Chapter

Physical Activity, Fitness, and Cognitive Function in Children and Adolescents

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Abstract

From the playground to youth sports, the benefits of physical activity for children and adolescents are primarily known. Less understood is how participation influences cognitive function at different stages of development. This chapter aims to summarize the literature on child and adolescent physical activity, fitness, and cognitive performance by translating empirical research to school and community settings. The specific effects of physical activity vary by intensity, mode, volume, and domain. This review suggested that physical activity and fitness were positively associated with higher cognitive function. Children who are aerobically fit and regularly physically activite are faster, more accurate responders and tend to do better in school. Participation in light to vigorous intensity physical activity cognitively benefits children. Additional benefits come from cognitively demanding (e.g., team sports) and vigorously intense (e.g., jumping rope) activities. Because benefit varies by physical fitness component and physical activity type, it is recommended that preschool children participate in an assortment of movements for 3 h a day, working up to 60 min of moderate-to-vigorous physical activity by age 6. Comprehensive approaches across multiple settings, offering opportunities to participate in physical activity, have the most significant potential for enhancing cognitive health among children and adolescents.

Keywords: development, cognitive performance, executive function, maturation, physical fitness, academic achievement

1. Introduction

Across the lifespan, childhood is the time when the rate of physical activity participation is highest. From a child running on the playground to a teen on the basketball court in the high school playoffs—human movement has many benefits, including disease prevention and improved physical, emotional, mental, and cognitive health [1–3]. Because physical activity is a health-protective factor, participation is essential. Human movement profoundly impacts cognitive development, beginning with the maternal physical activity during pregnancy in the first 1000 days of life and evolving to habitual participation in physical activity as an emerging adult. Behaviors of speaking, smiling (a facial expression of emotion), kicking, and transitioning from one place to another require sensorimotor integration; however, we often dismiss these learned behaviors as reflexive and unassociated with physical activity across the lifespan. Early life physical activity experiences like this shape a child's cognitive developmental trajectory and provide opportunities for sustained participation in later life. The purpose of this chapter is to summarize the literature on child and adolescent physical activity, fitness, and cognitive performance by translating rigorous empirical research to school and community settings.

2. Physical activity behavior and recommendations for youth

How physical activity is defined has evolved. The initial definition differentiated between the term exercise from physical activity. As goal-oriented energy expenditure, exercise was associated with targeted training to increase physical fitness and workouts organized within a given competitive activity or sport (e.g., personal best in running the mile, playing a competitive game of tennis). *Physical activity* was broadly defined as "any bodily movement produced by skeletal muscles that result in energy expenditure". This seminal position paper by Caspersen et al. [4] framed how we classify forms of human movement. Sports, occupations with physical demands, and household tasks are considered physical activities. Today we still think of physical activity as behavior and fitness as a state of being, but its application is more nuanced and contextually grounded, reflecting physiological, metabolic, and psychological specific demands of participation within a given context and activity.

Regardless of the stage of development, human movement is classified using a continuum from sedentary to high levels of physical activity. The first physical activity continuum (**Figure 1**) [5] was based on data published in the 1996 Surgeon's General's Report [6] and intended to outline motivational behavior management strategies to increase adult participation. It is worth noting that the report did not contain specific recommendations for children's physical activity but did highlight behavior research studies like Child and Adolescent Trial for Cardiovascular Health (CATCH) and Sports, Play, and Active Recreation for Kids (SPARK) that transpired in schools to encourage that educational policy focus on offering physical activity and physical education within schools. Across the highlighted studies, physical activity

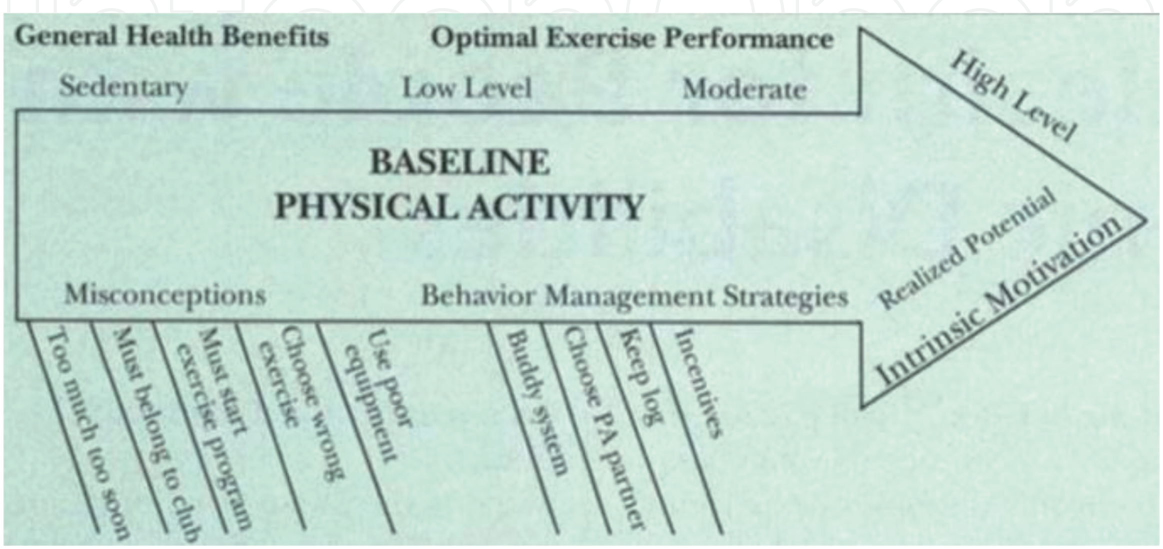

Figure 1.
Physical activity continuum [5].

programs as treatment increased participation and health markers, but there was little evidence that the effects were sustained during follow-up studies.

A 2021 report shows that adults in the United States (US) are more physically active than they were 20 years ago [7], but adults and adolescents continue to be insufficiently active, given the high prevalence of sedentary behaviors [8]. To promote physical activity in early life, the 2018 Physical Activity Guidelines for Americans targeted two distinct population groups of preschool (ages 3–5 years) and children and adolescents (ages 6–17). The US guidelines recommend that children under the age of 6 be physically active throughout the day. In contrast, the Canadian Physical Activity Guidelines have specified recommendations from birth to 5, with 3–4 year olds accumulating 180 minutes of physical activity at any intensity throughout the day [9]. Physical activity should engage a variety of movement skills in different environments. Life experiencing movement should progress toward a daily accumulation of 1 h of moderate to vigorous physical activity (MVPA) by age 5, which should be sustained throughout childhood.

A contemporary version of the physical activity continuum (**Figure 2**) [10] identifies multiple movement forms across a 24-h day. The visual representation suggests that participation in physical activity, as both daily living and planned behaviors, may mitigate health risk, especially when long periods of sedentary behaviors are disrupted. Although predominantly driven by data on chronic disease in later life, the physical activity continuum is applicable across the lifespan. Physical activity should be part of every child's day, from tummy time in infants to riding balance bikes in preschool. Among children ages 0–4, the Canadian Physical Activity Guidelines endorse more time moving and sleeping with less time sitting [11]. For school-aged children, the emphasis is placed on sweating (MVPA), stepping (light physical activity), uninterrupted sleep, and less time sitting [12]. The only similar designation in the US is the National Academies of Science, Engineering, and Medicine (NASEM) Consensus Report focused on US physical activity surveillance [13], with two of the four areas focusing on children and community support for physical activity. The report provides evidence-based strategies that will be presented later in the chapter.

2.1 Physical activity: why is promotion important?

Evidence demonstrating the health benefits of physical activity has grown substantially over the last 20 years [14]. Children globally and specifically benefit from

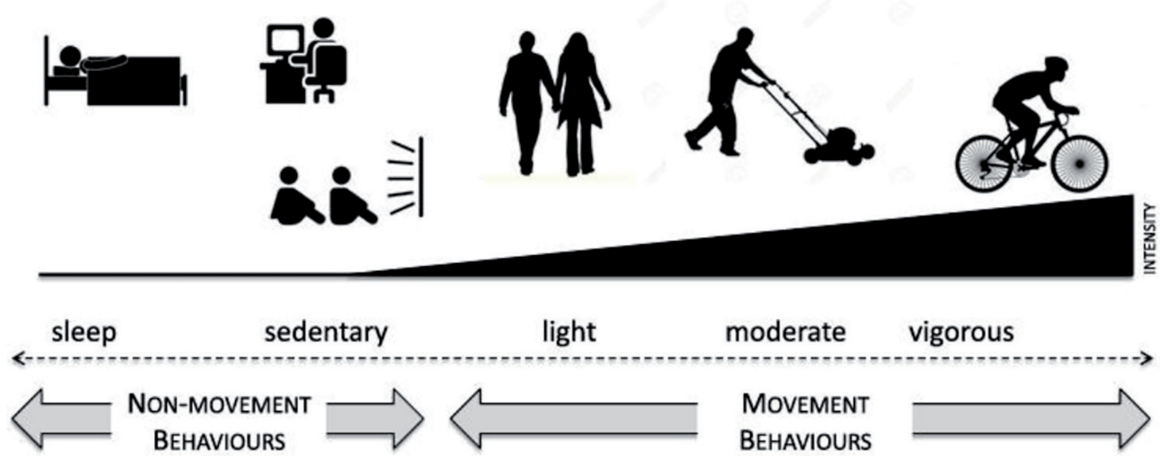

Figure 2.
Range of movement and nonmovement behaviours over a 24 h day.

physical activity, as regular participation decreases the risk of cardiovascular disease, especially when physical activity participation leads to increases in cardiorespiratory fitness [15]. Habitual participation in MVPA increases aerobic fitness and bone mass during childhood and reduces obesity, hypertension, and diabetes.

Independent of physical activity, sedentary behaviors continue to rise. Since the turn of the century, lifestyle has dramatically changed with technology manifesting sedentary behaviors because there is no longer a need for physical exertion in our contemporary lives. We most often think of this as accurate for adults, but the idea is also applicable to the lives of children. On average, children spend 41–51% of their time after school engaged in sedentary behaviors [16], with National Health and Nutrition Examination Survey (NHANES) accelerometer-assessed data demonstrating that sedentary behaviors ranged from 5.5 h/day among 6–11 year olds to 8.5 h among 6–19 year olds [17].

2.2 Racial and ethnic differences in rates of participation in physical activity and sedentary behaviors

It is recommended that school-aged children participate in 60 or more minutes of MVPA each day. Despite these recommendations, only 42% of children aged 6–11 years and 8% of adolescents meet this standard [18]. The Behavioral Risk Factor Surveillance System (BRFSS), a Centers for Disease Control and Prevention sponsored phone survey, collected data from 49 states by asking people how physically active they have been in the last month (https://www.cdc.gov/physicalactivity/data/inactivity-prevalence-maps/index.html). Data from 2017 to 2020 identified an overall prevalence of physical inactivity of 25.3%. Among Hispanic and non-Hispanic youth, 31.7% and 23.4% reported no physical activity participation in the last month. The prevalence of sedentary behavior such as prolonged sitting is on the rise.

The amount of time spent engaging in physical activity decreases continuously from childhood to older adults, and both physical activity and obesity during childhood track into adulthood [19]. In view of the numerous health benefits of physical activity, sedentary behaviors in America have become a public health concern and need to be addressed in research and practice.

3. Physical fitness among children and adolescents

Physical fitness is different from physical activity because it is not a behavior but is considered a state of being. Fitness is made up of 11 different elements and can be thought of as both health and skill-related, representing the capacity of body systems to work together to effectively perform the activities of daily living [20, 21]. Cardiorespiratory, muscular endurance, body composition, flexibility, power, and strength are health-promoting and are therefore called components of health-related fitness. Agility, balance, coordination, reaction time, and speed, are associated with better motor and sport performance and are therefore called skill-related fitness. There is a reciprocal interaction between physical activity, physical fitness, and health. If someone is regularly physically active, they will improve fitness and reduce their risk for disease, thus improving health. Likewise, if someone is physically fit, they are more likely to be physically active and healthy. Once thought of as the absence of disease, we now think of a child's well-being as the interaction between physical, mental, social-emotional, and cognitive health.

3.1 Physical fitness and development

Physical fitness is easily achieved and maintained in early life as functional movement throughout daily living, and natural growth and maturation will increase physical fitness, especially cardiorespiratory and muscular fitness. During pubescent and adolescent stages of development, there will be a slowing down of the natural benefits from any movement. More intense and specified types of physical activity are needed to improve fitness. Adolescents will need to add resistance to their physical activity, like lifting weights, to maximize their potential for strength and power. Greater attention needs to be given to the type of physical activity than the amount of weight being added. Resistance or weight training should improve both upper and lower body muscular fitness, and the program should encourage muscular balance and monitor fitness by component through standardized measurement in 3rd through 12th grade where there are established standardized cutpoints [22].

Physical fitness is a crucial state of being that should be sustained across the lifespan. Unfortunately, policymakers sometimes narrowly consider fitness from a competitive sport perspective only, particularly when deciding about physical education and physical activity opportunities in and around schools. Types of fitness that impact cognitive health and function should be integrated into all settings in which children spend significant amounts of time (e.g., home, school, child care, recreational and community programs) given its causal relationship with multiple types of health.

3.2 Effects of physical fitness and cognitive health

The examination of the effects of physical fitness on children's cognitive health ranges from big data analysis and cross-sectional studies in specified contexts to randomized controlled trials. The cognitive outcome variables of interest are commonly related to executive function, a set of higher-order cognitive processes that leads to goal-directed behaviors [23]. There are three primary mental processes: (a) cognitive flexibility, (b) inhibitory control, and (c) working memory. Since humans are not multi-taskers, cognitive flexibility is essential because it shifts one's attention from one thing to another, while inhibitory control blocks or resists the temptation to attend to irrelevant information sources (e.g., a ventilation system humming in the distant background). Working memory is the active process of retaining information.

Cross-sectional data evidencing a positive association between physical fitness and academic achievement are plentiful [24–26]. Research revealed more consistent effects with girls over boys [27] and significant effects in math and language arts versus other academic subject matters [28]. A year long study of Estonian children with a beginning average age of 6.6 years revealed that objectively measured physical activity predicted cardiorespiratory fitness, related to higher perceptual skills [29]. Another cross-sectional study called Cogni-Action Project assessed cardiorespiratory and muscular fitness and a range of executive functions in 1171 Chilean schoolchildren aged 10–14 in fifth to eighth grade. Positive associations were found between both types of fitness and five of the seven cognitive tests. Notably, speed and agility were not significantly related to cognitive function. The favorable association suggests that we should continue to encourage 60 min of MVPA per day, given the physical and cognitive benefits, with further examination of the effects of sleep, nutrition, and duration of sedentary behaviors as potential contributing factors.

The most robust data emerged from clinical trials with children. Randomized controlled trials named FITKids1 and FITKids2 ran for more than 10 years and produced a large body of empirical evidence surrounding habitual physical activity and aerobic fitness effects on several cognitive outcomes ranging from academic achievement to neural activation [25, 30, 31]. The trials focused on providing a physical activity-focused afterschool program for third and fourth grade students, who were randomly assigned to the program or a wait-list. Among the findings from the series of studies was that physical fitness can be significantly increased through an afterschool program [32]. Further, this series of studies suggested that aerobic fitness enhances brain function and changes brain structure [31, 33–35].

A 6-week study of 10–12 year olds randomized into team games, aerobic exercise, and control conditions suggests that both physical activity conditions improved aerobic fitness, but only the team games condition was positively related to inhibitory control and cognitive flexibility [36]. The researchers concluded that team games were superior to aerobic physical activity and recommended that children participate in the cognitively demanding sport over aerobic activities like running. The length of the fitness intervention, the type of cognitive function assessments, and an inability to control physical activity intensity for all players in a team sport suggest that we cautiously interpret these results. Moreover, a ceiling effect may influence the relationship between physical fitness and academic achievement [37]. Another caution is that trials involving adolescents may suffer from a lack of treatment fidelity (e.g., participating at a lower intensity required for the research) [38].

4. Effects of physical activity on cognitive health

As presented, there is compelling evidence supporting the protective role of physical activity against obesity and other chronic diseases. When safe, all types of physical activities have potential benefits for mental, physical, cognitive, and brain health for children and adolescents and, when there is continued adherence, can offer both short- and long-term positive cognitive outcomes [1]. Specifically, there is robust evidence of a causal association between regular physical activity and cognitive function in children [39]. The greatest substantiation has been produced among school-aged, preadolescent children.

4.1 Chronic or habitual physical activity participation effects on cognitive health

The reciprocal relationship between physical activity, fitness, and academic achievement has received much attention because of the increasing prevalence of overweight and unfit children and the inescapable pressure on schools to produce students who meet academic standards [24]. A seminal study examined 259 public school students in third and fifth grades and found that physical activity during physical education class, measured as field physical fitness tests, was positively related to academic achievement [25]. Specifically, aerobic capacity was positively associated with achievement, whereas body mass index (BMI) was negatively related. Associations were demonstrated in total academic, mathematics, and reading. Findings from this cross-sectional study led to the development of school-based physical activity programs and the more refined examination of the effects on children's cognitive function and academic achievement.

Among the findings from the FITKids program regarding executive function was that participants produced significantly faster and more accurate responders than children in the control group [40]. The treatment group had better neural conflict management as information processing [41] as well as enhanced relational memory [42]. The children who participated in the physical activity-oriented afterschool program for the 9-months used more complex mental processing strategies to move information from working memory to long-term memory, while children who went home after school regressed from their baseline performance-related processing speed and working memory capacity.

Beyond the neurobiological and cognitive influences of physical activity, there has also been a focus on better understanding the characteristics of physical activity interventions [43] and investigating the effects of the cognitive demands of the activity. Evidence that complex motor movements requiring higher cognitive demands produce higher cognitive benefits than rote physical activity is currently being gathered [44]. A meta-analytic review evaluating the cognitive function effects of physical activity interventions for children ages 3–7 years determined that in addition to MVPA, the programs offered activities that required combinations of motor skills (e.g., dribble and pass a ball) likely produce more significant cognitive gains [45]. The positive, moderate gains in executive functions suggest that children should engage in physical activity with varying motor demands.

A 2-year exploratory, non-controlled study of one hundred and sixteen 8–9 year old children that examined hot- (emotion associated actions) and cold-related (emotionless actions) executive functions suggested that there may be dispositional and emotional health benefits (self-control) from participation in physical education. The cognitive engagement required to execute combinations of complex motor movements likely produces even more significant cognitive benefits; however, further study is warranted, as the existing evidence is correlational. It is unclear whether an underlying mechanism like neurotrophic factors such as brain-derived neurotrophic factor (BDNF) and cerebral blood flow increases during complex tasks and enhances cognitive function. BDNF is a growth factor that promotes cell repair and activity-dependent plasticity, facilitating behavior adaptations due to environmental changes [46].

In sum, there is proof of causality and positive associations among chronic physical activity, fitness, cognitive function, and academic achievement. However, the findings vary in strength, and the effects of numerous elements of physical activity on cognition need to be explored, such as how much, how often, how hard, and when to offer physical activity.

4.2 Acute or immediate effects of participation in a single session of physical activity

Although high doses of chronic physical activity are associated with superior life expectancy, primarily when habits were formed in early life, low doses of physical activity that disrupt sedentary behaviors may also have health benefits [14]. Specifically, an acute bout of physical activity is one session lasting less than 60 min and typically represents the most substantial participation during a given day [47]. The single bout varies in intensity from light (e.g., walking to school) to vigorous (e.g., sports competition). Most research in this area has been completed in a laboratory setting, where the physical activity intensity and duration can be held constant and compared to control groups.

There is evidence that even a single bout of physical activity, such as a short bout of light to moderate physical activity, improves response accuracy and reaction time within laboratory experiments [24]; however, not all studies in educational settings have produced the same results [48]. Despite the mixed findings, no known studies have identified adverse cognitive effects resulting from physical activity participation when examining the effects of a single session of or regular participation in physical activity.

One study conducted in schools examined the timing of the physical activity break and the intensity among 123, 10–11 year olds and measured selective attention before and after the physical activity [45]. The results showed a positive increase in selective attention after the physical activity break compared to the baseline. Using different measures related to academic success, a randomized controlled trial investigating the effects of physically active academic lessons in the classroom [49] demonstrated that time on task was higher among active lessons than those that covered the same content but were delivered in a sedentary (seated) format [50].

Results from investigations of acute bouts of physical activity vary. For example, 156 fifth and sixth grade students were randomized into two of four physical activity conditions classified by intensity (sedentary, light, moderate and vigorous), concluding that 10-min bouts of physical activity did not significantly differ from one another [48]. Similarly, in a study of 465 children in 40 different classrooms across 6 different school districts, classrooms were assigned to high-intensity physical activity breaks or low-intensity physical activity breaks. Children participated in pre/post cognitive assessments related to math facts, memory, and the executive function of inhibitory control. There are were no significant differences between the different intensities of physical activity. Although the study was limited by not having a sedentary comparison group, it increased our understanding that the duration of the acute bout may impact the potential effects on cognitive function. Less than 10 min did not produce immediate cognitive benefits regardless of intensity. It is important to note that there were no adverse effects of participation (e.g., the decline in overall academic performance).

Acute bouts of physical activity disrupt prolonged periods of sedentary behaviors. The effects of sedentary behaviors on children in school have been understudied. Further, the mode or type of physical activity is related to the unique benefits. The effects of play, which can be unstructured (e.g., walking and talking with a friend) or structured (e.g., intense exercise for elite performance), need to be examined in authentic contexts, like schools and community physical activity programs like youth sports and clubs.

4.3 Dose-response effects of physical activity on cognitive function

Identifying a potential dose-response relationship between physical activity that can improve cognitive function in children has implications for education and the offering of opportunities for physical activity in and around schools. Although there is believed to be a dose-response relationship between physical activity on cognitive function, there is only limited empirical evidence of direct effects of physical activity volume, duration, frequency, intensity, and domain.

The cognitive assessment deployed to measure cognitive function influences study results and the generalizability of the findings. Neuroscientists have been using electroencephalogram (EEG) neuroimaging and executive function tasks, like Flanker's task, to assess the accuracy and reaction time of responses. Standardized test scores such as the Woodcock-Johnson and systematic observational scales of time on task have also been used. The variability of how cognitive function is measured, from academic success in schools to concentration and attention and neural activation, hinders the development of standardized recommendations for children at specific developmental stages.

Cross-sectional accelerometer and EEG data collected during the multiple waves of the FITKids trials were examined to determine a dose-response relationship between physical activity and neurocognitive function among 8–10 year old children [35]. It was concluded that vigorous physical activity is strongly associated with inhibitory control and other neuroelectric indices related to processing speed. The researchers recommended that short bouts of physical activity be vigorous, like jumping rope, hiking/walking up stairs, playing soccer, and fast bicycling, be included in children's daily routines.

As previously detailed, the trait of aerobic fitness is associated with better academic performance [25], while the effects of specific physical activity like dancing have only been studied in older adults and have not comprehensively been explored among preschool children [51]. Further, the effects of elite training are understudied, as complex motor skills like playing soccer are associated with a better concentration than their matched control participants, peers who participated in non-motor demanding physical activity [52]. The general and specific effects of the volume of physical activity should be investigated, particularly in early childhood educational contexts. Overall, there is believed to be a dose-response relationship between physical activity and cognitive function; however, the lack of study replication across multiple samples and developmental stages of children limits the recommendations that can be made at this time.

5. Physical activity recommendations for healthy cognitive development

Meeting or exceeding the physical activity guidelines for daily physical activity duration and intensity will enhance cognitive function. These benefits vary by the total volume of physical activity, achievement of aerobic fitness, and the type of cognitive assessment measure used. Despite the variability in outcomes, there are no known detrimental effects to adhering to the guidelines. Health disparities include the lack of equitable access to physical activity opportunities, rise in sedentary behaviors related to screen time and use of technology, and various psychological factors, like a lack of perceived skill, that prohibit most children from meeting these guidelines. Therefore one overarching recommendation is to provide inclusive, equitably accessible physical activity programs for all children. What we currently understand to be true about such effects is outlined next [1].

5.1 Children who are ages 3–5 years

We know the least about preschool-aged children since there is a paucity of research focused on this developmental stage. However, new investigations that leverage wearable technologies and mobile neuroimaging devices to collect data are currently underway. A meta-analysis of seven studies enrolling 414 participants from 5 countries demonstrated that higher physical activity produced cognitive benefits in 67% of the studies [53]. A cross-sectional study of 552, 3 and 4 year olds investigated the interaction and codependence of sleep, physical activity, and body composition (measured as BMI and adiposity). Not surprisingly, healthier children moved more, thus revealing additional home and community-level health disparities, as children with access to fruits and vegetables are more likely to have a healthy BMI [54].

As globally stated in both the US and Canadian Guidelines for physical activity at this developmental stage, children should be physically active throughout the day across multiple environments engaged in differing physical and cognitive demands. Whether in the home or school environment, adult caregivers should conscientiously seek out such opportunities for the child. The total daily participation should equal or exceed 3 h of movement, whether light or moderate in intensity. Movement should involve multiple motor skills and transpire in structured (e.g., circle time dancing, clapping, singing) and unstructured settings (e.g., the playground, sandbox, and water play). Finally, researchers and policymakers alike should develop methods for surveillance of physical activity participation and locations where participation transpires (e.g., home, green space, preschool).

5.2 Children ages 6–17 years

At this developmental stage, we have causal evidence that physical activity moderately enhances cognitive health and is essential for academic success in later school years. A single bout of physical activity should be considered one session and contributory to the accumulated physical activity across the day. The daily 60-min of MVPA should include at least 3 days of the week dedicated to aerobic type of activities (e.g., running, jumping), and 3 days to muscle-strengthening, which can likely happen in conjunction with the aerobic activities or as separate sessions (e.g., gymnastics taking weight on hands, or by adding resistance to the body, climbing, pushing/pulling). Bone-strengthening physical activity should be part of the 60 daily minutes for at least 3 days. For school-aged children, bone-strengthening activities may include hopping, jumping rope, or sports involving rapid direction changes. The activities become more complex for adolescents, as someone may be a goalkeeper, ride horseback, and/or visit a local skate park. Adolescence is also a time to increase resistance training by moving away from using one's own body weight as resistance and begin weight training with machines or free weights. The last stage of "childhood" should also be a time to participate in active recreation leading into adulthood. Activities like kayaking, hiking, adult recreational leagues outside of high school, and forms of yoga, pilates, and dynamic stretching should also be integrated into planned physical activity. The book *Fitness for Life* comprehensively outlines the specificity and progression of such engagement for adolescents [21].

It is reasonable to believe that adherence to these prescribed guidelines will improve cognitive health among children and adolescents. How cognitive health will be enhanced depends on the outcome measure and the timing, type, duration, and intensity of physical activity. There is no "one size fits all" prescription for physical activity participation. Instead, such participation should be based on the child's interests, likes, motives, and developmental readiness. When activities are enjoyable, we tend to adhere and come back for more.

5.3 Physical activity by place and context (domain)

There should be opportunities to participate in physical activity from the moment they awake to when a child's head hits the pillow. Since adults are responsible for building regulatory systems, making policy, securing resources, providing inclusive and equitable access to physical activity opportunities, we all must share the burden of children's physical activity. **Table 1** outlines the recommended strategies for enhancing physical activity surveillance and how this information could be used to inform our current practice [55].

If children are to engage in physical activity over sedentary behavior, we must continue to engage policymakers to monitor where, when, and how children are active. Knowing who the children are within the activity space (e.g., parents, teachers, friends, classmates, community leaders) also adds value to our understanding of such contexts. Understanding the facilitators and barriers of participation will help inform policy and practice within formal child care and educational settings, but moreover, may also shed light on mechanisms for enhancing population health. Cognitively and physically healthy individuals have a more positive impact on the economy.

5.3.1 Physical activity in school for improving cognitive function

Every child attends school; some do so in a building, others do so from home. A meta-analytic review confirmed that curriculum derived physical education interventions designed to increase daily physical activity were most effective [56]. Having physical activity surveillance systems associated with such educational experiences is paramount. Schools that take a health-first approach to policy and implement Comprehensive School Physical Activity Programs (CSPAPs) are well-position to have children reap the benefits associated with physical activity [57]. The cornerstone of the CSPAP is physical education, with physical activity also offered across the curriculum through before/after school programs and active transportation, staff involvement by modeling healthy behaviors, during the school day physical activity (e.g., recess, classroom breaks), and community engagement where physical activity includes youth sport and community venues (e.g., skate parks, bike trails, disc golf courses, swimming pools).

Quality physical education is where surveillance is already and could continue to be advanced. The use of fitness testing and reporting the results to parents as a proxy measure of health risks is a practice that should continue to be undertaken as part of

Children
Strategy 1: Develop and implement state- and national-level systems for monitoring physical activity policies and practices in early child care and early childhood education settings. Estimated costs: high.
Strategy 2: Enhance existing surveillance systems for monitoring elementary through high school-based physical activity policies and programs. Estimated costs: medium.
Strategy 3: Develop a protocol that leverages ongoing administration of physical fitness tests, such as FitnessGram, for the purpose of monitoring fitness levels of children and youth. Estimated costs: low.
Strategy 4: Expand objective monitoring of physical activity in children (ages 3–18 years) by incorporating validated wearable technologies into the existing surveillance systems. Estimated costs: medium.
Strategy 5: Develop a system for monitoring community-level availability of organized sports and other physical activity programs for children. Estimated costs: medium.
Strategy 6: Identify features of the built environment that are most likely to influence physical activity in children and embed an assessment of perceived ability and use of these features into existing surveillance systems. Estimated costs: low.

Table 1.
Recommended strategies to enhance physical activity surveillance and estimated relative costs for implementation [55].

the CSPAP. Fitness testing must be implemented in ways that do not disenfranchise students. Such data should be collected with a student's perceived ability. Do they feel capable of participating in the physical activities offered? Fitness testing should never be associated with grades. The fitness assessment can be used for personalizing physical activity participation by drawing on the individual's strengths and used for goal setting to increase perceived abilities. The cost and investment for physical activity programs in and around schools are minimal and embedded in our societal norms. We should continue supporting and providing school-based physical activity programs like physical education, athletics, and clubs.

5.3.2 Physical activity in the home and community to enhance cognitive function

Wearable technologies and sensors of physical activity are ubiquitous. Watches, cell phones, and other devices contain accelerometers and applications that can interpret human movement. Sharing such data in aggregate and cyber secure ways can help us understand who has mobility, the energy expenditure related to mobility, and if persons are alone or with others when engaging in physical activity. Although further research is needed to define what devices are best for whom, there is great potential for advancing our understanding of the role of place and context in physical activity participation across the lifespan.

Developing community and home level monitoring systems can aid in joint land use and sharing potentially scarce resources. Identifying what youth sports programs and activities may be popular can augment the value of the community [58]. In Australia, only 27% of adolescents surveyed used the park nearest to them because it lacked the most desired features (the presence of a skate park) [59]. The universal tracking of the usage of community venues is a form of surveillance that should be expanded.

If you build it, they will come and be active. The built environment influences our decision to participate in physical activity. We need to understand the subcultures that emerge in specific venues. For example, a female may be anxious in one weight room but feels comfortable in another. No one ever feels good about themselves when they are cut from a team. Even though such psychological outcomes may be seen as beyond the scope of this chapter, it should be noted there are mental and emotional benefits also stem from physical activity participation. Appreciating what features of the built environment facilitate and those that inhibit participation are sometimes far less obvious than one might observe. Embedded surveillance systems would help us understand how best to financially invest in a healthy, active community.

6. Conclusions and implications

There are numerous benefits related to daily participation in physical activity ranging from short bouts like riding a bike to school to more formal, sport-specific exercise in adolescence. Our work begins with **Figure 2** and identifying and participating in health-enhancing behaviors each day. Schools, community, and home environments are situated to contribute to a child's total accumulated physical activity. Models like the CSPAP provide the framework for organizing and providing opportunities for physical activity. However, because the behavior of physical activity is a socially constructed norm, we must consider the intersectionality of time, type, intensity, volume, and domain of physical activity and how these impact ethnicity, race, culture, and community initiatives.

The seminal research in 2007 [25] was the first modern-day empirical publication associating academic achievement with aerobic fitness among elementary school children. Since then, hundreds of studies have been published, and our understanding has exponentially evolved. There may be many more research questions about preschoolers and place and context, but we now know that children and adolescents who meet the national daily physical activity guidelines will benefit cognitively. Given the dose-response relationship between physical activity and cognitive function, participation for 60 min of movement in the home, school, and community settings in activities requiring various motor skills has the most significant potential to maximize children's cognitive function. This recommendation sets the stage for habitual engagement across the lifespan.

Conflict of interest

The authors declare no conflict of interest.

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