6	60	PE lessons taught by teachers who participated in the physical education continuing professional development intervention.	Teaching and learning domain (24 h): pedagogical workshop on fundamental movement, Teaching Games for Understanding (TGfU), and sports education; PE homework; and using IT in PE. Student development domain (8 h): seminar on understanding students' diverse needs; workshops and sharing session on planning and organization of student development sports activities. School development domain (6 h): exemplary sharing of home–school collaboration on parent-related school activities; roles of PE and sports as promoting factors of the school culture and school image. Professional relationships and services domain (12 h): workplace learning through action research; institutional learning to facilitate understanding of research findings and best practices.	Yes	No	Yes	Protocol	PL evaluation planned	

*Sum et al. (30): This intervention was carried out in primary and secondary schools. Therefore, it is mentioned in both sections. IG, intervention group; Min, minutes; PL, physical literacy; PLS, physical literacy session; SD, standard deviation; wk, week.

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TABLE 3 Identified interventions conducted as after-school interventions.

Author, year: project	Country	Participants			Intervention characteristics			Structure of intervention	Content of intervention				Study design	Construct: Instrument	Results
		N	Age (mean ± SD) [years]	Female [%]	Length [wk]	Frequency [PLS/wk]	Duration [min/PLS]		Description	Cognitive	Affective	Physical			
Primary school															
Caldwell et al. (2022a) and Caldwell et al. (2022b): Build Our Kids' Success (BOKS) programming	Canada	14	9.3	55.0	8	–	70	Contains different elements: full-length physical activity plans (20–45 min), short movement breaks (1–10 min), and movement-based games, activities, and resources for school or at-home use.	The full-length physical activity plans include a warm-up activity (i.e., adventure run, BOKS Says), running-related activity (e.g., running relays, musical run), skill of the week (i.e., planks, sprints), game (i.e., crab walk, soccer, red light-green light), cool down (i.e., deep breaths, full-body stretch), and a BOKS Bits nutrition talk. The short movement breaks are designed to keep children active throughout the activity and may include activities such as an ABCWorkout, Bingo Burst, or BOKS Says.	No	No	Yes	Non-controlled study	Physical activity enjoyment: Physical Activity Enjoyment Scale (PACES). PL self-perception: PLAYself.	Only post-intervention descriptive results.
Carl et al. (2023): PLACE	Germany	–	Range: 8–11	-	24 in each of three cycles (2 pilot studies, 1 main study).	1	60–90	Sessions will be driven by the concept of PL (physical, affective, social domain), with direct links between theory, content, and actual movement.	Rule-based games primarily via ball games and racket sports. The aesthetic input will focus on dancing and acrobatics, and fitness will be dominantly targeted via endurance-oriented games or in the context of parkour. Theory-based inputs in each session (i.e., content knowledge, rules, strategies and planning, tactics, awareness, as well as purposing and reasoning). Transferring and supporting principles of motivation, autonomy, enjoyment, self-awareness, and confidence. Application of diverse group compositions and game arrangements.	Yes	Yes	Yes	Protocol	PL evaluation planned.	

(Continued)

TABLE 3 (Continued)

Author, year: project	Country	Participants			Intervention characteristics			Structure of intervention	Content of intervention				Study design	Construct: Instrument	Results
		N	Age (mean ± SD) [years]	Female [%]	Length [wk]	Frequency [PLS/wk]	Duration [min/ PLS]		Description	Cognitive	Affective	Physical			
Mandigo et al. (2018): Teaching Games for Understanding (TGfU) for the PlaySport Intramural Program	Canada	22	–	72.7	8	3–4	60	One session consisted of a game activity to introduce the main objectives of the lesson, a movement development, and a culmination, which provided the participants with an opportunity to integrate what they had learned throughout the lesson into a game activity.	Overall, there were seven target/ individual game sessions, three net/ wall game sessions, five striking/ fielding game sessions, and 10 territorial game sessions delivered during this time period.	Yes	No	Yes	Non-controlled study	PL: Passport for Life	PL subscales: pre-post-intervention time effect for subscales Balance $p < 0.001$, Cardiovascular $p = 0.001$, Diverse environments $p = 0.003$, and Diverse interests $p < 0.002$ (paired *t*-test, balance: pre intervention 2.23 ± 0.69, post intervention 2.91 ± 0.43; Cardiovascular: pre intervention 1.57 ± 0.60, post intervention 2.43 ± 1.08; Diverse environments: pre intervention 2.68 ± 0.37, post intervention 2.97 ± 0.41; Diverse interests: pre intervention 2.74 ± 0.75, post intervention 3.00 ± 0.75); for eight subscales, no significant results.
Secondary school															
Grimes et al. (2022) and Lightner et al. (2023): Move More, Get More	USA	116	IG: 13.4 ± 1 CG: 13.8 ± 1.0	39.7	36	1–3 (based on school)	60–120	One session consisted of warm-up (10 min), activity (40–100 min), and cool-down (10 min) activities and sports rotated every 2 weeks.	Variety of sports and skills necessary to participate in diverse sports; snowball recruitment and focus on team-oriented sports; scrimmages and step challenges using accelerometers. Incentives were used. Skill development and inclusiveness and limited over-competitiveness by implementing no-cut policies. Activity types included traditional sports (basketball, soccer, football, etc.), team-based activities (capture the flag, dodgeball, etc.), dance, yoga, and others.	No	Yes	Yes	Post-intervention only design	Physical competence: PLAYbasic	Physical competence: post-intervention IG favored, $p = 0.004$ (unpaired *t*-test IG 75.62 ± 13.14, CG 50.71 ± 19.73).

(Continued)

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TABLE 3 (Continued)

Author, year: project	Country	Participants			Intervention characteristics			Structure of intervention	Content of intervention				Study design	Construct: Instrument	Results
		N	Age (mean ± SD) [years]	Female [%]	Length [wk]	Frequency [PLS/wk]	Duration [min/PLS]		Description	Cognitive	Affective	Physical			
No information															
Bremer et al. (2020)	Canada	90	IG: 9.1 ± 1.4 CG: 10.5 ± 1.8 Range: 7–13	46.67	12	5	30	Each skill block lasted 3 days. One session consisted of 15 min of learning fundamental movement skills and 15 min of an active game.	Skill block: focused on learning and practicing a different set of fundamental movement skills (e.g., jumping, throwing, catching). Active game: incorporating the day's movements. All active games were chosen from the PlaySport activities. The level of difficulty of both the skill stations and the active game progressed over the course of the 3-day skill block and more generally over the 12-week intervention.	Yes	Yes	Yes	RCT	Physical competence: PLAYfun. PL self-perception: PLAYself. Self-efficacy, motivation, enjoyment, perceived knowledge: questionnaire.	Multiple linear regression models adjusted for age, sex, baseline score: Physical competence: experimental group $p = 0.10$, r-squared = 0.728. Self-efficacy: experimental group $p = 0.85$, r-squared = 0.541. Motivation: experimental group $p = 0.14$, r-squared = 0.330. Enjoyment: experimental group $p = 0.03$, r-squared = 0.391. PL self-perception: experimental group $p = 0.90$, r-squared = 0.289.
Crozier et al. (2022): PL-focused afterschool activity programs (ASAPs)	Canada	29	IG: 8.3 ± 1.3 CG: 8.6 ± 1.7 Range: 5–12	55.2	24	5	180	–	PL-focused afterschool activity program that promotes healthy active lifestyles to children via introducing and facilitating a wide range of sports and athletic opportunities.	No	No	Yes	Quasi-experimental controlled intervention trial	Aerobic capacity: PACER, Motor skills: Test of Gross Motor Development–2 (TGMD-2)	Aerobic capacity: No significant pre-post-intervention time and post-intervention group effects (paired and unpaired t-test, Wilcoxon test). Motor skills: pre-post-intervention time effect for subscale object control, $p = 0.024$. No significant post-intervention group effects
Lewis et al. (2013): Growing Young Moves	No information	–	–	–	–	2	–	–	Various physical education activities in the gymnasium space.	No	No	Yes	Project description	No PL evaluation	

IG, intervention group; Min, minutes; PL, physical literacy; PLS, physical literacy session; RCT, randomized controlled trial; SD, standard deviation; wk, week.

3.6.1 Structure, domains, and effects in after-school programs: primary school

Three after-school interventions took place at primary schools (48–51, 56). Two interventions provided information about participants. There were 14 participants in one (female = 55%, mean age = 9.3 years) and 22 in the other (female = 72.7%, no information about age). The lengths of the interventions ranged from 8 to 24 weeks, with a frequency between 1 and 3.5 sessions per week and a single session duration of 60–75 min.

One intervention addressed all three PL domains (50). One intervention focused on two PL domains, namely, the cognitive and physical domains (56). The last intervention targeted solely the physical PL domain (48, 49).

Two interventions were evaluated. The intervention by Mandigo et al. reported the most relevant positive effects on four out of 12 PL subscales, namely, balance ($p < 0.001$), cardiovascular ($p = 0.001$), diverse environments ($p = 0.003$), and diverse interests ($p = 0.002$), compared to the pre-intervention assessment. It addressed the physical and cognitive PL domains through an intervention drawing on the Teaching Games for Understanding approach (56). Further results are shown in Table 3.

3.6.2 Structure, domains, and effects in after-school programs: secondary school

One intervention was developed for secondary school children (53, 55). The intervention involved 116 participants, with a mean age of 13.6 years, and 39.7% female participants. The length of the intervention was 36 weeks, with two 90-min sessions per week.

The "move more, get more" intervention incorporated the affective and physical domain through step challenges using accelerometers, among others. A positive effect on physical competence was reported compared to the control group ($p = 0.004$) (53, 55).

3.6.3 Structure, domains, and effects of additional after-school programs

For three interventions, no information about the type of school was provided (47, 52, 54). Two of them addressed children and youth between 5 and 12 years old and between 7 and 13 years old, respectively, with 29 and 90 participants. The shares of female participants were 46.7 and 55.2%. The lengths of the interventions were 12 and 24 weeks, respectively, with five sessions per week each. The length for one session was 30 and 180 min, respectively. For the third intervention, very limited information was available (54).

One intervention addressed all three domains (47), whereas the other two focused solely on the physical domain (52, 54).

Two interventions were evaluated (47, 52). A positive effect on enjoyment was achieved by the intervention studied by Bremer et al. ($p = 0.03$, r-squared = 0.391). It addressed all three PL domains through daily 30-min skill blocks. During the first 15 min of each block, fundamental movement skills were taught, and the remaining time was dedicated to active play. Interestingly, no effects on physical competence ($p = 0.1$), self-efficacy ($p = 0.85$), motivation ($p = 0.14$), and PL self-perception ($p = 0.9$) compared to the control group were found (47). The effects of the other evaluated after-school program are presented in Table 3.

3.7 Implemented as multi-component interventions

Seven interventions were classified as using a multi-component approach that required more than one setting at a time (Table 4) (57–64).

3.7.1 Structure, domains, and effects in multi-component interventions: primary school

Five interventions took place in primary schools (58–62, 64). Although four of these were described in detail, one only gathered information about content and not about the formal structure and participants. Among these four interventions, the number of participants ranged from 79 to 925, with a mean age of 9.7 to 10.8 years. The information about the proportion of female participants in the intervention was only given for two studies, standing at 51.0 and 59.1% (62, 64). The lengths of the interventions ranged from 8 to 33 weeks. One intervention was implemented with continuous measures. The others were implemented through 2, 2, and 10 sessions per week with a duration of 15, 15, and 30 min per session, respectively.

Two interventions addressed two PL domains, namely, the affective and physical domains (58, 64). The other three focused solely on the physical PL domain (59–62).

Three interventions were evaluated (60, 62, 64). The most pronounced positive effects on the motor skill of object control ($p = 0.008$) and the physical self-perception of sport competence ($p = 0.013$) were achieved by the "physical education and physical literacy" intervention (64). This intervention addressed the affective and physical PL domains and consisted of an additional PE lesson that emphasized the development of fundamental movement skills. Physical activity sessions were also conducted during lunch breaks and after school. Noteworthy is the positive effect ($p = 0.004$) on physical competence on the daily behavior subscale of a PL assessment in the "Stand+Move" intervention, which vanished at the 3-month follow-up (61, 62). Further results are shown in Table 4.

3.7.2 Structure, domains, and effects in multi-component interventions: secondary school

For the two interventions in secondary schools, no information on participants, length, frequency, or duration was obtained (57, 63).

Regarding the content structure, one intervention incorporated all three PL domains, with students wearing pedometers and using their step data to set goals. In addition, the PE curriculum was divided into blocks offering health and fitness content (e.g., health-related fitness knowledge), motor skills, and activities (63). The other intervention only focused on the physical domain (57). Neither intervention evaluated PL outcomes.

4 Discussion

To the best of the authors' knowledge, this is the first scoping review to compile interventions that promote PL in school settings. A total of 31 interventions were identified across 37 papers, most of which took place in primary schools during PE lessons. The

TABLE 4 Identified interventions classified as using a multi-component approach.

Author, year: Project	Country	Participants			Intervention characteristics			Structure of intervention	Content of intervention				Study design	Construct: instrument	Results
		N	Age (mean ± SD) [years]	Female [%]	Length [wk]	Frequency [PLS/wk]	Duration [min/PLS]		Description	Cognitive	Affective	Physical			
Primary school															
Hulteen et al. (2023): Peer Leadership for Physical Literacy (PLPL)	Canada	227	–	–	10	2	30	Two phases: (i) development of leadership among Grade 6/7 peer leaders; (ii) Grade 6/7 peer leaders deliver a 10-week movement skills program to the younger Grade 3/4 students.	Each movement skill session focused on one of six object-control skills (i.e., catching, overhand throwing, underhand throwing, kicking, dribbling, and a two-handed strike with a baseball bat). Each of these skills was taught between three (catch, overarm throw, two-handed strike, dribble) and four times (underarm throw, kick) throughout the 10-week program.	No	No	Yes	RCT	Motivation: Self-determined motivation questionnaire. Perceived competence: questionnaire. Self-concept: Physical Self-Description Questionnaire-Short Version. Motor skills: Test of Gross Motor Development, third edition.	Multiple linear regression models adjusted for sex, baseline score: Motivation: experimental group $p = 0.236$, r-squared = 0.228. Perceived competence: experimental group $p = 0.181$, r-squared = 0.361. Self-concept: experimental group $p = 0.153$, r-squared = 0.347. Motor skills: maximal throw speed: experimental group $p = 0.128$, r-squared = 0.770; Throw-catch combination: experimental group $p = 0.870$, r-squared = 0.263; throw process score: experimental group $p = 0.839$, r-squared = 0.497.
Li et al. (2021) and Li et al. (2022): Stand+Move	Hong Kong	79	SSPLAY: 9.7 ± 0.7 PLAY: 9.6 ± 0.6 CG: 9.6 ± 0.6	SSPLAY: 62.5 PLAY: 55.6 CG: 60.7	13	10 (active breaks)	15 (active breaks) Continuous sit-stand desks	Children participated in a play activity during recess time followed by several minutes of cool-down.	PLAY: unstructured outdoor interactive games led by PE interns (skipping rope, shuttlecock, kicking, hide-and-seek). SSPLAY: additional height-adjustable sit-stand desks in the classroom. The goal was to use the stand desk for at least 1 h/day.	No	No	Yes	RCT	PL: Canadian Assessment of Physical Literacy-2 Chinese.	PL subscales: time*group effects favored IG post intervention for subscales Physical competence $p = 0.02$ and Daily behavior $p = 0.004$. No significant results at 3-month follow-up.

(Continued)

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TABLE 4 (Continued)

Author, year: Project	Country	Participants			Intervention characteristics			Structure of intervention	Content of intervention				Study design	Construct: instrument	Results
		N	Age (mean ± SD) [years]	Female [%]	Length [wk]	Frequency [PLS/wk]	Duration [min/PLS]		Description	Cognitive	Affective	Physical			
Telford et al. (2020): Physical Education and Physical Literacy (PEPL)	Australia	303	IG: 10.41 ± 0.39 CG: 11.14 ± 0.39	51	33	Continuous	Continuous	An additional PE lesson each week together with four activity sessions of 15–40 min in the schoolyard.	Classroom teacher professional development; in-class PE assistance; provide PE lesson and activity plans as required; provide lesson plans for physical activity breaks; support, encourage, and motivate classroom teachers to deliver PE lessons; conduct physical activity sessions during school lunch breaks focusing on fundamental movement skills; provide teachers with strategies and activities to increase physical activity during breaks and before and after school; encourage students to join an extracurricular sports club.	No	Yes	Yes	RCT	Motor skills: Test of Gross Motor Development, second edition (TGMD-2). Physical self-perception: Children and Youth – Physical Self-Perception Profile (CY-PSPP). Physical activity enjoyment: Shortened-Physical Activity Enjoyment Scale (S-PACES).	Multiple linear regression models adjusted for study condition, sex: Motor skills: object control: IG value of $p = 0.008$; locomotor: IG value of $p = 0.471$. Physical self-perceptions: sport competence: IG value of $p = 0.013$; physical condition: IG value of $p = 0.466$; physical self-worth: IG value of $p = 0.551$. Physical activity enjoyment: IG value of $p = 0.737$.
Gavigan et al. (2023): Moving Well-Being Well (MWBW)	Ireland	925	7.55 Range: 6–10	–	8	(i) 2 PE classes; (ii) five active classroom activities; (iii) one home activity sheet.	(i) 30; (ii) 5–10	Three main components: (i) FMS-based PE classes, (ii) active classroom activities, (iii) home activity sheet.	The content of the three main components focused on just three locomotor (hop, skip, and jump) and three object-control skills (kick, catch, and throw).	No	No	Yes	Qualitative study	No PL evaluation	
Driscoll and Linker (2022)	United States	–	–	–	–	–	–	The homework (home fun) should reinforce the skills learned in PE in other subjects or at home with family and friends.	The homework (home fun) should include enjoyable physical activity. The purpose is to reinforce concepts, knowledge, and skills (locomotor skills: hopping, galloping, running, sliding, skipping, leaping, yoga/stretching) learned in PE outside regular PE class (in other subjects, at home with family and friends).	No	Yes	Yes	Project description	No PL evaluation	

(Continued)

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TABLE 4 (Continued)

Author, year: Project	Country	Participants			Intervention characteristics			Structure of intervention	Content of intervention				Study design	Construct: instrument	Results
		N	Age (mean ± SD) [years]	Female [%]	Length [wk]	Frequency [PLS/wk]	Duration [min/PLS]		Description	Cognitive	Affective	Physical			
Secondary school															
Shawley (2016): Creating Healthy Active Minds for Personal Success (CHAMPS)	United States	–	–	–	–	–	–	Two PE semester blocks, each consisting of 4–7 weeks separated into four blocks. One block provides two 49-min lessons, followed by two 72-min lessons.	(i) Students wear a pedometer daily and download steps at the end of each class. Students use this data for goal setting. (ii) Each block offers health and fitness content (health-related fitness knowledge, intensity levels, measuring MVPA, fitness testing, program design, technology and apps, skill-related fitness, circuit training) and motor skills and activities (football or rugby, ultimate frisbee, tennis, choice week, soccer, pickleball, disc golf, weight room and functional fitness, social dance, basketball, weight room fitness plans, volleyball, health lab). Health and fitness content is provided in the first half of the long lessons.	Yes	Yes	Yes	Project description	No PL evaluation	
Altieri (2019): Get Ready Program	United States	6	–	–	52	–	–	–	The Get Ready program engages students in physical activity in the school's weight room, gym, and dance studio. The program's elements are designed to help the students with their physical development through physical activities and help them take personal and social responsibility in this physical activity setting. Gradually, the students are empowered to be able to run the program with less and less direction from the Get Ready facilitators. Eventually, the goal is for them to become more and more confident to be able to coach themselves and even other students through these sessions.	No	No	Yes	Qualitative study	No PL evaluation	

IG: intervention group; Min, minutes; PL, physical literacy; PLS, physical literacy session; SD, standard deviation; wk, week.

interventions were highly heterogeneous in terms of sample size, content, duration, and frequency. All three domains were covered by only five interventions, whereas nearly all studies addressed motor skills, focusing on a diverse range of physical activities. About half of them were designed to promote the joy of movement and, thus, motivate students to increase physical activity. The cognitive domain was rarely addressed.

About two-thirds of interventions were evaluated regarding PL outcomes (21 out of 31). Here, too, there was great heterogeneity in terms of study quality, measurement methods, and intervention content, making comparisons difficult. Small/medium effects, if any, were found for interventions, mostly addressing the physical and affective domains. When an intervention concerned all three PL domains, the effects were promising regarding physical competence and enjoyment. One intervention showed large effects on physical competencies. However, other PL outcomes (e.g., self-efficacy, PL self-perception, motivation) were not affected. Additionally, no long-term effects were measured. Therefore, it remains unclear how sustainable the effects of interventions are and how they correspond to the idea of a lifelong learning process.

It is hardly surprising that PL is mainly taught in primary school and especially in PE lessons. Early encouragement is intended to lay the foundations for a lifelong physical activity. On top of this, PE, besides its purely physical component, plays a critical role in promoting an active and healthy lifestyle by imparting knowledge and understanding to students and motivating them (65).

However, the extent to which this is sustainable remains to be determined. In addition to the lack of data, tracking evidence-based progress in this context is methodologically challenging as decades of study are often necessary to assess the sustainable (health) effects of interventions in childhood. Because this is hardly feasible, surrogate parameters are frequently used to evaluate an intervention's effectiveness, such as motor skills performance, measures of fitness, academic performance, and health parameters (body composition, lipids, blood pressure, mental health, etc.). But even here only small effects become clear. Based on a meta-analysis of 20 studies integrating data about 6,621 children and adolescents aged 4–18 years, Hartwig et al. (66) reported a very small "increase" in cardiorespiratory fitness of 0.47 mL/kg/min and in moderate-intensity physical activity of approximately 1 min a day for school based interventions that are not based on holistic approaches like PL.

Therefore, even though strategies like the Global Action Plan on Physical Activity of the World Health Organization have already been developed, the effects are (very) small. A rethink in terms of skills/literacy promotion as fundamental for physical activity behavior seems to make sense. The idea of improving skills/literacy has also been discussed in health. Chrissini and Panagiotakos (67) called for the inclusion of health literacy in health policy agendas as an essential and decisive strategy to empower individuals to take action. To enhance health literacy, people should be empowered to comprehend and apply information related to healthy lifestyles, particularly in the context of self-care. In turn, a healthy lifestyle supports health literacy by improving the cognitive and physical resources needed to process health information. This way of thinking is applicable to the promotion of PL. Corresponding initiatives could be useful tools in the (early) fight against non-communicable diseases, especially in the school setting. For example, teaching skills through play, including physical activity as part of self-care, may help students to increase their relevant knowledge, gain (positive) experience, and adapt their behavior accordingly (mod. after) (68). In other words, a holistic and competence-oriented approach to promoting physical activity is necessary. In Germany, this can already be found in a broader sense in school curricula with the dual mandate of "education in and through sport" (69). In the literature, however, an underlying theoretical framework is often missing (70).

Nevertheless, what conclusions can be drawn from the contents? The aim of the review was to develop appropriate recommendations for the promotion of PL in schools. Due to the heterogeneity of the studies described above and the largely non-holistic implementation of the interventions, we are unable to develop concrete recommendations at this state of research. More high-quality studies that implement the holistic PL concept are needed as a basis for recommendations. Nevertheless, it can be tentatively hypothesized that primary school environments and PE classes present promising venues for the promotion of PL. Diverse and playful forms of movement such as dance, fitness, games, gymnastics, individual activities, and outdoor activities seem to contribute to the development of different competencies. However, emphasis should not solely be placed on advancing the physical domain, but also on nurturing affective and cognitive domains to align with a holistic perspective, as delineated by Whitehead. The incorporation into teacher training programs holds promise for yielding the most profound effects, fostering an accompanying mindset and favorable disposition toward PL education. As concerns lifelong learning, the role of educators is to teach individuals to make healthy, active choices throughout their lives and to understand that physical activity is not limited to one school subject or the school setting.

4.1 Strengths and weaknesses

Our scoping review has several strengths and weaknesses. The methodological approach of a scoping review allows for a methodologically clear and high-quality presentation of the existing literature. We attempted to present the data, including the interventions and their effects, in as much detail as possible to derive recommended actions. However as mentioned above, the described interventions were highly heterogeneous. Moreover, in several cases, not all measures were evaluated, or an evaluation was not (yet) available. Possible influencing factors, such as students' neighborhoods or their families' levels of education, were also missing, which made an evaluation or derivation of good practice models difficult. Another challenge was categorizing the interventions in terms of which PL domains were addressed and which were not. In doing so, we followed the Whiteheadian definition and relied on what the authors reported in their publications. This was challenging because some authors briefly mentioned individual domains, while others provided detailed and comprehensive information. This point should be taken into consideration when assessing the interventions presented in this study.

5 Conclusion

The promotion of PL in schools appears to be a promising approach as a basis for a lifelong active (and healthy) lifestyle and as a means to combat non-communicable diseases. Currently, PL promotion mostly occurs in PE classes in primary schools through a variety of playful activities. The implementation in school curricula and the qualification of teachers are encouraging, but the effects of these efforts have not yet been tested. This is largely because although more data on PL promotion is becoming available, the application of this concept to the context of physical activity and health promotion is not well established in the scientific literature. Further research is therefore needed on the nature and direction of the relationship between PL, its individual domains, physical activity, and health to clarify the possible lifelong role of PL in promoting physical activity, increasing health and well-being, and to actually enable development of recommendations for action.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary materials, further inquiries can be directed to the corresponding authors.

Author contributions

MG: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. LK: Conceptualization, Data curation, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. SW: Conceptualization, Supervision, Writing – review & editing. CJ: Conceptualization, Project administration, Supervision, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2024.1322075/full#supplementary-material

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Promoting physical activity and youth development in schools: the case for near-peer coaches

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Background: Sports-based youth development (SBYD) programs provide an inclusive, supportive environment for promoting physical activity as well as nurturing the development of life skills which, in combination, promote physical, mental, and emotional health in youth. The Up2Us Sports SBYD program was implemented in six schools in New Orleans, Louisiana in 2020–2022, where near-peer coaches from the community were placed in schools and present throughout the school day. The intervention period straddled the COVID-19 pandemic as well as extreme weather events, modifying program delivery.

Process/methods: An exploratory case study was conducted to understand participant experience amid program disruptions and modifications, as well as their perceptions of program impact on physical activity and health. Interviews with coaches ($n = 7$), focus groups with youth ($n = 14$) and program observation data were triangulated to provide a description of the case.

Results: The major theme that emerged from the case study was the centrality of the near-peer mentorship relationships between coaches and youth. Participants believed near-peer relationships facilitated life skill development and increased opportunity for physical activity in schools, but pressures on coaches' time and external challenges in the community were limiting factors to the extent of program impact.

Conclusion: This community case study demonstrates the potential role for near-peer mentors in influencing the health and wellbeing of youth from under-resourced communities and highlights the opportunity for school-based SBYD programming to provide youth with a consistent source of both relational and physical activity support.

KEYWORDS

physical activity, school environment, children and youth, near-peer coaching, sports-based youth development

1 Introduction

According to physical activity surveillance data from 120 countries, more than three-quarters of the global youth population do not engage in the recommended 60 min per day of moderate to vigorous physical activity (1). Low levels of physical activity among children and youth are associated with poor physical (2, 3) and mental (4, 5) health outcomes throughout the life course, and childhood physical activity habits are likely continue into adulthood (6, 7). Amidst these already existing concerns, the disruptions and isolation of the COVID-19 pandemic greatly exacerbated worrying trends in the mental health of children and youth, prompting the U.S. Surgeon General to put out multiple advisories on the issue (8, 9) and make protecting youth mental health a key priority. Given the associations between higher youth physical activity and a range of physical (10), mental (11), and social–emotional (12) health benefits, there is great opportunity for addressing multiple youth health concerns synergistically through strategies that promote both physical activity and psychosocial development.

Sports-based youth development (SBYD) programs offer a strategy to increase physical activity levels in youth while also cultivating the development of social and life skills (13), in turn promoting multiple positive health outcomes. SBYD programs have been shown to increase perceived athletic competence among youth (14), and higher perceived competence has been associated with higher levels of physical activity (15). These programs have also demonstrated an effect on the development of life skills that foster overall health and wellbeing, such as self-worth, impulse control, and social competence, by intentionally teaching these skills as a part of programming (16, 17). Central components of SBYD programs include surrounding youth with protective factors, such as motivating, inclusive, and safe environments, and mentorship relationships with adult coaches who have been trained in youth development and in building trust and connection (18, 19). The youth-coach relationships have been identified as a facilitator of life skill development (19), but there is also an identified need for more coaches from the local community in SBYD programs (20). Furthermore, there is a call for greater collaboration between SBYD programs and other community entities to go beyond a focus on individual outcomes and leverage resources to build health-promoting environments (21).

The present study reports on the Up2Us Sports SBYD program, which addresses both limitations identified above: program coaches are intentionally recruited from the communities they serve, and program delivery is integrated into the school-day of partner schools to build a healthier school environment. The coaches in this study are young adult "near-peers" from the same or similar communities and demographic backgrounds as the youth they serve. This similarity in background and proximity in age provides youth with mentors who understand their context and experience (20). Additionally, school-based SBYD coaches offer programming universally to all enrolled students and are thus well-poised for maximal reach and impact on positive youth outcomes (22). We therefore used an exploratory case study approach (23) to investigate coach and youth experiences with the Up2Us Sports SBYD programs implemented in New Orleans, Louisiana schools. Our objective was to understand how SBYD coaches and youth perceived program implementation and impact on physical activity and broader health outcomes.

2 Context

Up2Us Sports is a national service program that has trained over 3,700 coach-mentors since 2010 through their Up2Us Coach flagship program. These coaches in turn have served more than 655,000 youth from historically under-resourced, largely urban communities through partnerships with recreation departments, non-profits, and local schools. Up2Us Sports provides extensive training for their coaches on creating an inclusive environment and building strong mentoring relationships with youth from all backgrounds and fitness levels. A key feature of the Up2Us Coach program is that the majority of coaches are near-peers recruited from the communities in which the program is implemented. Among Up2Us Sports large city program sites, New Orleans, Louisiana, is unique in that the coaches are primarily school-based, as opposed to working with community organizations or recreation departments that offer only out-of-school programs.

New Orleans is highly geographically segregated by race, and life expectancy has been found to differ by as much as 25 years between city ZIP codes with the highest and lowest life expectancy (24). In New Orleans schools, 92% of pupils are students of color and 80% are economically disadvantaged (25)—representing populations at greater risk for experiencing health disparities. Furthermore, youth in Louisiana are more likely to not be active for 60 min a day compared with U.S. youth as a whole (26). With many existing challenges to multiple aspects of youth health, including but not limited to low physical activity, New Orleans provides an important context in which to investigate the effectiveness of the SBYD approach in increasing physical activity and facilitating positive youth health outcomes.

3 Key programmatic elements and events affecting implementation

The present study is part of a wider project, Creating Opportunities for Adolescents through Coaching, Healthy Eating, and Sports (COACHES), which faced multiple external barriers to implementation, including the COVID-19 pandemic and major adverse weather events. The COACHES Project was initially conceived to evaluate the impact of school-based Up2Us Coach programs on physical activity and physical fitness, social–emotional learning, and nutrition among New Orleans middle school students. Coaches were recruited into the Up2Us Coach program from local communities to deliver free, inclusive SBYD programming at school sites. In addition to receiving the full Up2Us training, coaches participating in the project would take part in additional, contextualized training sessions on youth nutrition and physical activity. Coaches were recruited and began Up2Us training in the Fall of 2019. Baseline data for the COACHES project were collected from three intervention and two comparison schools in January 2020, SBYD programming began in the intervention schools, and repeated measurement data collection was planned for two points during the 2020–2021 school year.

Each of the school years over which the COACHES study was implemented, however, was severely disrupted, primarily by the COVID-19 pandemic, but also by multiple large weather events. School closures and transitions between virtual, hybrid, and in-person learning models in 2020 and 2021 prevented the full implementation of the COACHES project as planned. The project was extended into the 2021–2022 school year, but Hurricane Ida, which struck in August 2021, displaced families, significantly damaged multiple schools, and again altered learning models and programming. Despite these unexpected events, coaches were still trained and placed in schools and were able to offer SBYD programming during virtual learning, as well as through in-person physical education classes, elective courses, and after school activities. Additionally, evidence-based (27) coach trainings focused on nutrition and physical activity were developed and provided as planned. Youth engaged in the programming and still participated in modified data collection, providing early insights into their experiences during the pandemic (28). At the end of the COACHES study period in Spring 2022, we undertook the qualitative study described here to investigate the participant experience amidst the programming disruptions and modifications.

4 Methods

4.1 Study design

We chose an exploratory case study design to allow us to consider the program within its unique context using multiple data sources (23) and understand details of the program through the perspective of participants (29). With the many unusual circumstances surrounding program delivery, a case study methodology is an appropriate approach for an exploratory investigation into participant experiences during this period (23). The case study methods included interviews and focus groups with program coaches and youth participants, program observation, and informal interviews with Up2Us program staff. The rationale for these multiple methodologies was to allow for triangulation of data to increase validity through verification of themes emerging the analysis (30). The research was approved by the George Washington University Committee on Human Research Institutional Review Board.

4.2 Participants and recruitment

All active Up2Us school-based coaches in New Orleans ($n = 11$) in Spring 2022 were invited to participate in the study to include as many perspectives as possible in the case description. Coaches were contacted by email to explain the study, and their participation was requested on a voluntary basis. Originally, eight coaches at a total of four schools agreed to participate. In the wake of the pandemic, outside access to schools was limited, and coaches, who were embedded in the schools, served as the primary facilitators of contact with school administrators. The schools available for youth focus group recruitment were thus limited to a convenience sample of the four schools with participating coaches. A research team member provided administrators at these schools with information about the objectives for this study and requested their participation. Three of the schools agreed to participate, and the coaches assisted in recruiting a convenience sample of up to 10 youth from their school for a focus group. Coaches provided informed consent, and parental consent and child assent were obtained for youth participants. Coaches received a $50 stipend and youth received a $25 gift card as tokens of appreciation for their participation.

4.3 Data collection

Interviews and focus groups were conducted by a trained PhD student and a trained undergraduate student under the supervision of a senior university faculty researcher. None of the researchers were previously known to the participants. In schools where there were multiple coaches ($n = 2$), group interviews were conducted. The group interview approach allowed for interactions between coaches during the discussion, providing depth of inquiry that may not arise from individual interviews (31). The facilitators used semi-structured discussion guides developed via discussion between all study authors. The guides contained open-ended questions for exploring participant perceptions of (1) their program experience, and (2) connections between program experience and their physical activity and health. Facilitators asked probing questions and engaged in member checks to support confirmability of participant perspectives. All interviews and focus groups were held at schools in a quiet room or outdoor space and were audio recorded.

To further inform the case description and build context for the interview and focus group responses, facilitators observed programming at two sites and had informal interviews with program staff and coaches at all four sites. These observations and conversations provided additional insight into nuances in program implementation and school culture across the different sites. The facilitators also attended a meeting with representatives from several programs engaged in youth development work in New Orleans, which provided additional data on the ongoing coordination and partnerships to support youth across the city. The facilitators took detailed field notes during these observations, informal interviews, and meetings or as soon as possible after their conclusion. The field notes were then incorporated into data analysis alongside the focus group and interview transcripts.

4.4 Data analysis

All interviews and focus groups audio recordings were transcribed verbatim using NVivo Transcription software (QSR International). A research team member reviewed the audio recordings and transcripts together for accuracy and removed any identifying information. Cleaned transcripts were coded and analyzed using NVivo 12 (QSR International) We developed an initial codebook based on the discussion guides focused on identifying salient elements of participant experiences and connections to physical activity and health. The same two coders reviewed each transcript and the field notes multiple times, using iterative inductive analysis to identify patterns in the data, add codes as needed, and distill the codes into themes. The coders met after each round of transcript review to discuss patterns and update codes as needed. Differences in coding were discussed until consensus was reached. One overarching theme with three subthemes emerged from the analysis.

During data collection in Spring 2022, a number of events outside the control of the research team affected the richness of the data we were able to collect. First, the only consenting female coach was unable to participate in an interview. Secondly, unforeseen changes to the school schedule curtailed the length of two of the youth focus groups. These methodological constraints affected our ability to collect data from a fully representative participant sample. In our results and discussion, therefore, we focus on a description of and reflection on the local participant experience, which nevertheless provides lessons that can inform future programming.

5 Results

Seven coaches (100% male, 100% Black, 24.4 ± 5.1 years) at 4 schools participated in the interviews, and focus groups were held at 3 schools with a total of 14 students (71% male, 93% Black, 14.8 ± 1.7 years), for a total of 21 participants. Demographic data for coaches and youth are displayed in Table 1.

The centrality of the near-peer relationships between coaches and youth to the program experience was the major theme identified through the triangulation of coach interviews, youth focus groups, and program observation. Across every interview and focus group, coaches and youth noted ways coaches were relatable and "more like the youth" than other adults in the school specifically because they were closer in age and from similar backgrounds. One youth participant described it this way:

> "I feel like they [the coach] might know more because they are also younger and they might have experienced it and their brain might be able to go quickly to it and might be able to understand like what we are saying."—*Participant 14.*

Under this broader theme, we identified three subthemes: the impact of near-peer relationships beyond programming time, increased opportunity for physical activity facilitated by near-peer relationships, and limitations to the impact of the near-peer relationships.

5.1 The impact of near-peer relationships beyond programming

Although SBYD programming facilitated the initial opportunity for near-peer mentor relationships to form, both coaches and youth described the impact of these relationships extending to multiple areas of life. In a particularly tight-knit group at one of the schools, participants talked about how the strength of the bond with their coach motivated them to support one another in making positive choices. As examples, youth discussed how their relationship with their coach influenced their decisions on matters that could have a major impact on their life trajectory, including staying in school.

> "And it also made me look different at school, because last year, I wasn't coming, I was about to drop out. But when I met [Coach], he was like, stick to it, you know."—*Participant 11.*

TABLE 1 Participant demographic characteristics.

Variable	Coaches (*n* = 7)	Youth (*n* = 14)
Age (y ± SD)	24.4 (5.1)	14.8 (1.7)
Race (%)		
African-American/Black	100%	92.9%
Caucasian/White		7.1%
Ethnicity		
Hispanic/Latino	14.3%	14.3%
Sex		
Male	100%	71.4%

> "We try to keep each other out of trouble, you know, prevent all that because you know, that would look bad on our group. We try to really look good for [Coach], like we try to look as best we could, so we try to hold each other accountable if something going wrong, try to talk to each other."—*Participant 8.*

Youth described additional ways their relationships with their coaches affected them beyond programming time, including striving for accomplishments in multiple areas and also in personal growth. They invited their coaches to significant events, such as band performances or school awards, noting their coaches were important supporters in their lives. Youth also described taking risks in opening up to others, an action they attributed to the bonds they built in the program.

> "One of my favorite memories was [learning drums] with [Coach]. Like me and him are like, really close…he really inspired me to like push myself."—*Participant 14.*
>
> "I like being around a group of people that I can really express myself to, and I do not really…I cannot really express myself to a lot of other people."—*Participant 12.*

Coaches shared a similar perspective on the role of the mentorship relationship in influencing youth choices and reactions in various challenging situations. In their roles, they are on site through much of the school day, and in each interview, coaches shared examples of opportunities both during and outside of programming time to mentor youth in navigating challenges they were facing. They related examples of conversations with youth where they consciously decided against illegal means of making money that were readily available to them or turning to fighting when they were upset with someone.

> "They will come tell me, 'I was about to go fight and then I thought about it. Let me sit down and ask them "what's the problem?" first, before I, I just believe what somebody told.'"—*Participant 2.*

Coaches also noted that they perceived added influence as role models due to being from the same communities and similar backgrounds as the youth. They discussed ways they used their own life experiences to inform how they approached youth going through similar situations. A unique connection in New Orleans was that coaches who had experienced Hurricane Katrina could support youth as they dealt with the effects of Hurricane Ida in Fall 2021.

> "That's why I like even coming to work, for them to see like, someone…who they could probably relate to, like doing something that's right instead of…because I know when they leave school, it's easy to see somebody doing something that's not right."—*Participant 3.*
>
> "With the hurricane, I just gave them what we did not get as children. So, coming back from school during Hurricane Katrina, we were not asked…how we felt about the situation. But like [after Ida], we sat down and we had a conversation. I did not get that as a child, and I still had to experience all of the hurricanes and just figure it out. But I want them to be not afraid of it."—*Participant 1.*

5.2 Increased opportunity for physical activity facilitated by near-peer relationships

The interview and focus group discussions indicated that near-peer relationships between coaches and youth were also perceived as a catalyst for increased youth participation in sports and physical activity. Coaches talked about tailoring the programming to maximize youth engagement and enjoyment as they built relationships with youth and learned more about their interests. Some coaches shared about starting new sports or activities at their schools that were not previously offered, such as flag football and a majorette program. Coaches also viewed active demonstration of skills or joining in the game alongside the youth as facilitating greater youth excitement for participation in physical activity.

> "When we play with them, it gives them a thrill, like oh I'm 'bout to beat Coach!"—*Participant 4.*

In focus groups, some participants described themselves as initially resistant to being active or "not really a sports person," but noted they were more willing to participate as the coaches consistently showed up for them and invested in relationships. Similarly, one of the coaches talked about how over time, as he cultivated trust and youth bought into the program, he noticed a transition from youth coming to practice late or unprepared to their being ready to go as soon as he came outside.

> "Building a culture was literally the difference between pulling teeth and me walking out there [now], and just my presence is like, oh, is [Coach] here? Hey bro line up."—*Participant 2.*

At some schools, coaches were also available to offer both a listening ear and a physical activity outlet if a student was struggling during classroom time. Coaches would engage youth in conversation while doing something active and help them get to a place where they were ready to return to class. At two of the schools that participated in this study, coaches had opportunities to work with younger children in addition to the youth who were the focus of the COACHES project. With younger grades, coaches provided structured activities during recess, ensuring this was a time students spent being active, rather than sitting. The relationships with coaches also led youth to seek out coaches for both conversation and physical activity when they had free time.

> "When I go in the gym, that's where I be in when we have free play, me and [Coach] just go and do one versus ones on either side of the court."—*Participant 15.*

Of note, there were some participants in one of the focus groups, who were negative cases in terms of this subtheme. The negative cases were in the only focus group that included participants who identified as female, and they expressed feeling like the sports offered during programming were more often "boys sports." They also indicated they wanted their coaches more involved in physical education classes, which they said would motivate them to be more engaged and play harder.

> "Yeah, have some fun activities. And activities for girls too, not just basketball and football."—*Participant 19.*

5.3 Limitations to the impact of near-peer relationships

As coaches and youth discussed their experiences, they also identified limits in the extent to which the mentoring relationships and the broader program could impact youth physical activity and holistic health. Coaches highlighted the demanding nature of the work at multiple levels—physically, mentally, and emotionally—and indicated that limited time kept them from investing as deeply as they wished.

> "I start feeling as if I'm not giving everyone enough time, but it's a lot of students and at the end of the day, it is, it's almost impossible to give every child all the time that they need."—*Participant 3.*
>
> "Like, they come in with that weight and you take it. Right? And in some situations, you almost feel like because you like their village and they have confided, and trust you so much, you almost feel like you have to kind of help, you know figure something out."—*Participant 2.*

Both coach interviews and informal interviews with program staff indicated part of this limitation came from constraints in the amount of hours coaches could be offered. Under current funding structures for operating the program, most coaching positions are less than full-time. Coaches described challenges from having to hold multiple jobs in order to meet their financial obligations, and program staff perceived that the limited hours had a negative impact on coach retention.

Beyond the demands on coaches, both youth and coaches identified broader challenges to physical activity and overall wellbeing in the community that the program alone could not address. Participants perceived that the disruptions during the case study period had taken a toll on the community in multiple ways. Coaches and program staff noticed a high frequency of behavioral issues at school, which they attributed to many stresses youth faced in their home environments and changing learning environments. They also described high teacher turnover and challenges with school culture that at times limited program implementation. Youth and coaches alike described barriers they felt to being active and making healthy choices in their communities, specifically highlighting an awareness of high levels of violence.

> "So like one of the rules [during virtual instruction was] nobody else could be in your camera. But like if you living with like a large group of family, how can you know, how can you help that? You know, so it's just like they carried a lot of stuff on them when they came [to school in-person]."—*Participant 2.*
>
> "Well, one thing that's been kind of stopping me is the violence, stopping me from actually like going a lot of places because like, you never know, like what can happen to you. So I've been kind of slacking."—*Participant 14.*

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6 Discussion

This case study describes participant perceptions of their experience with a school-based SBYD program during a time period of major disruption to school and programming schedules. In line with other SBYD program research (32, 33), participants identified the coach-youth mentor relationship as a key element of the program experience. In the present study, the similarities in background and relatively small age difference between coaches and youth were specifically highlighted as factors that contributed to close mentorship relationships. Beyond shared demographics, shared experiences due to living in the same community were perceived by coaches and youth as creating opportunity for greater depth of connection that extended beyond the program. Despite acknowledged potential benefits of near-peer relationships in sports and physical activity, recruiting coaches from local communities can be difficult (20). The formation of these relationships and the level of meaning coaches and youth ascribed to them amidst so many challenges to program implementation indicate the importance of SBYD programs continuing to work toward recruiting and retaining near-peer coaches from the communities they serve, despite the difficulties.

In this program, both near-peer relationships and the school-based setting were identified as facilitators of increased opportunities for youth physical activity. Coaches started new programs and incorporated additional time for physical activities at their school sites, and the majority of youth indicated their coaches helped increase their interest in sports. From our observations and informal interviews, the school-based nature of the SBYD programs in New Orleans seemed to be an important factor in maintaining programming in some form despite all the disruptions. Schools had to find ways to continue learning, and thus coaches were still able to connect with youth and offer opportunities for physical activity within alternative models. Community-based programs, in contrast, given that they exist outside the school day, could be canceled or slower to pivot to virtual programming. Our observations are in agreement with previous work indicating the important role of school-based programs in extending physical activity opportunities to all students regardless of their perceived athletic ability or intrinsic interest in sports (34) and the need for programs to offer a range of options that align with the interests and strengths of each particular youth population (35). More research is needed to understand the impact of SBYD programs administered during the school day (36), particularly in regard to youth who are less likely to engage in sports or physical activity on their own.

Although there was a perceived increase in physical activity opportunities for youth at these New Orleans schools, this study also reinforces the challenges that have been identified in quantitatively reporting on physical health outcomes of SBYD programs (19). Since the COVID-19 pandemic, schools have been less willing to participate in external research (37), a reluctance—understandable given the many demands placed on schools—experienced firsthand by our research team. The data collection challenges we faced point to an opportunity for greater collaboration between researchers, program partners, and schools to identify indicators and data collection methods that provide evidence of program efficacy while minimizing burden on schools.

While this study identified a potentially important role for near-peer relationships in promoting youth physical activity and wellbeing, participants recognized limitations in the ability of a single program to address the social issues youth were facing. The need for SBYD programs to expand beyond a focus on individual development toward greater integration into the community has previously been identified (20, 21), and community capacity building has been put forward as a framework for enhancing program impact (38). The Up2Us Sports SBYD program in New Orleans already demonstrates some community capacity building strategies through coach recruitment and school partnerships. Training leaders from within the community can facilitate diffusion of youth development principles through social networks and expand the supportive environment beyond the program setting (38). Furthermore, integration of SBYD into the school setting has been shown to improve school climate perception and school connectedness (36). Continued efforts by SBYD programs to invest in local leadership development and deepen interorganizational collaboration is vital to work toward "changing the odds" rather than helping youth from underserved communities "beat the odds" (38, 39).

7 Conceptual and methodological constraints

This case study has several limitations that are important to recognize. First, factors outside our control related to school schedules and coach availability limited the representativeness of the coaches and youth who participated in this study and the depth of insight we were able to gain. With girls already less active than boys on average (1) and predominantly male-identifying voices in this case study, more work is needed to understand the role of near-peer relationships among female-identifying and gender non-conforming youth in SBYD programs (40). We also recognize the potential for selection bias in having coaches recruit youth participants, as those who were more engaged in programming may have been more likely to participate. In the interviews and focus groups, there is also potential for social desirability bias from coaches and youth providing answers they believe facilitators wanted to hear. To minimize social desirability bias, the facilitators endeavored to create a comfortable environment and invited honest feedback at multiple points during the interviews and focus groups. Lastly, the confluence of unique events that affected Up2Us school-based programs in New Orleans over the case study period also limits generalizability to other contexts. Despite these limitations, this case study provides valuable insight into the experiences of youth in urban, under-resourced communities that can inform programs and intervention targeting the multiple facets of youth health.

The combination of near-peer coaches and integration of programming into the school day distinguishes the New Orleans Up2Us SBYD program described in this case study from the majority of SBYD programs that have previously been described. During a series of major external stressors on top of ordinary day-to-day challenges, near-peer relationships still appeared to promote factors associated with positive youth health outcomes, namely physical activity and life skill development. The school-based setting of program delivery allowed for greater continuity in programming relative to out-of-school settings during the intervention period, and this consistency demonstrates one of the benefits of partnerships between SBYD programs and other community entities. Further research into the role of near-peer SBYD coaches in schools is needed to inform best practices to increase youth physical activity and improve both individual and community health outcomes.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the George Washington University Committee on Human Research Institutional Review Board. The studies were conducted in accordance with local legislation and institutional requirements. Participants 18 and older provided their written informed consent to participate. For participants under 18, written informed consent was provided by the participants' legal guardians/next of kin.

Author contributions

CS: Conceptualization, Formal analysis, Writing – original draft. JM: Conceptualization, Project administration, Writing – review & editing. WG: Conceptualization, Methodology, Writing – review & editing. JS: Conceptualization, Resources, Supervision, Writing – review & editing.

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Conflict of interest

WG is employed by Social Insights Research, LLC.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Pre-school-based behaviour change intervention to increase physical activity levels amongst young children: a feasibility cluster randomised controlled trial

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Background: A significant rise in childhood obesity worldwide over the past three decades highlights the urgent need for early interventions, especially in preschools as key settings for child development. This study aimed to assess the feasibility and fidelity of a randomised controlled trial of "I'm an Active Hero" (IAAH), a theory- and evidence-based multi-component behaviour change intervention targeting physical activity and sedentary behaviour amongst preschool-aged children.

Methods: Two preschools in Taif city, Saudi Arabia were randomly assigned to either the intervention ($n = 3$ classrooms) or the usual curriculum control group ($n = 3$ classrooms). The intervention ran for 10 weeks from February to April 2023 and consisted of teacher-led physical activity and sedentary behaviour sessions in preschools, with an additional interactive home component. Primary outcome measures included intervention fidelity, recruitment rates, attrition rates, and compliance with trial procedures. Secondary outcomes included body mass index (BMI), objectively measured physical activity, and sedentary time via the ActiGraph GT3X accelerometer. Outcomes were measured at baseline and at 10 weeks in both study arms.

Results: The preschool intervention component had high fidelity (93.3%), but the home component fidelity was lower (74%). A cluster-level recruitment rate of 12% (13/112 centres) was attained, whilst the individual-level recruitment rate stood at 36% (52/143 children, mean age of 4.16 years; 23 girls). Attrition was 10%. Compliance varied with 90% for BMI, 71% for accelerometery, and 45% for questionnaires. The intervention group showed small decreases in BMI, slight increases in physical activity, and decreases in sedentary time at follow-up compared to the control group. Parents, facilitators, and assistant teachers considered the intervention to be feasible and beneficial.

Conclusion: The IAAH intervention was feasible to implement in Saudi Arabian preschools. Facilitators showed high fidelity in delivering it. However, preliminary data did not demonstrate effectiveness. A more comprehensive evaluation across a broader population is warranted. The intervention could be revised to optimise recruitment, compliance, and fidelity of the home-based component. Successful elements from this pilot should be retained whilst adaptations to implementation are made to strengthen key areas.

Clinical trial registration: ClinicalTrials.gov, NCT05754359.

KEYWORDS

feasibility, physical activity intervention, sedentary behaviour, childhood obesity, young children, prevention, Saudi Arabia

1 Introduction

Physical activity (PA) constitutes a significant behavioural factor which is intricately associated with obesity during early childhood (1, 2). An expanding body of research has underscored the vital role of PA from birth to age 5 in promoting positive health outcomes (3, 4) including enhanced bone density, cardiovascular health, body composition, and cognitive and motor development (4, 5). Furthermore, the early childhood phase is a crucial period for establishing enduring tendencies toward physical activity, as patterns formed during this time can persist into middle childhood (6, 7) and early adulthood (8).

Current PA guidelines recommend that preschoolers accumulate at least 180 min per day of light, moderate to vigorous intensity PA (LMVPA) (9–11). However, recent evidence has suggested a concerning trend whereby a substantial number of preschoolers worldwide are not meeting these recommended PA guidelines. According to research, between 62 and 90% of young children do not meet the recommended level of PA for optimal health benefits (12, 13). Furthermore, studies from the United States have indicated that more than half of preschool children do not fulfil recommended PA standards (14). Compounding this issue, most preschoolers spend the majority (79%) of their day engaged in sedentary behaviours (SB) (15–18).

Childhood obesity represents one of the most pressing global public health challenges, as both developed and developing nations grapple with excessive population weight gain (19). Recent estimates indicate that over 40 million children under 5 years of age worldwide are affected by overweight or obesity (20), and without effective preventative measures, the global prevalence of childhood obesity is projected to increase exponentially to 91 million by 2025 (21). Obese children face increased risks of developing hypertension, cardiovascular disease, and diabetes (22). They are also more likely to remain obese into adulthood (23, 24).

Saudi Arabia faces a concerning prevalence of obesity across all ages and genders, including preschool populations (25, 26). From 1980 to 2013, Saudi Arabia experienced one of the most pronounced increases in obesity rates globally (25, 27), leading to its current ranking amongst the top 10 countries with the highest proportion of overweight/obese individuals (28). This worrying trajectory persists (25). Research on early indicators of overweight and obesity in Saudi preschool children (aged 2–6 years) reveals an alarming rate of overweight and obesity (29). Therefore, developing etiological insights into determinants of early childhood obesity within the Saudi cultural context, compared to global benchmarks, is an urgent public health imperative (29, 30). Early intervention programmes to prevent childhood obesity are critically needed as, otherwise, the long-term health and economic impacts could be very significant (31, 32).

Globally, most preschool-aged children are enrolled in early childcare programmes in which they spend a majority of their day (33). With preschool attendance exceeding 8 h per day for most children, these settings have become the primary setting of care and education during early childhood. Consequently, preschools have garnered increasing attention as potentially efficacious venues for improving PA levels amongst this population (34, 35). Multicomponent interventions which target PA and SB, both in the preschool and home environment, tend to show the most promise with regard to improving energy-balance-related behaviours and mitigating unhealthy weight gain trajectories in early childhood (36, 37).

Over the past decade, numerous PA interventions have been implemented and empirically evaluated in preschools in an effort to increase young children's PA levels and address the global childhood obesity epidemic (34, 37–40). However, intervention effects have proven largely heterogeneous thus far, underscoring the need for the continued optimisation and refinement of preschool-based PA promotion. Most experimental interventions to date have taken place within the home (17, 41) or childcare-based settings (39, 42). Syntheses of the literature have indicated intervention components characterised by structured PA opportunities, parental involvement, expert delivery agents, and grounding in behavioural theory, as representing critical determinants of intervention success (37). However, a limitation of the extant literature is the geographical concentration of studies largely within developed Western nations such as the United States, Canada, Australia, and Western Europe. Very little research in this area has been carried out within other global contexts such as the Middle East. Given previous findings indicating a critical research gap and an urgent need for interventions targeting obesity-related behaviours amongst preschool children in Saudi Arabia, there is still a lack of preschool interventions promoting healthy PA. No intervention programme for childhood obesity has been implemented or administered in this population to date.

To address this research gap and align with the established need for a systematic approach to intervention development, we executed a multi-phase process. The objective was to identify an optimal delivery mode, components, and content for a novel intervention, "I'm an Active Hero" (IAAH), designed to address PA and reduce SB in young children. This preschool-based behaviour change intervention, incorporating family engagement, followed a systematic development process in accordance with the Medical Research Council (MRC) Framework for the Development and Evaluation of Complex Interventions (43, 44). This framework outlines key steps, including development, feasibility, evaluation, and implementation. The initial phase involved a comprehensive systematic review to identify behaviour change techniques associated with increased PA in preschoolers (45). Subsequently, qualitative research was undertaken, incorporating input from key stakeholders (including principals, teachers and parents) through focus groups and interviews (46). This approach aimed to establish priorities and objectives tailored to our target demographic.

The Socio-ecological model (SEM) (47) and social cognitive theory (SCT) (48) served as our theoretical foundation, elucidating the expected mechanisms of behaviour change. The preschool-based IAAH intervention, complete with family involvement, was meticulously designed, following the Template for Intervention Description and Replication framework (49) and methodically mapped to specific behaviour change techniques (50). Informed by evidence suggesting superior performance, we opted for face-to-face delivery and supervision as the most favourable implementation strategies (51, 52).

However, the MRC recommends conducting a feasibility study before launching full-scale effectiveness trials, considering it a vital step in developing and evaluating interventions (53). This phase offers significant advantages, chiefly identifying potential limitations in the study design, intervention delivery, or components that could undermine its benefits for the target population. Addressing such issues at an early stage avoids expending significant resources on a fully powered trial when fundamental flaws exist that preclude intended outcomes. Beyond conserving often scarce resources, optimising protocols and methods at this stage also enhances subsequent randomised trials' integrity and impact.

Moreover, within a context of limited public health resources, confirming feasibility brings economic benefits by ensuring that investments in scaling avoid funding an expensive yet ineffective programme. Therefore, the aim of this study was to test the feasibility of a cluster randomised controlled trial (RCT) of the IAAH programme to inform amendments prior to conducting a larger scale evaluation, which is likely to be useful for policy and add to the existing body of knowledge in this field. This will highlight a variety of aspects that emphasise the importance of a comprehensive intervention programme that would serve as a basis for future obesity-related interventions. Notably, this constitutes pioneering research in Saudi Arabia as it is the first such study to be conducted in this context.

2 Methods

2.1 Study design

This study adhered to the guidelines outlined in the CONSORT statement's extension for randomised pilot and feasibility trials (54). The trial utilised a cluster-randomised controlled design, with preschools serving as the units of randomisation and individual children as the units of analysis. The study involved two preschools, each with three classrooms, which were randomly assigned to either the intervention or control condition. As this was a feasibility study, no formal sample size calculation was performed. The participating preschools were matched based on key characteristics such as size and demographics, eliminating the need for pre-randomisation matching procedures. To assign preschools to study conditions, an impartial researcher randomly selected one of two opaque envelopes, prepared by a separate team member, containing the names of the participating schools. One envelope was allocated to the control group, and the other was assigned to the intervention. Data collection occurred at two time points, baseline and post-intervention, spanning February to April 2023. This study was approved by the Saudi Arabian Ministry of Health's Research and Studies Department (IRB Registration Number with KACST, KSA: HAP-02-T-067).

2.2 Setting, sampling, and participants

In the context of Saudi Arabia, a substantial proportion of young children enrol in both public and private preschools. This study was carefully designed to take place within preschools situated in the city of Taif, Saudi Arabia. These preschools are officially registered with the Ministry of Education and adhere to national curriculum guidelines. To initiate the study, a representative from Taif City Council contacted a convenience sample of all locally operated kindergartens within the geographic boundaries of Taif City through electronic communication to assess interest in participating ($n = 112$). Of these schools, 13 preschools expressed their willingness to participate in the study. Through a considered selection process, two preschools with similar demographics were chosen based on their size, socioeconomic status (SES), and demographic composition.

The study director personally visited the principals of the selected preschools, providing them with comprehensive information sheets and consent forms. These documents were subsequently distributed by principals to parents/caregivers of all 3–5-year-old children at their preschools. Exclusion criteria were applied to children with significant health issues that could impede participation or those lacking parental consent. The intervention was then delivered to all eligible 3–5-year-old children in the intervention preschool.

2.3 Intervention

2.3.1 The IAAH intervention programme

The IAAH intervention is a 10-week, preschool-based behaviour change programme aimed at increasing PA amongst 3–5-year-old children. A 10-week duration was selected to align with the local preschool calendar and allow for adequate time to assess short-term experimental effects (55). This programme was delivered by preschool teachers who had undergone two preparatory sessions directed by the lead researcher. This face-to-face method of delivery was adopted based on prior research suggesting its effectiveness (37). Details of the intervention's development will be provided in a separate publication. Briefly, the IAAH programme focused on two key behaviours related to energy balance: PA and sedentary time. The programme involved materials used both in the preschool and at home.

2.3.1.1 Intervention materials to promote PA in the preschool

2.3.1.1.1 Setting environmental changes in the preschool

This emphasised "unstructured PA"—the spontaneous PA that children engage in during recess with minimal teacher intervention. A classroom activities guide provided examples of how to modify the classroom to develop a more PA-conducive, friendly, and fun environment.

2.3.1.1.2 Structured PA sessions

Ten physical education sessions were crafted to guide teachers on organised PA activities for children. Apart from unstructured PA, children were offered two structured PA sessions each week lasting between 45 and 60 min. These sessions aimed to bolster their movement skills and elevate their PA. They encompassed playful exercises targeting endurance, coordination, speed, strength, and flexibility.

2.3.1.1.3 Classroom movement breaks

These were brief PA interludes designed to punctuate prolonged sitting periods. Over 10 weeks, trained teachers integrated 3-5-min movement breaks into their daily routines, accumulating 15 min of PA on four school days per week. The breaks were tailored for classrooms and designed for limited-space environments. They were flexible and easily incorporated into the preschool day with minimal disruption. They included interactive, fun, and non-competitive activities aimed at seamlessly integrating PA into academic lessons. Teachers received classroom guides outlining activities to deliver throughout the day and week. They were encouraged to deliver a total of 1 h of activities per week, gradually introducing more advanced options as the intervention progressed. Educators also received resources supporting PA break delivery.

2.3.1.2 Intervention materials to promote PA at home

Educational materials were provided to parents/caregivers whilst the intervention was implemented at the preschools. These included three newsletters, three tip cards, and two posters promoting PA and reducing SB.

The newsletters and tip cards offered practical, easy-to-understand advice for families from all socioeconomic backgrounds participating in the IAAH intervention. They explained the importance of daily PA for preschoolers and provided suggestions for integrating movement into family routines, including simple ideas for everyday life, active weekend excursions, and being physically active role models. Posters displayed brief messages emphasising the implementing of PA into daily family life (e.g., "Keep moving!" "The car is a 'movement killer'!" "Come to kindergarten actively!").

Compared to previous studies (56, 57) that used passive techniques like tip cards and newsletters, the IAAH used interactive games and activities requiring active involvement from both parents and children. Families also received "No TV Day" challenges to potentially decrease sedentary time and increase active family time.

To ensure effective implementation, early years practitioners in the intervention group underwent two distinct 3-h training sessions led by the primary researcher. The first session took place before the intervention's commencement, whilst the second occurred 5 weeks later. During the initial session, educators were briefed on the study's background, objectives, and details, with a focus on the IAAH programme. They were also reminded of the significance of embodying a role model for cultivating a healthy, active lifestyle. This session provided an opportunity for preschool teachers to clarify their queries. Additionally, during this training session (i.e., before the start of the intervention), educators received the IAAH materials including a teacher's guide, classroom activity guides, newsletters, tip cards, and posters. The teacher's guide provided background information on defining PA and underscored the importance of increasing preschoolers' PA levels to establish healthy behaviours. The classroom activity guide for PA included three themes: (1) setting classroom environmental changes (retained all year), (2) children performing PA during structured sessions (implemented for 10 weeks), and (3) movement break classroom activities (also implemented for 10 weeks). The training also explained the home component and how to deliver it to parents. The subsequent session, scheduled at the midpoint, was designed to share experiences and reaffirm motivation and enthusiasm.

2.4 Procedures and outcomes

Participants were evaluated at two timepoints by two appraisers: one researcher (MA) and a field assistant. Both appraisers went through training for the measurement procedures. Initial assessments were conducted in February 2023, followed by a second round of measurements 10 weeks later. To prepare children and address any potential issues during data collection, an early childhood educator from each preschool was present. Whilst parental permission was obtained for all participating children, child assent was also obtained before measurements began. Children unwilling to take part in specific data collection procedures were not obliged to do so. Since the main focus of this study was examining the feasibility of the intervention and trial, key outcomes of interest included recruitment rates, attrition rates, implementation fidelity, and compliance with data collection. Additionally, several secondary outcomes, as described below, were also assessed.

2.5 Trial feasibility, recruitment and retention

These records encompassed crucial information pertaining to recruitment, which included initial outreach to potential schools and participants, details concerning individuals excluded from the study, those who expressed a willingness to participate further, as well as retention data, encompassing the number of participants who withdrew, were lost to follow-up, or provided data. Measurement sessions were a fundamental aspect of this study, and they were exclusively conducted at participating schools. These sessions were strategically scheduled at two key time points: the baseline assessment and a follow-up evaluation after a span of 10 weeks.

2.6 Implementation fidelity

Implementation fidelity refers to how much an intervention is carried out as planned by its developers (58). Fidelity was evaluated in both preschool and home settings using the following approaches:

2.6.1 Preschool component

To evaluate the implementation fidelity of the preschool programme, practitioners were provided with monthly logbooks which were based on the model of Saunders et al. (59, 60). These logbooks were utilised to document the execution of the programme throughout the intervention period. Using 5-point Likert scales, practitioners rated their monthly implementation of key programme components including modifications to the classroom layout, student engagement in targeted health behaviours, and the integration of health concepts into classroom activities and routines. This logbook methodology allowed for the systematic documentation of practitioner adherence to prescribed programme components on a month-to-month basis. All intervention teachers were asked to complete the log sheet to record frequency (number of times per day they implemented the intervention) and duration (length of each intervention).

2.6.2 Home component

To evaluate the reach of the home-based component of the intervention, practitioners documented the number of eligible children who received activity packs each month. Post-intervention, parents/caregivers completed a questionnaire (see Supplementary File S1) to assess their receipt of and engagement with the home materials. The questionnaire utilised binary yes/no response options and 5-point Likert scales. Questions were designed to determine if parents/caregivers obtained the intervention materials and used them at home with their child.

2.7 Attendance at sessions and intervention harms

Participant attendance at intervention sessions was documented at each session by the facilitator. The facilitator was also tasked with recording any accidents or injuries occurring as a result of the intervention.

2.8 Secondary outcome measures

2.8.1 Body mass index

Anthropometric measurements were conducted by a trained researcher (MA) under standardised conditions to ensure accuracy and reliability. Children were measured wearing light clothing and barefoot in a private room with 3–4 children present at a time. Height was measured to the nearest 0.1 cm using a stadiometer (Marsden, UK) and weight was measured to the nearest 0.1 kg on an electronic scale (Tanita, Amsterdam, Netherlands). Two measurements were taken for both height and weight and the average for each was calculated.

BMI were derived from the weight and height data using standardised anthropometric measurement techniques (61). This involved utilising age- and sex-specific reference data from the UK90 growth charts for children aged ≥4 years (62), as well as the World Health Organization growth charts for 3-year-olds (63). Based on BMI percentiles, children were classified as being of normal weight (<85th percentile), overweight (≥85th to <95th percentile), or obese (≥95th percentile) (64).

2.8.2 Objectively measured PA

PA was objectively measured using the ActiGraph GT3x accelerometer (ActiGraph, Pensacola, Florida, USA). The ActiGraph GT3x is a small, wearable device that attaches to the front of the mid-thigh and measures postural information. The device categorises activity into sitting/lying, standing, and moving/stepping (65). Once attached, the ActiGraph GT3x can be worn continuously for 7–10 days (66). Preschool educators fitted participants with the ActiGraph GT3x under researcher instruction. Parents were asked to place an ActiGraph GT3X accelerometer on a waistbelt on their child's right front hip. Participants were asked to wear the monitor during all waking hours for four consecutive days, including two weekend days (i.e., Wednesday to Sunday) each at baseline and 10 weeks, only removing it when the monitor would get completely wet. A motivational sticker chart was provided to encourage adherence to accelerometer wear. To assess PA patterns, the preschool day was divided into preschool (8:00 a.m.–2:30 p.m.) and after-school/evening hours (2:31 p.m.–10:00 p.m.). For inclusion in the analysis, participants were required to have a minimum of 8 h of accelerometer data per day, covering at least one weekend and two weekdays at each time point. The selection of PA outcome variables, cutoff points, and validation criteria were guided by precedent set in a prior study involving preschool children (11, 67, 68).

2.8.3 Objectively measured SB

Sedentary time during waking hours was assessed using the ActiGraph GT3X accelerometer following the same procedures used for PA measurement (69). Periods of nighttime sleep were differentiated from waking SB by examining the raw accelerometer data files to identify extended periods without significant changes in axis of movement (indicating a transition from sitting/lying to standing), which denote times when the participant was asleep (69).

2.9 Analysis

To evaluate implementation fidelity in this study, we adapted scoring systems used by previous studies (59, 60, 70) to code teachers' logbook and questionnaire responses that indicated the level of implementation. For dichotomous items, a positive response (yes) received a code of 1, whilst a negative response (no) was coded as 0. For Likert scale items, a response of 4 (agree/often) or 5 (strongly agree/always) was coded as 1, whilst all other responses (1-3) were coded as 0. Total implementation fidelity scores of 18 and 12 were revealed for teachers and parents, respectively, which were based on the model of Saunders et al. (59, 60).

To determine and categorise participant weight status from height and weight measurements, data was entered into the LMS Growth Excel add-in to generate percentile scores (71).

Accelerometer raw count data was processed using ActiLife version 6 software (ActiGraph, Pensacola, Florida, USA) and integrated into 15 s epochs (72). Non-wear time was defined as ≥20 consecutive minutes of zero counts. A valid wear-time was ≥8 h on any 3 days. Pate cut points (73) were used to estimate daily moderate-to-vigorous PA (MVP), total and light PA, steps, and sedentary time.

As this was a feasibility study with a small sample size, inferential statistics and effectiveness testing were not recommended (74, 75). Instead, descriptive statistics were used to assess feasibility parameters including fidelity of implementation, recruitment, retention, and attrition rates, presented as proportions. High, medium, and low fidelity were classified as overall implementation scores of ≥60%, ≥50 to <60%, and < 50%, respectively, following the methodology of similar studies (58). For secondary outcomes, the study presented means ± standard deviations, along with the mean change from baseline to follow-up and 95% confidence intervals where appropriate.

3 Results

3.1 Feasibility of trial recruitment and retention

The study received responses from thirteen out of 112 preschools, indicating a cluster-level response rate of 12%. Amongst the 143 consent forms distributed, 52 children (mean age 4.17 ± 0.145 years; 23/44% girls) obtained parental consent and completed the baseline assessment, resulting in an individual-level recruitment rate of 36% before preschools were randomised to the IAAH intervention arm (1 centre; $n = 27$; 13 girls) or the usual curriculum control arm (1 centre; $n = 25$; 10 girls). A CONSORT flow diagram illustrating the study's progression is presented in Figure 1.

Independent t-tests showed no significant baseline differences between the intervention ($n = 27$) and control ($n = 25$) groups in age (intervention: 4.18 ± 0.42 years; control: 4.16 ± 0.49 years; $p > 0.05$) or mean BMI (intervention: 16.38 (2.14) kg/m2; control: 16.58 (1.89) kg/m2; $p > 0.05$). Participant characteristics at baseline are presented in Table 1.

The accelerometer-based PA data showed no significant observed between-group differences at baseline for any PA variables including

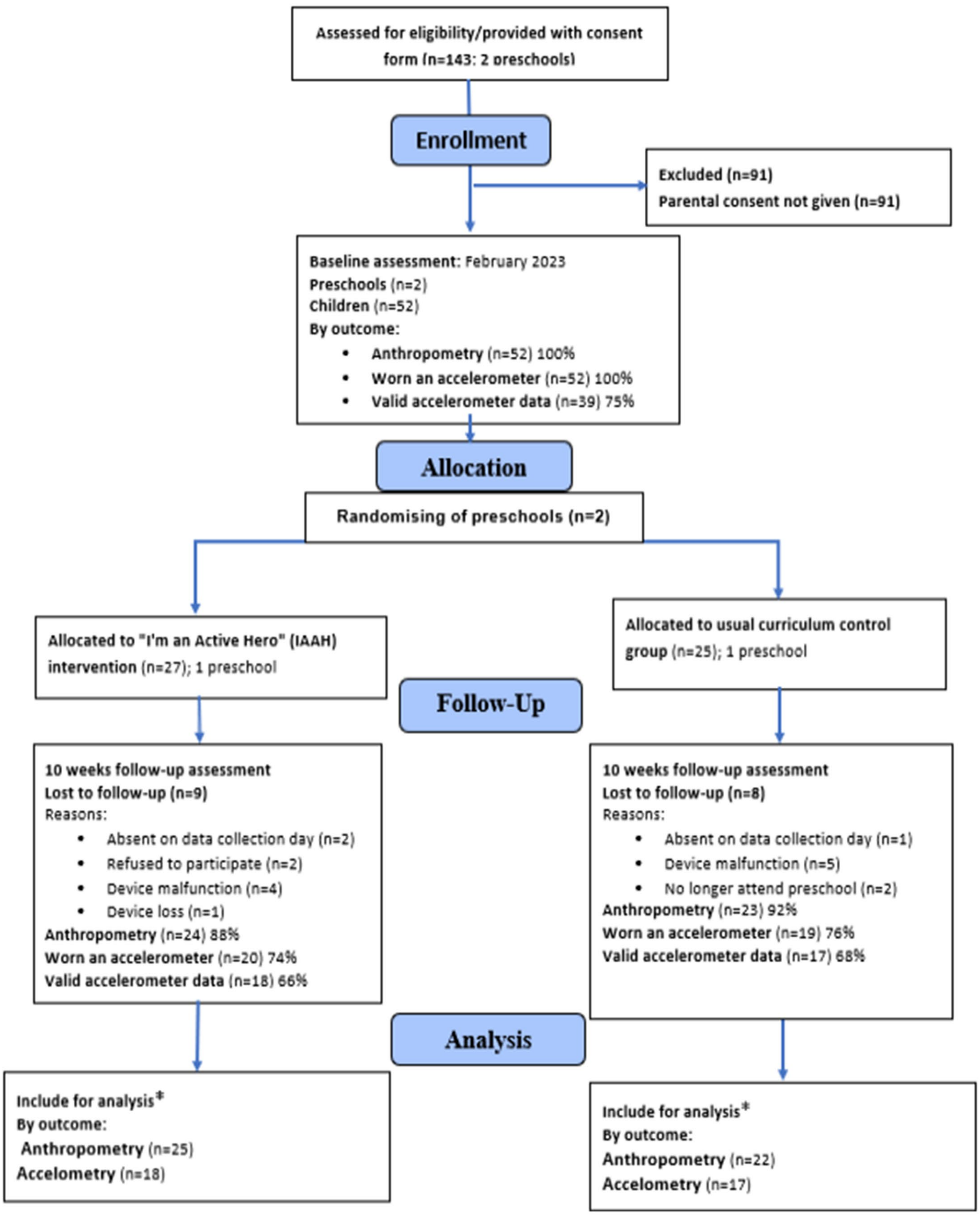

FIGURE 1
CONSORT flow diagram detailing trial recruitment and retention for the IAAH intervention. *Only participants that provided both baseline and post-intervention data were included within subsequent analyses.

TABLE 1 Baseline descriptive statistics of participants in the intervention and control groups.

Characteristics	Control (*n* = 25)	Intervention (*n* = 27)	*p*-value	All (*n* = 52)
Age (years) (mean SD)	4.16 (0.49)	4.18 (0.42)	0.90	4.17 (0.46)
N (%) girls	11 (44)	12 (44.4)	0.97	23 (44.2)
Height cm (mean SD)	100.78 (5.17)	101.45 (5.26)	0.64	101.11 (5.2)
Weight kg (mean SD)	16.86 (2.52)	17.01 (2.86)	0.86	16.93 (2.7)
Body mass index (BMI) Kg/m^2 (mean SD)	16.58 (1.89)	16.38 (2.14)	0.75	16.48 (2.02)
BMI category *n* (%)				
Obese	3 (11.1%)	2 (8%)	0.10	5 (9.6%)
Overweight	4 (14.8%)	5 (20%)	0.73	9 (17.30%)
Normal	15 (55.6%)	17 (68%)	0.72	32 (61.5%)
Under weight	2 (7.4%)	1 (4%)	0.65	3 (5.7%)

vigorous PA, moderate-to-vigorous PA (MVPA), and sedentary time. Over 70% of baseline activities were sedentary in both groups. Additionally, 17.3% of participants were considered overweight as per the BMI. Descriptive PA data at baseline (Time 1) and post-intervention (Time 2) are presented in Table 2.

The assessment of initial intervention effects on PA variables during preschool hours, as depicted in Table 3, did not demonstrate significant differences between the evaluated groups. However, we noted a promising trend toward increased MVPA and decreased sedentary time in the intervention group, as evidenced by *p*-values of 0.058 and 0.063, respectively. These findings suggest the potential effectiveness of our intervention in promoting positive changes in these variables amongst preschool children. The observed trends underscore the potential of structured interventions to significantly impact PA levels within educational settings, despite the inherent challenges of modifying activity behaviours amongst this young demographic. Nonetheless, the small sample size and short duration of the intervention may have limited our ability to detect statistically significant differences in PA levels. This indicates the need for further research with longer durations and larger sample sizes to definitively ascertain the intervention's impact.

3.2 Intervention fidelity

The intervention preschool submitted complete activity logbooks for the 10-week study. Overall implementation fidelity across the intervention preschool was high at 93.3% (Table 4). Intervention components related to PA were implemented with higher fidelity compared to SB components based on the logbook data. The post-intervention survey indicated a 74% overall implementation score for the home-based intervention component. Table 4 provides detailed preschool implementation fidelity scores from the practitioner logbook data.

3.3 Attendance at sessions and adverse events

No intervention-related adverse events, accidents, or injuries were reported by the IAAH facilitators. Facilitators indicated that intervention sessions were well-attended on a consistent basis. Attendance was generally high, with approximately 95% of participants attending each session according to facilitator and staff records. No barriers to attendance or participation were identified during the 10-week intervention period.

3.4 Participation in outcome measures

3.4.1 Anthropometry

Valid height and weight measurements were obtained for 90% (47/52) of participants at baseline and follow-up. Five children lacked follow-up data due to absence ($n = 4$) or declining participation ($n = 1$).

3.4.2 Accelerometery

At baseline, 75% ($n = 39/52$) provided valid accelerometer data. Invalid measurements resulted from device issues ($n = 4$), refusal ($n = 2$), absence ($n = 2$), or device loss ($n = 1$). Only those with valid baseline data wore accelerometers at follow-up. Of the original sample, 71% ($n = 35$) returned valid follow-up data. Invalid data resulted from absence ($n = 1$), leaving preschool ($n = 2$), or device malfunction ($n = 5$).

3.4.3 Post-intervention questionnaire response

Post-intervention, 75% (3/4) of teachers and 45% (9/20) of parents returned valid surveys. Five parent surveys were incomplete and therefore excluded.

3.5 Behavioural and health outcomes

For participants with valid baseline accelerometer data ($n = 39$; intervention $n = 20$, control $n = 19$), the mean daily minutes of total PA were 159.79 ± 44.79 in the intervention group and 161.10 ± 28.23 in the control group. The mean daily steps were 8,965.20 ± 3,030.03 in the intervention group and 8,826.88 ± 3,165.6 in the control group. The intervention group spent 406.33 ± 93.52 min per day sedentary, whilst the control group spent 398.11 ± 71.75 min per day sedentary at baseline ($p > 0.05$). The average time wearing an accelerometer per day was 566.12 ± 68.257 min in the intervention group and 559.22 ± 73.06 min in the control group. There were no significant between-group differences in any PA variables (Table 2).

TABLE 2 Summary of results for participants that completed PA measurement at baseline and follow-up.

Variable	n	Baseline, M (SD)	n	10 weeks M (SD)	Adjusted within-group change from baseline to 10 weeks			At 10 weeks (post-intervention) comparison between groups		
					M	(95% CI)[a]	*p* value	*M*	(95% CI)[b]	*p* value
Total daily SB (min)										
Control	19	398.11 (71.75)	17	407.01 (66.45)	8.9	(65.9-,37.9)	0.571			
Intervention	20	406.33 (93.5)	18	388.26 (69.7)	−18.07	(−45.5, 66.9)	0.694			
Group X time interaction								−18.8	(−67.4, −29.9)	0.085
Light PA (min/day)										
Control	19	113.09 (22.33)	17	118.5 (31.87)	−6.54	(−23.8-,10.72)	0.434			
Intervention	20	112.975 (39.4)	18	115.83 (27.7)	−2.85	(−29.3, −23.63)	0.623			
Group X time interaction								−2.7	(−20-,14.07)	0.076
Mod PA (min/day)										
Control	19	36.54 (13.52)	17	35.11 (9.57)	2.11	(−7.04-11.27)	0.631			
Intervention	20	35.56 (11.8)	18	40.49 (10.5)	−5.98	(−14.06–2.09)	0.137			
Group X time interaction								−2.7	(−20–14.07)	0.0.076
MVPA (min/day)										
Control	19	48.01 (13.34)	17	44.49 (13.62)	−4.04	(−6.11–14.20)	0.411			
Intervention	20	47.25 (13.7)	18	54.41 (16.9)	8.01	(−45.5 66.9)	0.147			
Group X time interaction								9.91	(−0.62–20.5)	0.064
Total daily PA (CPM)										
Control	19	161.10 (28.23)	17	163.001 (39.43)	−2.49	(−25.63–20.36)	0.820			
Intervention	20	159.79 (44.79)	18	170.24 (35.89)	−10.9	(−42.9–21.2)	0.485			
Group X time interaction								7.23	(−15.06–29.5)	0.051
Total daily steps (count)										
Control	19	8826.88 (3165)	17	8985.19 (2695)	−187.1	(−2,469–2094)	0.864			
Intervention	20	8965.204 (3030)	18	10130.2 (2775)	−1,223	(−2,746–298.5)	0.108			
Group X time interaction								1,144	(−899–3,188)	0.067
Wear time (min/day)										
Control	19	559.22 (73.06)	17	570.01 (73.31)						
Intervention	20	566.12 (68.257)	18	558.5 (59.23)						
Group X time interaction										0.061

Values are mean SD. SB, sedentary behaviours; PA, physical activity; CPM, counts per minute; Min, minute; Mod, moderate; MVPA, moderate-vigorous PA. [a]All variables were adjusted for their respective baseline value, age, wear time and gender. [b]The adjusted delta differences between groups are significant at the 0.05 level.

Whilst the intervention group demonstrated higher total PA minutes at the 10-week follow-up compared to the control group, the changes within and between groups across outcomes were nonsignificant. Specifically, from baseline to 10 weeks, the intervention group increased moderate-to-vigorous PA by 8.01 min/day (95% CI−19.2 to 3.12; $p = 0.147$) whereas the control group decreased by 4.04 min/day (95% CI−6.11 to 14.20; $p = 0.411$). Regarding total daily sedentary time, the intervention group decreased by 18.07 min/day (95% CI−45.5 to 66.9; $p = 0.694$) and the control group increased by 8.9 min/day (95% CI−37.9 to 65.9; $p = 0.571$). Despite more favourable changes in the intervention versus control group for moderate-to-vigorous PA, light activity, and sedentary time, there were no statistically significant within-group changes or between-group differences from baseline to 10 weeks across any outcome measures (Table 2).

4 Discussion

This study examined the feasibility of conducting a cluster randomised controlled trial of the IAAH intervention in preschools. The participating preschools were willing to be randomly assigned to study conditions. We assessed the feasibility of recruitment, follow-up, data collection, intervention attendance, and the implementation of school-based and parent-based intervention components. Overall, the findings showed that the intervention was delivered as intended to all participants. Further, it was well-received by both teachers and parents and considered feasible and deliverable. However, the results suggested that some modifications to the study intervention delivery are needed before moving on to the next stage of evaluation.

TABLE 3 Physical activity variables during preschool day.

Variable	Intervention (*n* 20)		Control *n* (19)		*p* value
	Baseline	week 10	Baseline	week 10	
During preschool PA (% time spent)					
Sedentary PA	70.73 (4.2)	68.01 (4)	70.56 (6.3)	72.07 (3.7)	0.063
Light PA	20.91 (3.3)	21.94 (3.8)	20.49 (3.6)	21.07 (2.1)	0.082
MVPA	8.53 (3.1)	9.85 (2.9)	8.74 (3.1)	8.86 (2.1)	0.058
After-school/evening (% time spent)					
Sedentary PA	70.11 (5.2)	69.42 (4.2)	70.15 (6.6)	71.34 (3.8)	0.082
Light PA	20.72 (3.4)	21.41 (3.7)	20.31 (3.7)	20.96 (2.3)	0.093
MVPA	8.24 (3.2)	8.65 (2.7)	8.31 (3.2)	8.73 (2.2)	0.124

All values are the mean and standard deviation.

The recruitment rate at the cluster level in this study (13/112, 12%) demonstrated similarities with a comparable preschool PA intervention (11% uptake) (76), though was lower than what has been observed in other early childhood feasibility studies (77–79). The individual-level recruitment rate (52/143, 36%) was consistent with existing preschool research reporting uptake rates ranging from 25 to 52% (77, 78, 80). Whilst our trial employed comparable recruitment methods to those seen in a previous high-enrolment study (57), the socioeconomic disparity across samples may explain the recruitment discrepancy. Specifically, the prior trial likely benefited from medium-to-high socioeconomic status (SES) preschools, whereas our sample was skewed low-to-middle SES. Extensive literature has documented greater recruitment and retention difficulties amongst economically disadvantaged populations (81, 82). To optimise the future trial recruitment of preschoolers, it is advisable to contemplate diversifying SES and employing tailored methods for hard-to-reach groups. For the planned cluster randomised controlled trial, proactive retention strategies will be used such as reminders, incentives, and closely monitored participation tracking (83) to boost recruitment and minimise attrition.

Overall participant retention in this study surpassed that of comparable studies, reaching 90%, with a minimal 10% attrition rate after the 10-week period. This is in contrast to 68–75% retention observed at 12 weeks in other studies (57, 77, 84). However, amongst those participants who completed follow-up, the amount of valid data collected differed substantially depending on the outcome measure. The noteworthy accomplishment of a 95% attendance rate in this feasibility study exceeded the attendance reported in similar preschool interventions in the UK (53%) (85) and Finland (70.4%) (86). This provides promising indications that the intervention can successfully engage and retain preschool participants. The maintenance of strong attendance will be a pivotal focus as the study advances into the larger-scale effectiveness trial.

The intervention was delivered with high fidelity (93.3%) in the preschool setting. Logbook responses showed that PA components were implemented at a higher level than SB components (Table 2). Previous studies also found relatively low implementation scores for SB activities across multiple sites (36, 87, 88). Considering these findings, despite adapting the programme to reduce time-intensive activities, poorer SB implementation highlights the need for further modifications to the SB components.

However, implementation fidelity for the home component was 74%. This is consistent with other preschool interventions, including home elements (89). These results are unsurprising, as the home environment has been identified as particularly challenging for implementing obesity prevention efforts (85), especially in disadvantaged groups. The low fidelity of the home component highlights the difficulties of extending preschool interventions into the home setting. Strategies to improve engagement and adherence for home-based components should be explored before implementing similar interventions. Overcoming barriers in the home environment is key to maximising the effectiveness of preschool interventions which target healthy lifestyle promotion.

In this study, 90% of participants completed height and weight measurements, aligning with the anthropometric measurement rates achieved in similar studies (90–92), indicating that these procedures are feasible in the preschool population.

Regarding accelerometery, at baseline, 39 children (75%) provided valid data, but only 35 (71%) had valid wear time at both baseline and 10 weeks. This aligns with other preschool RCTs reporting 42–80% valid wear time at both timepoints (i.e., baseline and follow-up) (57, 93, 94). There were several factors that prevented the collection of valid accelerometer data at both timepoints in previous studies, such as device loss or malfunction and child absence on the data collection day (36, 95–97). The literature offers inconsistent findings regarding compliance with accelerometer measurement procedures in studies assessing PA and SB in children. Recent reviews of attrition rates and noncompliance with accelerometer protocols in children's PA trials indicate that noncompliance at follow-up assessments ranged greatly from 3 to 70% across 23 studies (98).

Previous studies using Actigraph accelerometers for brief 2-day wear periods reported a high adherence rate of 96–97% at baseline and 6-month follow-up (99), suggesting that a shortened monitoring period could improve compliance. However, another study requiring 7 days of Actigraph wear in preschoolers achieved only 86% adherence, indicating that additional factors likely influence accelerometer compliance beyond wear duration alone (100). As the ActiGraph GT3X was comparable to other potentially less invasive and participant-friendly wearable devices (65, 101), there may be valid alternatives which could be considered for future trials. Regardless of the device chosen, enhancing communication with parents throughout recruitment and follow-up could facilitate collecting more valid accelerometer data in any future trial. Multiple studies have shown favourable results by utilising strategies such as reminder messages, check-in calls, and small monetary incentives for accelerometer returns (91).

TABLE 4 Preschool implementation fidelity score logbook items and responses.

Component	Logbook question	Scoring and results (% coded as 1 over the 3 months)	
		PS (%)	(%) (Fidelity score)
Preschool environment	Was equipment and space appropriately arranged for PA sessions every day of the week?*	100	100 (high)
	Was the classroom appropriately arranged for movement breaks every day of the week?*	89	89 (high)
	Were any movement corners set up and made available to the children?*	100	100 (high)
Children performing the health behaviours	How much time did you devote to PA sessions on an average weekly basis this month?⁺	98	98 (high)
Classroom experiences	Did you implement the classroom experiences for PA as described in the manual?*	100	100 (high)
	Did you devote on average at least 1 h per week to the classroom activities for PA as described in the manual?*	97	97 (high)
	Did you devote on average at least 1 h per week to the classroom activities for SB as described in the manual?*	86	86 (high)
	Which classroom activity (ies) regarding PA did you implement this month?⁺	98	98 (high)
	Which classroom activity (ies) regarding SB did you implement this month?⁺	85	85 (high)
Delivery of home materials and engagement with parents	Did you provide parents with the pre-prepared home activity packs when these were delivered to the nursery?*	100	100 (high)
	Estimate the number of parents to whom you directly delivered programme materials, if you did⁺ (total 29 children)	31	31 (low)
	Estimate the number of parents with whom you spent time explaining the purpose of the material and encouraging them to follow the recommendations of the material⁺ (total 29 children)	100	100 (low)
	Total aggregate scores (% responses coded as 1. Total available points = 12)	93.3	Overall score = 93.3

This form was repeated three times, once for each month the intervention was delivered. *Scoring determined by 5-point scale, "1 = never, 2 = not often, 3 = sometimes, 4 = often, 5 = always," ≥ 4 = 1; ≤ 3 = 0. ⁺Scoring determined by a "yes/no" response or a numerical response. Yes = 1; no = 0. Numerical responses equate to ≥ 60% = 1; <60% = 0. PS = preschool.

In this study, only 45% of parents responded to the post-intervention questionnaire, indicating even lower engagement than the suboptimal benchmark. This response rate is comparable to some previous studies (for example, 48%) (88) but lower than others (for example, 75%) (102). Whilst we attempted to shorten the questionnaires before starting the trial, further adaptation may be necessary to improve response rates. Several factors likely contributed to the modest questionnaire return rate in this study. Poor awareness about the importance of the questionnaire and its potential to inform decision-making, as well as privacy concerns, may have reduced participation. Some may have believed that offering opinions would not impact the situation. To optimise response rates in future trials, more efficient questionnaire alternatives should be explored, such as clarifying the purpose of the research, ensuring privacy, simplifying the design, offering small incentives, using direct communication methods like phone or SMS reminders, and providing flexible response options (for example, paper, electronic, or phone). Generally, understanding and accommodating the target community's needs and expectations when designing the questionnaire may elicit improved engagement and results in subsequent studies (103).

Comparing the findings of this feasibility study with prior research offers valuable insights into the potential impact of the intervention. Although our intervention demonstrated enhancements in step counts, BMI, moderate-to-vigorous PA (MVPA), and SB (SB), these improvements did not reach statistical significance. This concurs with certain studies (85, 86) but diverges from others that reported significant enhancements in comparable outcomes (57, 104). Conversely, some studies identified increases in BMI and inactivity post-intervention, with no discernible changes in PA (76). The absence of statistical significance in our results may be attributed to the brief 10-week duration, as more substantial effects could necessitate interventions lasting 6 months or longer (41). This underscores the imperative for a more comprehensive evaluation in an upcoming randomised controlled trial (RCT), wherein augmented sample sizes and an improved study design should enhance the precision of assessing effectiveness.

Should our intervention prove effective in an RCT, the implications for promoting PA and self-efficacy amongst young children would be significant. Successful interventions documented in other studies have underscored that meticulously planned and supported initiatives can yield positive outcomes (99). Scaling up and integrating our intervention into health and education curricula would align with the success observed in analogous endeavours (34), thereby reinforcing the importance of engagement with key stakeholders.

Furthermore, considering the broader ramifications of PA, our intervention aligns with the idea that fostering healthy behaviour can positively impact other aspects of well-being. This is corroborated by research indicating that PA interventions have favourable effects on behaviours such as diet, sleep, and overall wellbeing (105).

5 Strengths and limitations

The main strength of this study was the first systematic pilot testing of the feasibility of implementing the IAAH intervention in Saudi Arabian preschools, filling a significant gap in research into delivering a physical activity promotion programme tailored for young children in this context. Additionally, the multimethod data collection allowed for a comprehensive evaluation of feasibility parameters.

However, this study had some key limitations. The sample was restricted to preschools in one urban area, which limits broader generalizability. The modest sample size, whilst reasonable for a feasibility study, precluded blinding of participants or intervention providers. Several feasibility outcomes, such as questionnaire response rates and accelerometer compliance, were suboptimal and highlighted target areas needing improvement before an effectiveness trial. As this pilot was not powered to detect intervention effects, assessments of preliminary outcomes should be interpreted with caution. Finally, detailed information on the acceptability of the intervention procedures and content from participants and providers would further contextualise the feasibility findings this aspect remains unexplored in the current study.

6 Conclusion

This feasibility study has provided critical insights into the implementation of the IAAH intervention within preschools settings, demonstrating promising recruitment and retention rates and indicating that a larger-scale trial is both feasible and warranted.

The feasibility of conducting such interventions in preschool settings, along with their acceptable and implementable nature as perceived by facilitators, lays a solid foundation for future large-scale applications aimed at combating childhood obesity. Insights into barriers and facilitators to intervention implementation provide valuable guidance for improving future interventions, ensuring they are more tailored, attractive, and effective. Furthermore, our study highlights the way forward for subsequent trials, particularly by emphasising the importance of strategic improvements in recruitment and data collection methodologies. These improvements will not only improve the power of future research but will also enhance our understanding of effective strategies for promoting physical activity amongst preschool children.

We recommend that interested researchers, key stakeholders, and policymakers pursue a revised approach to the IAAH intervention that incorporates the successful elements identified in this pilot project with necessary modifications based on the challenges encountered and considering environmental, cultural, and other contextual factors. This strategic intervention development is expected to contribute significantly to ongoing efforts to promote a more active and healthier lifestyle from an early age, ultimately helping to address childhood obesity.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by Saudi Arabian Ministry of Health's Research and Studies Department's IRB Registration Number with KACST, KSA: HAP-02-T-067. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

MA-w: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Writing – original draft, Writing – review & editing. MD: Conceptualization, Formal analysis, Investigation, Methodology, Resources, Supervision, Writing – review & editing. AA: Conceptualization, Data curation, Formal analysis, Software, Supervision, Writing – review & editing. NH: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2024.1379582/full#supplementary-material

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Examining associations between physical activity context and children meeting daily physical activity guidelines: the role of outdoor play, sports, and other organized activities

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Background: Less than one-quarter of US children meet physical activity (PA) guidelines. Understanding the context in which PA occurs and how these contexts may play a role in meeting PA guidelines is an essential step toward developing effective behavioral interventions. The purpose of this study was to examine associations between PA context (sports participation, participation in other organized physical activities, active travel to school, and outdoor play) and the number of days children met PA guidelines in a representative sample of children living in Texas.

Methods: We analyzed cross-sectional data from a statewide sample of fourth-grade children in Texas who completed the 2019–2020 Texas School Physical Activity and Nutrition (Texas SPAN) survey. The Texas SPAN survey was designed to monitor the statewide prevalence of overweight/obesity among school children and assess habitual self-reported obesity-related behaviors, including diet and PA. Weighted Poisson regression models were employed to examine the associations between PA contexts (sports participation, participation in other organized physical activities, active travel to school, and outdoor play) and the number of days children met PA guidelines, adjusting for sex, race/ethnicity, overweight/obesity, urban–rural status, and economic disadvantage.

Results: A total of 16.7% of fourth-grade children met physical activity guidelines every day during the week (mean age = 9.4 ± 0.6 years; female = 48.7, 51.8% Hispanic, mean days meeting PA guideline = 3.6 ± 2.3 days). One in ten (11.2%) children did not meet daily PA guidelines on any day of the week, and 72.1% met them between 1 and 6 days. Participating in sports (b = 0.22, 95%CI:0.14, 0.30), any other organized physical activities (b=0.13, 95%CI:0.017, 0.19), and playing outdoors 1–3 days (b = 0.25, 95%CI:0.04, 0.46) and 4–7 days in the past week (b = 0.77, 95%CI:0.57, 0.97) was significantly and positively associated with the number of days children met PA guidelines.

Conclusion: Participating in sports, participating in other organized physical activities, and playing outdoors may beneficially influence the number of days children meet PA guidelines. PA programs should consider these contextual factors and investigate how to promote organized activities and outdoor play effectively and appropriately among children.

KEYWORDS

physical activity, context, children, sports, outdoor play, organized activities, active travel

Introduction

Physical activity (PA) is associated with many health outcomes in children including fitness and cardiovascular health (1), cognitive functioning, depression, and other mental health outcomes (2), and metabolic outcomes including overweight and obesity (3, 4). Current national guidelines from the American Heart Association and the Centers for Disease Control recommend children aged 6–17 years accrue at least 60 min of moderate-to-vigorous physical activity (MVPA) daily (5–8), yet based on current observational research, most children do not meet this daily recommendation (9). Furthermore, while there have been many high-quality PA interventions designed for and delivered to children, many with multiple components including buy-in from schools, families, and communities, few have been able to make a substantial impact on children's PA (10–14). There is a need for more informative observational research to guide the development of these interventions in an effort to increase the proportion of children meeting PA guidelines in the US.

Children are exposed to a variety of opportunities (i.e., contexts) to accrue PA throughout their day, including physical education, recess, after-school programs, sports and other out-of-school structured activities, active travel, and unstructured free play at home and outdoors. These contexts differ in the degree to which they are structured, how they are made available to children, and their environmental and social correlates (10, 11, 13, 15–18). For example, sports participation is often delivered as a structured PA opportunity, overseen by adults at set times during the day/week, and often involves larger groups of children participating at one time (15, 16). There is also often a cost associated with sports participation, potentially limiting the opportunity for children from families who cannot afford it (19). Conversely, unstructured outdoor play (free play) is more likely done at recess or around the home environment, is rarely supervised, and often involves fewer children participating together at one time (20). While technically free from any associated monetary cost, playing outdoors may have other barriers including neighborhood safety and/or limited access to parks, recreation facilities, or play equipment at the home (20–23).

Understanding the differential influence of these contexts on children's PA guideline adherence is key when designing maximally effective behavioral interventions targeting PA, as this could provide a way to identify potential intervention components that will have the best chance at "moving the needle." There are many examples of PA-based interventions using different types of contexts as their mode of delivery including sports, after-school programs, and recess. Technically, differential success across these programs (10–13) should allow us to make some inferences regarding how different contexts may influence PA from these intervention studies. However, it is difficult to compare different contexts across studies due to unquantifiable heterogeneity. Additionally, we are not aware of any interventions that have been designed to compare how PA contexts may differentially impact PA outcomes in children (i.e., compare the effect of a sports intervention to a recess intervention). Thus, cross-sectional, observational data remain the only viable source of inference regarding these questions. Even though such data do not permit causal inference, it does provide the opportunity to compare PA behaviors across contexts with the same sample of participants in a naturalistic setting. It is also important to identify how differences in key demographics, like sex and socioeconomic status, play a role in PA context, as these may influence the dose of individual contexts children receive. For example, sports and other out-of-school structured activities are cost prohibitive, and certain PA contexts, like outdoor play and active travel, may be viewed by parents as more or less dangerous depending on the sex of the child, resulting in both socioeconomic and sex-based differences in PA context (23–27).

The Texas School Physical Activity and Nutrition (Texas SPAN) survey provides a unique opportunity to explore how different PA contexts associate with children meeting daily PA guidelines and to identify socioeconomic and sex-based differences in daily PA guideline adherence and differences in PA engagement across several contexts at a representative statewide level. While there have been previous studies exploring contextual factors associated with PA in children (17), and even some comparing PA engagement across contexts (28), most use small samples and have limited generalizability. Texas ranks 10th for rates of childhood obesity (29) and is home to nearly 7.5 million children, accounting for 10% of the entire US population of children (30), underscoring the need for more informative, large-scale, obesity-related behavioral research in this region. Therefore, the purpose of this study was to examine associations between PA contexts (sports participation and other out-of-school structured physical activities, active travel to school, and outdoor play), and the number of days fourth-grade children met PA guidelines in a representative sample of children living in Texas using data from the 2019–2020 Texas SPAN survey.

Abbreviations: BMI, Body Mass Index; MVPA, Moderate-to-Vigorous Physical Activity; OWOB, Overweight and Obesity; PA, Physical Activity; PHR, Public Health Region; SDH, Structured Days Hypothesis; Texas SPAN, Texas School Physical Activity and Nutrition; TEA, Texas Education Agency; US, United States.

Methods

Study design

The Texas SPAN survey is a cross-sectional survey designed to monitor the statewide prevalence of children with overweight/obesity via objective measures of height and weight and assess habitual self-reported health-related behavioral outcomes, including diet and PA. It uses a stratified, multi-stage sampling plan to produce representative data for second-, fourth-, eighth-, and 11th-grade students in the state of Texas. The current study uses data collected from fourth graders during the 2019–2020 cycle of data collection. The Committee for the Protection of Human Subjects at the University of Texas Health Science Center at Houston (UTHealth Houston) (HSC-SPH-18-0432), the Texas Department of State Health Services Institutional Review Board, and local school district review committees reviewed and approved all study-related activities for Texas SPAN survey. Specific methodology is briefly described below, but detailed descriptions of the study have been reported elsewhere (31).

Data collection and sampling

The Texas SPAN survey is a self-administered survey questionnaire administered to second-, fourth-, eighth-, and 11th-grade students in Texas. Survey items include questions about demographic characteristics, nutrition, PA, screen time, and dental habits. The survey has been previously tested for reliability and reproducibility (32). In addition to questionnaire items, Texas SPAN collects objective measures of height and weight used to calculate body mass index (BMI). Specific details on data collection methods have been reported elsewhere (31). Briefly, the Texas SPAN project is conducted, and data are collected by researchers at the Michael and Susan Dell Center for Healthy Living at the University of Texas Health Science Center Houston, School of Public Health in Austin. Data collection consists of survey administration and measurement of student's height and weight to calculate BMI. All data collection procedures are completed in participating schools. A detailed process overview of all recruitment and data collection procedures has been published elsewhere (33). The stratified, multi-stage sampling of the Texas SPAN survey and statewide representativeness of the data is achieved by collecting representative data in each of Texas' eight public health regions (PHRs) and by using data obtained from Texas Education Agency (TEA) on public school enrollment to create the sampling frame (weighting structure) for the study. The PHRs in Texas include: 1 (Lubbock area), 2/3 (Dallas area), 4/5 (Tyler area), 5/6 (Houston area), 7 (Austin area), 8 (San Antonio area), 9/10 (El Paso area), and 11 (Brownsville area). A comprehensive map of the Texas PHRs sampled has been previously published (33).

Participants

The 2019–2020 Texas SPAN survey included a total of 8,710 participants in second, fourth, eighth, and 11th grades, representing a weighted sample of 1,407,016 students. The total number of fourth-grade participants, which is the sample used in the current study, was 2,897, representing a weighted sample of 355,314 fourth-grade children across Texas. The inclusion criteria for this study were the presence of completed measures of all variables of interest, which are described below in the Measures section. It is worth noting that all data were collected prior to the onset of the coronavirus disease 2019 (COVID-19) pandemic, which is why the total sample included is less than previous years, but also means estimates/results need not be interpreted through the lens of the pandemic.

Measures

The following section details the specific measures of the Texas SPAN survey used for this study, which included PA, contexts of PA, weight status, and various demographic variables. This section also includes descriptions of how data were processed to create variables prior to analyses.

Physical activity

The number of days children met PA guidelines served as the main outcome of this study and was assessed by asking participants "Last week, on which days were you physically active for a total of at least 60 min per day?." This was followed up by an explanatory sentence which stated, "Add up all the time you spent in any kind of physical activity that increased your heart rate and made you breathe hard some of the time." Examples of physical activities were also included to aid participants' understanding of the questions, including illustrations of activities such as basketball, soccer, running, fast dancing, swimming, tennis, and bicycling. Participants were then provided a list of each day of the week and were instructed to select all days in which they were physically active for at least 60 min that day. The number of days participants indicated they were physically active for at least 60 min per day was counted across all seven days of the week (range: 0–7) and served as the outcome variable for this study.

Contexts of PA

The Texas SPAN survey provides several questions related to PA context including sports participation, participation in other structured physical activities, mode of travel to school, and outdoor play. These variables were treated as the primary predictor variables for this study and are detailed below.

Sports participation

Participation in sports was assessed with one question which asked, "During the past 12 months, on how many sports teams did you play?," with explicit instructions to not count physical education class. Response options included "0 teams," "1 team," "2 teams," and "3 or more teams."

Other organized physical activities

Participation in other organized physical activities was assessed with one question which asked, "Do you currently take part in any other organized physical activities, lessons, or classes?," with response options of "Yes" and "No." Examples of structured physical activities were also listed along with this question and included activities such as martial arts, dance, and gymnastics.

Mode of travel to school

Participants mode of travel to school was assessed by asking participants, "On most days, how do you arrive at school," followed by several options including "walk," "bike," "school bus," "city bus," and "car." Prior to analyses, responses were recoded to a binary 'active travel' variable in which walking and biking were considered active travel (1) and all other options were considered non-active travel (0).

Outdoor play

The number of days participants engaged in outdoor play was assessed by asking, "Last week, on which days did you play outdoors for 30 min or more?." Participants were then provided with a list of each day of the week and were instructed to select all days on which they played outdoors. The number of days participants indicated they played outdoors was totaled across all seven days of the week and then recoded as a categorical variable with three levels: 1 = 0 days, 2 = 1–3 days, 3 = 4–7 days.

Weight status

Objective measures of height and weight were used to calculate body mass index (BMI) for each participant using SAS code provided by the Centers for Disease Control and Prevention (CDC) (34) and were further classified as obesity, overweight, and healthy weight, using the CDC growth charts and current recommendations (35). Prior to analyses, a binary variable was created by collapsing obesity and overweight into one category (overweight and obesity [OWOB]) and leaving healthy weight as a separate category. Methods for collecting height and weight data during the Texas SPAN survey administration have been reported elsewhere in detail (31). Briefly, height was recorded in centimeters with a stadiometer, and weight was recorded in kilograms using a calibrated top-loading scale. Height and weight measurements were taken after participants completed the written portion of the SPAN survey and were recorded directly on the questionnaire form.

Demographic variables

Sex

Participant sex was determined with a single question which asked. "Are you a boy or girl?," followed by the response options of "Boy" and "Girl."

Race/ethnicity

The race/ethnicity of participants was determined with a single question which asked, "How do you describe yourself?." Response options included "Black or African American," "Latino, Hispanic, or Mexican American," "White, Caucasian, or Anglo," "Asian," "American Indian or Alaska Native," and "Native Hawaiian or Other Pacific Islander." Prior to analyses, these responses were reduced to a three-category variable, which included "African American," "Hispanic," and "White/Other."

Urban–rural status

A three-level categorical variable for urban–rural status was determined by leveraging data from the TEA and applying it to school districts located within each of Texas's eight administrative PHRs. The two largest school districts in each PHR were designated as "Major Urban" districts. School districts from counties with populations above 50,000 were designated as "Urban" districts, and all other school districts not categorized as Major Urban or Urban were designated as "Rural."

Economic disadvantage

Data provided by the TEA were used to calculate the percentage of children whose family qualified for federal assistance programs by school. Economic disadvantage is categorized by the TEA to include qualifying for free or reduced meals under the National School Lunch and Child Nutrition Program (36, 37) and/or families with an annual income at or below the United States poverty threshold (38). Prior to analyses, a second binary variable was created by performing a median split on the percentage of children whose family qualified for federal assistance programs by school. This variable was coded as "Higher Economic Disadvantage" and "Lower Economic Disadvantage" and was used to categorize participants prior to conducting subgroup Poisson regression analyses. This variable served as the proxy for socioeconomic status.

Statistical analysis

The complex sampling plan of the Texas SPAN survey data, which is reported in detail elsewhere (39), was accounted for using STATA's 'svyset' prefix command, and missing data were not imputed. Weighted analyses used the Taylor series linearization variance estimation (40). Both the weighted and unweighted prevalence of all descriptive variables were calculated for the total sample and boys and girls separately. Descriptive statistics were compared between boys and girls using Chi-square tests for categorical variables and t-tests for continuous variables. McNemar's test was used to compare the proportion of days PA guidelines were met between weekdays and weekend days. Weighted Poisson regression models were employed to examine the associations between PA contexts (participation in organized sports, participation in any other organized PA, active travel to school, and outdoor play) and the number of days children met PA guidelines in the past week, adjusting for sex, race/ethnicity, OWOB, urban–rural status, and economic disadvantage. Weighted Poisson regression models were chosen to account for the weighted nature of the data and the fact that the primary outcome (number of days meeting PA guidelines) is a form of count data (41). Weighted Poisson regression models were employed for (1) the total sample, (2) for boys and girls separately, (3) for higher and lower economic disadvantage separately, and (4) boys × higher economic disadvantage, boys × lower economic disadvantage, girls × higher economic disadvantage, and girls × lower economic disadvantage separately. Separate models for boys, girls, and higher/lower socioeconomic disadvantage were chosen because sex and socioeconomic status have been shown to associate with PA in children (17, 24–26, 42). All analyses had significance established at an alpha level of $p < 0.05$ and were carried out using STATA v18.0 (StataCorp LP, College Station, Texas, United States).

Results

Demographic characteristics and weight status

Total sample

All characteristics for the total sample are shown in Table 1 as unweighted counts/means and weighted percentages. Briefly, the sample of fourth-grade children ($n = 2{,}897$, weighted $N = 355{,}314$) was 9.4 ± 0.6 years of age, 50.6% male, and 51.8% Hispanic. Most children

TABLE 1 Demographic characteristics and health-related behavioral variables presented as unweighted count/mean and weighted prevalence for the total sample (2019–2020 Texas SPAN).

Characteristics and behaviors	Total	
	n = 2,897	
	Weighted *n* = 355,314	
	Unweighted count/mean (SD)	Weighted percent
Age (years)	9.4 (0.6)	–
Race/ethnicity		
African American	457	12.2
Hispanic	1,535	51.8
White/other	905	36.2
Urban–rural status		
Major urban	934	22.4
Urban	925	68.4
Rural	1,038	9.2
Percent economically disadvantaged fourth graders (%)	70.5	–
Overweight/obesity status		
Healthy weight	1,518	54.0
Overweight/obesity	1,379	46.0
Days meeting PA guidelines		
0	344	11.2
1	337	11.7
2	277	9.6
3	367	13.8
4	443	14.3
5	407	14.4
6	216	8.3
7	467	16.7
Days meeting PA guidelines (mean)	3.6 (2.3)	
Number of sports teams participated in past 12 months		
0	1,071	35.2
1	769	28.5
2	495	17.9
3 or more	506	18.4
Participated in any other organized physical activity		
No	1,481	50.9
Yes	1,261	49.1
Commute mode to school		
Walk	130	5.2
Bike	29	1.3
School bus	661	19.8
City bus	10	0.3
Car	2000	73.6
Carpool	–	–
Days of outdoor play in the past 7 days (mean)	3.9 (2.4)	–

lived in either major urban (68.4%) or urban (22.4%) areas, and the average percentage of economic disadvantage by school was 70.5 ± 18.8%.

Boys and girls

Table 2 presents characteristics for boys and girls separately. While all participants were fourth graders, boys (9.5 ± 0.6 years) were slightly

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TABLE 2 Comparison of demographic characteristics and health-related behavioral variables presented as unweighted and weighted prevalence or mean and standard deviation between boys and girls (2019–2020 Texas SPAN).

Characteristics and behaviors	Boys		Girls		*p*-value	Higher economic disadvantage		Lower economic disadvantage		*p*-value
	n = 1,466		*n* = 1,431			*n* = 1,427		*n* = 1,470		
	Weighted *n* = 179,803		Weighted *n* = 175,511			Weighted *n* = 175,020		Weighted *n* = 180,294		
	Unweighted count or mean	Weighted percent	Unweighted count or mean	Weighted percent		Unweighted count or mean	Weighted percent	Unweighted count or mean	Weighted percent	
Age (years)	9.5 (0.6)	–	9.4 (0.5)	–	<0.001	9.5 (0.6)	–	9.4 (0.6)	–	0.10
Race/ethnicity					0.92					<0.001
African American	237	12.0	220	12.2		205	9.7	252	13.6	
Hispanic	738	51.3	797	52.2		992	76.2	543	36.5	
White/Other	491	36.7	414	35.6		230	14.2	675	49.9	
Urban–rural status					0.97					0.01
Major urban	480	22.4	454	22.4		568	41.3	366	10.6	
Urban	443	68.3	482	68.4		493	49.1	545	80.4	
Rural	543	9.3	495	9.1		366	9.6	559	9.0	
Percent economically disadvantaged fourth graders (%)	71.3 (18.5)	–	69.7 (19.2)	–	0.02	–	–	–	–	–
Overweight/Obesity Status					<0.001					<0.001
Healthy weight	707	49.5	811	58.8		683	47.6	835	58.0	
Overweight/obesity	759	50.5	620	41.2		744	52.4	635	42.0	
Days meeting PA guidelines					0.30					0.01
0	188	11.5	156	11.0		174	12.3	170	10.6	
1	188	13.4	149	9.8		200	16.4	137	8.7	
2	128	8.5	149	10.8		129	8.4	148	10.4	
3	165	13.1	202	14.5		166	10.9	201	15.5	
4	207	14.0	236	14.7		224	13.5	219	14.9	
5	197	14.2	210	14.6		211	16.5	196	13.1	
6	95	7.2	121	9.5		87	6.7	129	9.3	
7	271	18.1	196	15.2		213	15.5	254	17.4	

(Continued)

TABLE 2 (Continued)

Characteristics and behaviors	Boys		Girls		*p*-value	Higher economic disadvantage		Lower economic disadvantage		*p*-value
	n = 1,466		*n* = 1,431			*n* = 1,427		*n* = 1,470		
	Weighted *n* = 179,803		Weighted *n* = 175,511			Weighted *n* = 175,020		Weighted *n* = 180,294		
	Unweighted count or mean	Weighted percent	Unweighted count or mean	Weighted percent		Unweighted count or mean	Weighted percent	Unweighted count or mean	Weighted percent	
Days meeting PA guidelines (mean)	3.6 (2.4)		3.6 (2.2)		0.99	3.5 (2.3)		3.7 (2.3)		0.005
Number of sports teams participated in past 12 months					<0.001					0.02
0	455	29.9	616	40.8		569	41.5	502	31.3	
1	374	27.2	395	29.9		344	25.4	425	30.4	
2	274	19.2	221	16.5		233	16.0	262	19.1	
3 or more	324	23.7	182	12.8		248	17.0	258	19.2	
Participated in any other organized physical activity					0.25					0.07
No	799	53.6	682	48.1		738	55.0	743	48.4	
Yes	569	46.4	692	51.9		599	45.0	662	51.6	
Commute mode to school					<0.01					0.66
Walk	71	5.5	59	4.8		76	6.6	54	4.3	
Bike	22	2.1	7	0.4		15	1.3	14	1.2	
School bus	344	21.8	317	17.6		314	19.2	347	20.1	
City bus	7	0.3	3	0.2		4	0.2	6	0.3	
Car	983	70.3	1,017	77.0		975	72.6	1,025	74.2	
Carpool	–	–	–	–		–	–	–	–	
Days of outdoor play in the past 7 days (mean)	3.9 (2.5)		3.9 (2.3)		0.61	3.6 (2.4)		4.2 (2.4)		<0.001

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older than girls (9.4 ± 0.5 years). The average percentage of children attending schools with economic disadvantage differed between boys (71.3 ± 18.5%) and girls (69.7 ± 19.2%). Almost half (46.0%) of children were classified as having OWOB, which differed significantly between boys and girls such that 50.5% of boys and 41.2% of girls were classified as having OWOB.

Higher and lower economic disadvantage

Differences in characteristics between children attending schools with higher and lower economic disadvantage are shown in Table 2. Both the racial/ethnic distribution and the urban/rural distribution differed significantly between children attending schools with higher and lower economic disadvantage. Notably, 49.9% of children attending schools with lower economic disadvantage identified as White/Other, while 14.2% attending schools with higher economic disadvantage identified as White/Other. Also, 41.3% of children attending schools with higher economic disadvantage were from Major Urban areas while 10.6% attending schools with lower economic disadvantage were from Major Urban areas. Regarding health outcomes, 52.4% of children attending schools with higher economic disadvantage had OWOB while 42.0% attending schools with lower economic disadvantage had OWOB.

PA guidelines and PA context

Total sample

Daily PA guidelines were met every day of the week by 16.7% of fourth-grade children. A total of 11.2% did not meet PA guidelines on any day, while 72.1% met them between 1 and 6 days. For the total sample, the average number of days children met PA guidelines was 3.6 ± 2.3 days of the week. Figure 1 visually communicates the proportion of children meeting PA guidelines by day of the week. PA guidelines were met on 60.5% of weekdays and 55.9% of weekend days, which was a statistically significant difference. A total of 70.1% of children participated in at least one sports team in the past 12 months and 46.4% participated in other organized physical activities. Most children (70.7%) reported that a car was their typical commute mode to school, with 4.6 and 1.0% indicating they walked or rode a bike, respectively. On average, children played outdoors 3.9 ± 2.4 days of the week.

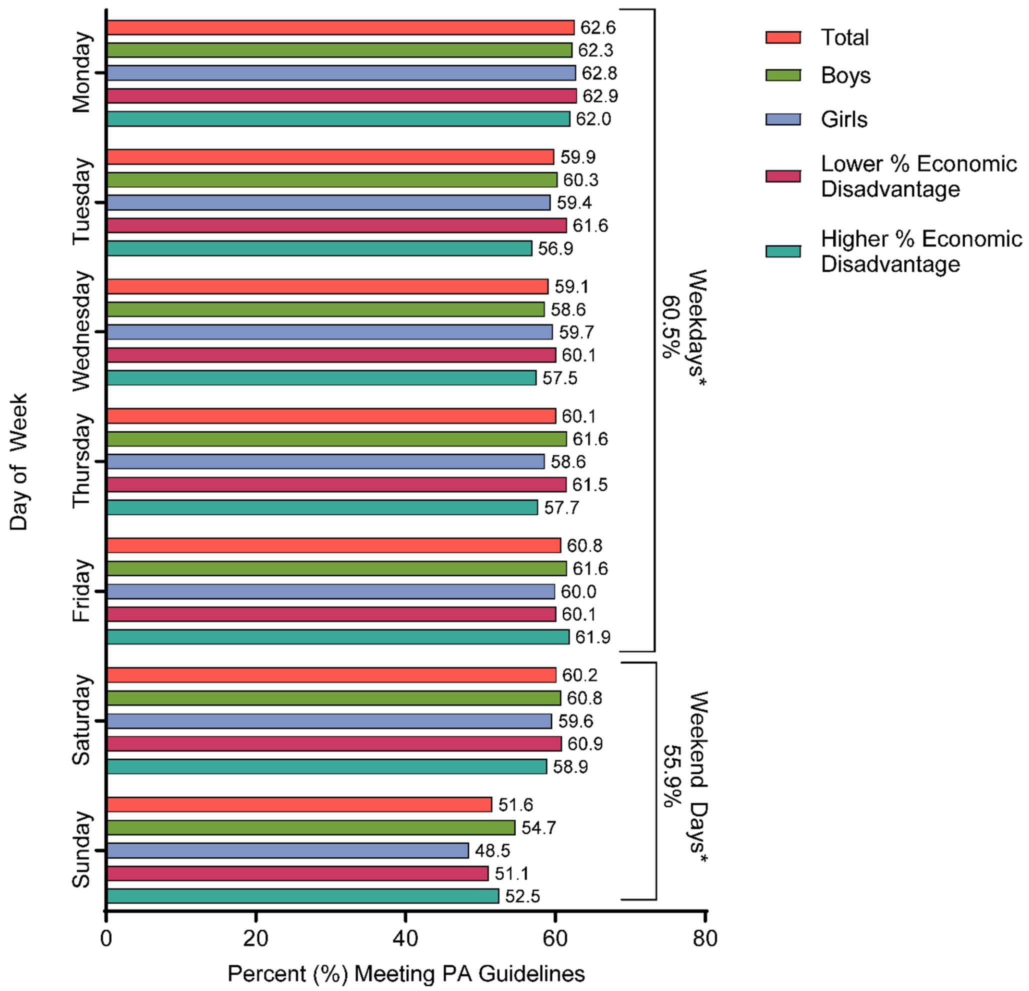

FIGURE 1
Comparison of the proportion of children meeting physical activity guidelines by weekday and weekend day. *Significant difference between the proportion of children meeting physical activity guidelines on weekdays and weekend days (McNemar's $X^2 = 194.6$, $p < 0.001$).

Boys and girls

Boys and girls differed significantly in the number of sports teams in which they participated in in the past 12 months. Compared with boys, a significantly higher percentage of girls reported participating in zero sports teams and a lower percentage of girls reported participating in three or more sports teams. The mode of travel to school also significantly differed between boys and girls. More girls reported taking a car to school compared with boys; more boys reported taking a school bus to school compared with girls; and more boys reported walking and biking to school compared with girls.

Higher and lower economic disadvantage

Children from schools with higher economic disadvantage met PA guidelines on fewer days compared with children from schools with lower economic disadvantage. Several PA context variables also differed significantly between children attending schools with higher and lower economic disadvantage. Compared with children from schools with lower economic disadvantage, children from schools with higher economic disadvantage participated in fewer sports teams and more children from schools with higher economic disadvantage reported participating in zero sports teams in the past 12 months. Children from schools with higher economic disadvantage also played outside on fewer days during the week compared with children from schools with lower economic disadvantage.

Associations between meeting daily PA guidelines and PA context

Total sample

The summary of Poisson regression analysis predicting the number of days children met daily PA guidelines for the total sample is displayed in Figure 2. Detailed estimates are shown in Supplementary Table S1. Compared to none, participating in any number of sports teams was positively associated with the number of days children met PA guidelines. Notably, a dose–response relationship was found in which participating in each additional sports team produced a stronger association with the number of days PA guidelines were met. Participation in other organized PA was also positively associated with the number of days children met PA guidelines. Playing outdoors 1–3 days and 4–7 days in the past week was positively associated with the number of days children met PA guidelines, and a dose–response relationship was found with this PA context as well. Active travel to school was not a significant predictor of meeting the PA guidelines.

Boys and girls

Analyses revealed some differences in both the strength and type of associations between meeting daily PA guidelines and PA context (Figure 3). Participation in sports teams was positively associated with the number of days both boys and girls met PA guidelines, but the strength of this association was higher for girls than boys. Participating in other organized PA also positively associated with the number of days boys and girls met PA guidelines. For boys, there was an apparent threshold effect, with only playing outdoors 4 or more days/week positively associated with PA guideline adherence, while for girls, playing outdoors any number of days was associated with PA guideline adherence, with a dose–response relationship noted.

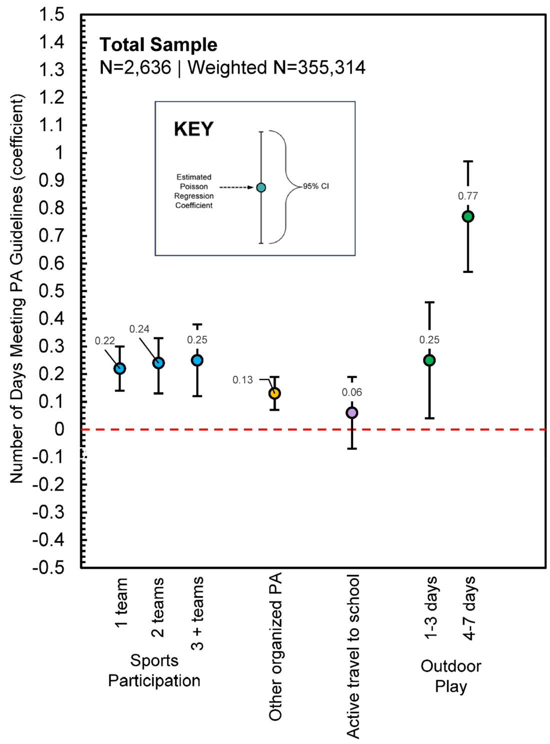

FIGURE 2
Poisson regression estimates for physical activity contexts predicting the number of days children met physical activity guidelines (Total Sample, *N* = 2,636, Weighted *N* = 355,314). Model adjusted for sex, race/ethnicity, urban/rural status, economic disadvantage, and overweight/obesity status; Supplementary Table S1 presents full model estimates.

Higher and lower economic disadvantage

Consistent with the total sample and boys/girls, participating in sports teams positively associated with the number of days PA guidelines were met in children from schools with both higher and lower economic disadvantage, although there was not a clear dose–response relationship (Figure 4). Participation in any other organized PA also positively associated with daily PA guideline adherence for both groups. For children from schools with lower economic disadvantage, playing outdoors any number of days positively associated with daily PA guideline adherence and a clear dose–response relationship was found. For children from schools with higher economic disadvantage, only playing outdoors 4–7 days of the week was associated with PA guideline adherence.

Boys/girls and higher/lower economic disadvantage

Some subgroup variability in estimates was evident among the analyses stratified by sex (boys/girls) and higher/lower economic disadvantage (Figure 5). Participating in sports teams positively associated with the number of days PA guidelines were met for each group, but the significant association only held constant for each additional sports team for girls from schools with higher economic disadvantage. The dose–response relationship was most notable for this group as well. Conversely, girls from schools with higher economic disadvantage were the only group in which participation in

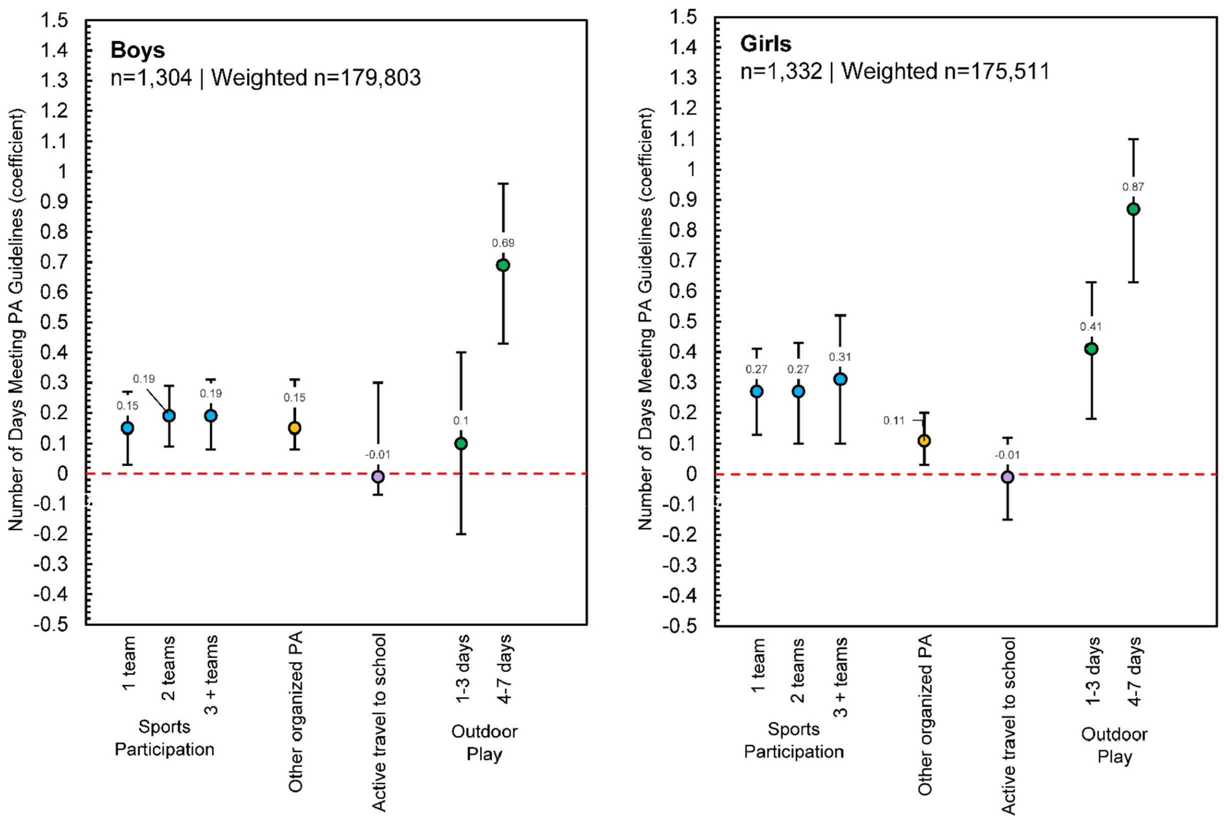

FIGURE 3
Poisson regression estimates for physical activity contexts predicting the number of days children met physical activity guidelines, reported separately for boys (n = 1,304, Weighted n = 179,803) and girls (n = 1,332, Weighted n = 175,511). *Note:* Each model adjusted for race/ethnicity, urban/rural status, economic disadvantage, and overweight/obesity status; Supplementary Table S1 presents full model estimates.

any other organized PA was not a significant predictor of daily PA guideline adherence. Finally, while the dose–response relationship for days of outdoor play was consistent across girls from schools with both high and low economic disadvantage, only 4–7 days of outdoor play was a significant predictor of daily PA guideline adherence for boys from schools with both high and low economic disadvantage.

Discussion

This study was a cross-sectional examination of daily PA guideline adherence in relation to several PA contexts using data from the 2019–2020 Texas SPAN survey. We sought to examine associations between PA contexts (sports participation and other out-of-school structured physical activities, active travel to school, and outdoor play), and the number of days fourth-grade children met PA guidelines in a representative sample of children living in Texas. We were also interested in comparing PA guideline adherence and PA context between boys/girls and between participants from schools with higher/lower levels of economic disadvantage. Overall, we found a significant dose–response relationship between sports participation and the number of days fourth-grade children met PA guidelines. We also found a similar dose–response relationship between the number of days children played outside and the number of days children met PA guidelines. Participating in other organized PA was also positively associated with the number of days children met PA guidelines but active travel to school was not. Several differences between boys/girls and children from schools with higher/lower levels of economic disadvantage were noted, but playing outdoors was a consistent predictor of PA guideline adherence across all model comparisons in this age group. Results shed light on how different PA contexts may associate with PA guideline adherence and identify potential salient intervention components for those designing and conducting PA-based health behavior interventions for children. Comparisons between boys/girls and children from lower/higher economic disadvantage also emphasize the need for more equitable PA promotion strategies focused on girls and on children attending schools with higher economic disadvantage.

The average number of days per week fourth-grade children living in Texas met PA guidelines (3.6 ± 2.3 days) is difficult to compare with much of the previously published literature, as most studies simply report the proportion of children meeting PA guidelines. A previous study using accelerometer-derived data reported the proportion of days fourth-grade children met PA guidelines was 47.5% (43), which is similar to our study ([3.6/7]*100% = 51.4%). Comparing the proportion of children meeting PA guidelines proves difficult, as many studies derive this proportion by averaging PA across all measured days, which does not consider the "daily" aspect of the guideline language (5–8). For our study, we accounted for each individual day of the week and found about 15% of children met daily PA guidelines, meaning 15% of children met the PA guideline every single day of the week. Other studies from the US have reported 23% (44), 71% (45),

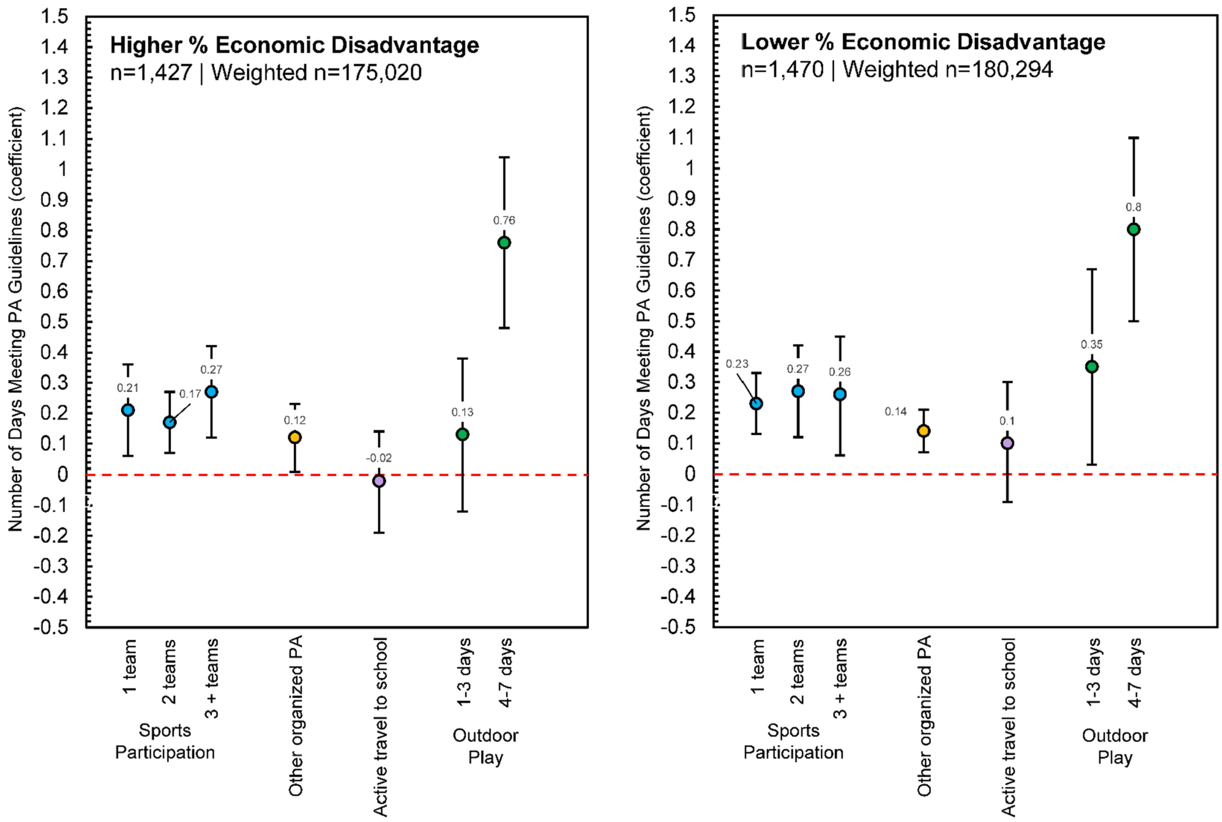

FIGURE 4
Poisson regression estimates for physical activity contexts predicting the number of days children met physical activity guidelines, reported separately for higher percent economic disadvantage (*n* = 1,427, Weighted *n* = 175,020) and lower percent economic disadvantage (*n* = 1,470, Weighted *n* = 180,294). Each model adjusted for sex, race/ethnicity, urban/rural status, and overweight/obesity status; Supplementary Table S1 presents full model estimates.

and even 91.5% (46) of youth meet PA guidelines, but again these estimates are difficult to compare due to differences in data handling strategies (47). For studies outside of the US that have operationalized the "daily" aspect of PA guideline adherence, estimates are comparable (42).

We also found children from schools with higher economic disadvantage met PA guidelines on fewer days than children from schools with lower economic disadvantage and this finding aligns with previously published literature involving samples from both inside and outside of the US that has explored various proxies for socioeconomic status and PA (24, 25, 48–50). There is no single reason for this disparity, but some include both financial and environmental accessibility to facilities and organized sports/activities that promote PA, neighborhood safety which may limit the ability to play outside or walk/bike to school, and the moderating effect of weight status, which has shown to favor children with higher socioeconomic status (26). In Texas, the percentage of children who experience socioeconomic disadvantage is higher than many other states, with 38% of families falling 400% below the federal poverty level, 19.6% of children experiencing poverty, and the median household income being $3,000 less than national average (51). This is also evidenced by the relatively high median of children from schools with higher economic disadvantage in our sample.

The results of our study also indicate children from schools with higher economic disadvantage participate in fewer sports teams. In terms of PA context, sports participation may be the most cost prohibitive. In fact, the average cost of participating in a single sport has been estimated to be $883 for children in the United States, with some families spending upward of $4,000 annually (19), making it an opportunity not afforded by every child. When making comparisons between boys and girls, we found girls participated in fewer sports teams as well. This is concerning as sports can have a profound impact on not only PA (16), and more specifically, MVPA (15), but children may also experience other benefits from sports participation including improved mental health (52), decreased risk of cardiovascular disease (53) and overweight/obesity (54), and higher academic achievement (55).

Regarding some of the other PA contexts we explored, our results indicate children from schools with higher economic disadvantage played outside on fewer days than children from schools with lower economic disadvantage. While playing outdoors is arguably less expensive than participating in sports, there still may be costs associated with playing outdoors, albeit in a more indirect manner (21–23, 56). Still, children living in neighborhoods with higher socioeconomic disadvantage have been shown to have better accessibility to opportunities for outdoor play, although this is variable by country and region (18, 57). However, neighborhoods with higher socioeconomic disadvantage tend to be less safe (18), limiting the chances that children will utilize these opportunities. Children from families with lower socioeconomic status also tend to face more restrictions on outdoor play

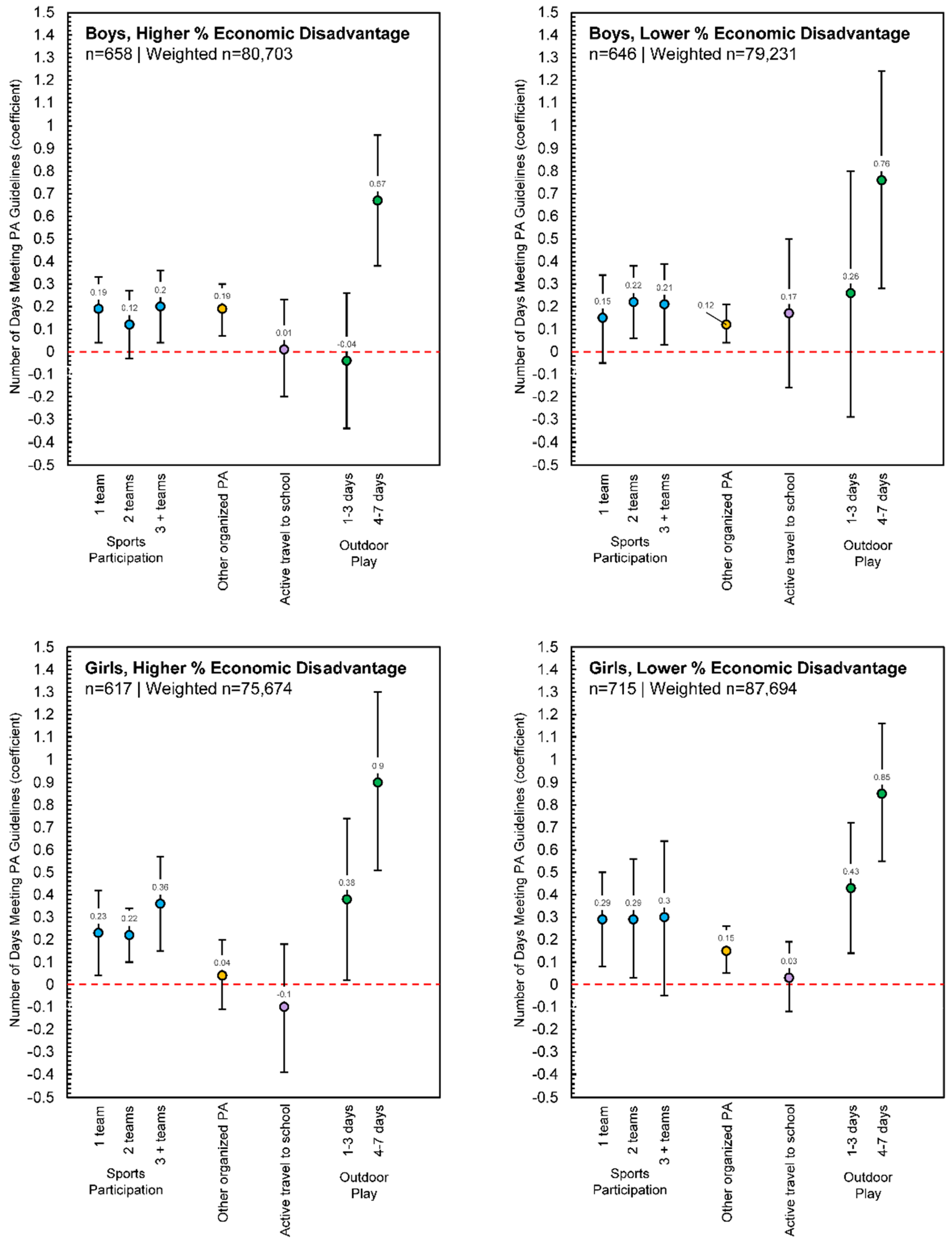

FIGURE 5
Poisson regression estimates for physical activity contexts predicting the number of days children met physical activity guidelines, reported separately for boys, higher percent economic disadvantage (n = 658, Weighted n = 80,703), boys, lower percent economic disadvantage (n = 646, Weighted n = 79,231), girls, higher percent economic disadvantage (n = 617, Weighted n = 75,674), and girls, lower percent economic disadvantage (n = 715, Weighted n = 87,694). Each model adjusted for race/ethnicity, urban/rural status, and overweight/obesity status; Supplementary Table S2 presents full model estimates.

than those from households with higher economic status, with evidence suggesting safety is a significant concern (58). Outdoor play can also occur around home environments but it has been found that families with lower socioeconomic status provide more opportunities for sedentary behavior and fewer opportunities to be physically active (58), which may also be driving these disparities.

While we did not find differences in commute mode to school when comparing children from schools with higher and lower economic disadvantage as others have (59, 60), we did find differences in commute mode to school between boys and girls, such that more boys indicated walking, biking, and taking a school bus. Perceived safety and the level of independent mobility given to boys and girls may contribute to this finding (61–66), although we did not assess these variables in this study. Programs, policies, and/or interventions that aim to promote active commuting to school should consider these sex-based differences and offer tailored strategies to alleviate parental concerns. In general, we found that a very small percentage of fourth-grade children in Texas reported walking and biking to school (6.5% overall), and this small percentage of active commuting is reflected in other state-level and national estimates (60, 67–69). This is a concerning statistic, especially since as children get older this percentage tends to decline past sixth grade (70). Regardless of sex or socioeconomic status, more effort should be put into promoting active travel among children by addressing concerns around safety, improving built environment infrastructure supporting walking and biking, and increasing promotion efforts.

In terms of the strength of associations between the number of days children met PA guidelines and different PA contexts, several important findings were noted. First, for the total sample, for girls, and for girls from schools with higher economic disadvantage, there was a clear dose–response relationship between the number of sports teams in which they participated and the number of days PA guidelines were met. This dose–response relationship was observed for other groups as well, but not in as consistent of a manner. Sports have long been an important intervention component for youth PA promotion, and there are several examples of these types of interventions in the literature (71). Findings from our study create an impetus for more sports-based interventions specifically designed for girls and for girls from schools with higher economic disadvantage as we found (1) girls and children from schools with higher economic disadvantage participated in fewer sports than boys and children from schools with lower economic disadvantage and (2) the association between sports participation and the number of days PA guidelines were met was stronger for girls and girls from schools with higher economic disadvantage than boys and children from lower economic disadvantage. There are few examples of sports-based interventions specifically for girls (72–74), but there have been several observational studies on various aspects of girls' sports participation (27, 75–80). More work should be put into these efforts and in attempting to scale programs up to increase reach to girls and children from schools with higher economic disadvantage.

Another important finding was the strength of the association between the number of days PA guidelines were met and outdoor play. Not only was there a clear dose–response relationship for many of the groups, but the strength of the association for 4–7 days of outdoor play was markedly higher than all other PA contexts. In many models, the strength of the association was 2–3 times higher than participating in three or more sports teams throughout the year. Recent work, sometimes categorized as and/or having overlap with "risky play" (81, 82), "unstructured play" (83), "nature play" (84), and/or "free play" (85), highlights the uniqueness of this PA context and offers an exciting avenue for youth PA promotion (20). Lee et al. (83) conducted a review of the correlates of outdoor play among children and found that individual, parental, home, and social environments influence the time spent playing outdoors. Based on this review, factors such as independent mobility, overweight status, parents' attitudes, concerns, and behavior, peer influence, housing type, and, supporting our findings, proxies for socioeconomic status, all play a role in influencing the amount of time children spend playing outdoors. Intervention efforts have yielded promising results for the efficacy of outdoor play increasing PA among children as well (86). It is worth noting many outdoor play studies and interventions have been conducted with younger children (preschool and Kindergarten), while not as much attention has been given to older children and adolescents. As this area of research grows, researchers should consider expanding investigations to older children and should also explore how outdoor play may track into adolescence and even adulthood, as parenting practices have been shown to influence outdoor play in children as well (23).

Finally, we found other organized PA positively associated with the number of days PA guidelines were met across most groups, except for boys from schools with lower economic disadvantage and girls from schools with higher economic disadvantage. While the survey question we used did not ask about specifics, the fact that any other organized PA positively associated with PA guideline adherence provides further support for the structured days hypothesis (SDH) (87), which posits obesity-related behaviors in children may be beneficially regulated by formal structure, in this case, organized PA outside of the school context. As with sports, participation in other organized PA can come with a financial burden, although we did not find significant differences in other organized PA participation between children from schools with higher and lower economic disadvantage. Using a more immediate proxy for children's socioeconomic status may have revealed significant differences, as previous literature has shown (88, 89), but we cannot be certain that is the case in our sample. Still, other organized PA may be a viable PA promotion alternative to sports, especially for children who are not interested in traditional sports, if economic barriers are addressed. Indeed, almost half of the fourth-grade children from our sample indicated participating in other organized PA throughout the year, and this estimate was not much different for children from schools with higher economic disadvantage. We also found that PA guidelines were met more frequently on weekdays compared with weekend days, which lends further support to the SDH, as weekend days tend to be less structured (87). Much like the summer months, PA intervention efforts should focus on providing opportunities for children on weekend days, which lack the formal structure school days provide during the week.

Strengths and limitations

The Texas SPAN survey provides a unique opportunity to leverage data that are representative of the entire state of Texas, which happens to be the second most populous state in the US (90) and is home to 7.5 million children, accounting for 10% of all children in the US (30). Participants in the Texas SPAN survey reflect the racial/ethnic and economic diversity of the state as well. Because of the questions asked in the SPAN survey, we were also able to conduct one of the first studies exploring how several different PA contexts associate with PA guideline adherence in a representative sample of fourth-grade children. As previously highlighted, this approach allows us to compare PA behaviors across contexts within the same sample of participants in a naturalistic setting, as past PA interventions have typically not compared how PA contexts may differentially impact PA outcomes across several domains (sports, outdoor play, structured activities, etc.) Results may be valuable to those wishing to conduct further research utilizing device-based measures of PA and for researchers hoping to design effective PA-based interventions for children of a similar age. However, results should also be interpreted with study limitations in mind. A clear limitation is the self-reported and cross-sectional nature of our study design, which limits us to only interpreting associations between PA context and PA guideline adherence and barring us from making any causal interpretations with the data. Another limitation is our inability to account for several school-based PA contexts, including recess and physical education. Survey questions regarding structured PA did make it clear not to include physical education classes in participant responses, but having information on recess and physical education would enrich the analyses. Finally, temporal differences in how certain questions were worded in the survey should be acknowledged. For example, children were asked to indicate how many sports teams they were on "in the past 12 months," how they traveled to school "on most days," and how many days they played outside "in the past week." These differences in temporality may have influenced the way in which questions were interpreted, answers were provided, and subsequent interpretations of the associations between these contexts and the number of days PA guidelines were met. For example, the self-reported "dose" of physical activity for questions that had participants report the frequency of participating in a structured activity "in the past week" could have potentially been higher than questions that had participants report the frequency of participating in a structured activity "in the past 12 months" and/or "on most days," which could result in stronger or weaker associations between certain types of structured activities and meeting PA guidelines.

Conclusion

Participating in organized sports and other structured physical activities, in addition to playing outdoors, may beneficially influence the number of days fourth-grade children meet PA guidelines, although there are sex- and economic-based disparities present. Programs that aim to enhance PA in children should consider these contextual factors in light of these disparities and further investigate how to promote sports, organized activities, and outdoor play effectively and appropriately among children, especially for girls and for children from schools with higher economic disadvantage. With results being generalizable to only fourth-grade children in Texas, USA, future work should be continued in other countries and cultures to investigate how certain contexts might differentially influence PA guideline adherence. Because participation in certain PA contexts may decline as children get older [e.g., walking/biking to school (70) and types of outdoor play (91)], more research and health promotion work should be conducted with adolescent participants to see if the relationships found in our study are maintained as age increases. Future studies should also employ more rigorous observational investigations with device-based measures of PA and should collect day-level contextual information about PA opportunities and their utilization. Future studies should also explore how PA contexts influence PA across the lifespan and how the context of PA might change as children get older. Our study highlights there is not a "one size fits all" approach to PA promotion for children. Sex- and economic-based differences in participation in different PA contexts and differences in the strength of associations between PA context and PA guideline adherence underscore what may be viable for some children may not be for other children, and interventions and programs hoping to promote PA in children should respond appropriately.

Data availability statement

The full datasets presented in this article are not readily available because public access was not specified in the consent forms. Reasonable requests to access the datasets should be directed to Deanna.M.Hoelscher@uth.tmc.edu. Limited datasets can be accessed at https://span-interactive.sph.uth.edu/.

Ethics statement

The studies involving humans were approved by the Committee for the Protection of Human Subjects at the University of Texas Health Science Center at Houston (UTHealth Houston) (HSC-SPH-18-0432), the Texas Department of State Health Services Institutional Review Board, and local school district review committees. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

CP: Conceptualization, Formal analysis, Investigation, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing. DB: Conceptualization, Investigation, Methodology, Writing – original draft, Writing – review & editing. NR: Conceptualization, Data curation, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. AS: Conceptualization, Writing – original draft, Writing – review & editing. RM: Data curation, Formal analysis, Methodology, Project administration, Resources, Writing – original draft, Writing – review & editing. DS: Conceptualization, Methodology, Writing – original draft, Writing – review & editing. DH: Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2024.1352644/full#supplementary-material

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