



## Review

# Systematic review of physical activity and cognitive development in early childhood



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## ARTICLE INFO

## Article history:

Received 14 February 2015

Received in revised form 18 May 2015

Accepted 2 July 2015

Available online 10 July 2015

## Keywords:

Child preschool

Infant

Physical activity

Growth & development

Language

Executive function

## ABSTRACT

**Objectives:** To comprehensively review all observational and experimental studies examining the relationship between physical activity and cognitive development during early childhood (birth to 5 years).

**Design:** Systematic review.

**Methods:** Electronic databases were searched in July, 2014. No study design, date, or language limits were imposed on the search. Included studies had to be published, peer reviewed articles that satisfied the a priori determined population (apparently healthy children aged birth to 5 years), intervention (duration, intensity, frequency, or patterns of physical activity), comparator (various durations, intensity, or patterns of physical activity), and outcome (cognitive development) study criteria. Study quality and risk of bias were assessed in December 2014.

**Results:** A total of seven studies, representing 414 participants from five different countries met the inclusion criteria, including two observational and five experimental studies. Six studies found increased or higher duration/frequency of physical activity had statistically significant ( $p < 0.05$ ) beneficial effects on at least one cognitive development outcome, including 67% of the outcomes assessed in the executive function domain and 60% in the language domain. No study found that increased or higher duration/frequency of physical activity had statistically significant detrimental effects on cognitive development. Six of the seven studies were rated weak quality with a high risk of bias.

**Conclusions:** This review provides some preliminary evidence that physical activity may have beneficial effects on cognitive development during early childhood. Given the shortage of the information and the weak quality of available evidence, future research is needed to strengthen the evidence base in this area.

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## 1. Introduction

Early childhood, defined here as birth to five years, is marked by one of the most critical and intensive period of brain development throughout the human lifespan.<sup>1</sup> Dynamic overproduction and pruning of synapses occur during this period, first in regions of the brain that process sensory information, then in association areas involved in higher-level processes, such as working memory, attention, and planning.<sup>2</sup> Healthy brain development during

this period facilitates optimal cognitive development and lays the foundation for future cognitive and academic accomplishments.<sup>1</sup>

Optimal cognitive development in early childhood involves the emergence and growth of cognitive abilities within multiple domains. For example, in the language domain, children should acquire the ability to comprehend and produce speech of increasing complexity to communicate with others.<sup>3</sup> In the memory domain, children should acquire the ability to encode information in their memory and access long-term stores over increasing delays via recognition and recall mechanisms.<sup>4</sup> In the spatial domain, children should acquire the ability to encode and use information about the spatial organization of objects and layouts, and use them to guide reaching and locomotor behavior.<sup>5</sup> In the domain of executive

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function, children should acquire increased ability to regulate their attention, thoughts, actions, and emotions, sometimes suppressing a dominant response to produce a less available, but more appropriate alternative.<sup>6</sup> Understanding and promoting the factors that support healthy brain and optimal cognitive development across domains in early childhood is of great importance.

Physical activity is increasingly being recognized as an important determinant of cognitive and neural functioning in middle childhood<sup>7</sup> and adulthood,<sup>8,9</sup> in addition to its various other physiological and psychosocial benefits.<sup>9–11</sup> Findings from systematic and meta-analytical reviews indicate that higher amounts of physical activity improve cognitive functioning and academic achievement in school-aged children and youth<sup>7,12,13</sup> and reduce the risk of age-related cognitive decline, dementia, and Alzheimer's disease in adulthood.<sup>9,14–17</sup> However, little is known about the relationship between durations, intensities, frequencies, or patterns of physical activity and cognitive development in early childhood among apparently healthy children (i.e., no diagnosed disease).<sup>18</sup>

The association between physical activity and a variety of health indicators (i.e., adiposity, bone and skeletal health, motor development, psychosocial health, cognitive development, cardiometabolic health) among apparently healthy children of the early years (0–4 years) was previously reviewed in 2011<sup>18</sup> to help inform the development of Canadian Physical Activity Guidelines for the Early Years.<sup>19</sup> The Canadian guidelines align with recently developed Australian<sup>20</sup> and United Kingdom<sup>21</sup> guidelines. For healthy growth and development, they recommend children <1 year be active several times a day and children 1–4 years accumulate at least 180 min per day of physical activity of any intensity. Only one study examining one domain of cognitive development (i.e., language) in infants was included in the review that informed these guidelines.<sup>22</sup> Overall, dose-response evidence was lacking.<sup>18</sup> It is important to note that this previous review excluded cross-sectional study designs to focus on designs that allow for the strongest causal claims and to keep the review manageable when looking at multiple health indicators.<sup>18</sup> Though causal claims cannot be made with cross-sectional designs, given the shortage of information in this area, such studies may provide further insight into the relationship between physical activity and cognitive development during early childhood while helping identify future research priorities.

One potential reason for the shortage of information on the relationship between physical activity and cognitive development in early childhood among apparently healthy children is that physical activity in this population has been largely neglected, until recently. This is primarily due to the assumption that young children are naturally physically active.<sup>19</sup> More recently, this assumption has been challenged with research indicating that young children spend a significant portion (>73%) of their waking hours sedentary.<sup>23,24</sup> Physical activity habits formed during early childhood have shown to moderately track into middle childhood.<sup>25</sup> These recent findings along with new physical activity guidelines in Australia,<sup>20</sup> the United Kingdom,<sup>21</sup> and Canada,<sup>19</sup> which have been released over the past 5 years, have sparked new research in the area of physical activity and health in early childhood. Cognitive development has been identified as a critical health indicator in this age group.<sup>18</sup> Therefore, investigating and identifying relationships between physical activity and cognitive development can inform updates to physical activity guidelines and other health promotion efforts aiming to provide children with the best opportunity to grow and develop optimally. The purpose of this paper was to comprehensively review all observational and experimental studies examining the relationship between physical activity and cognitive development during early childhood (birth to 5 years).

## 2. Methods

This review is registered with the international prospective register of systematic reviews PROSPERO network (<http://www.crd.york.ac.uk/prospero/>): Registration no. CRD42014009970. The PRISMA statement for transparent reporting of systematic reviews and meta-analyses was followed.<sup>26</sup>

The following databases were searched on July 17, 2014: Ovid MEDLINE(R) In-Process & Other Non-Indexed Citations, Ovid MEDLINE(R) Daily and Ovid MEDLINE(R) (1946 to Present), Ovid EMBASE (1974–Current), Ovid ERIC (1965–Current), Ovid PsycInfo (1806–Current), EBSCO CINAHL Plus with Full-text (1937–Current), EBSCO SPORTDiscus with Full-text (1975–Current), EBSCO Child Development & Adolescent Studies (1895–Current), Elsevier Scopus, (1960–Current). The search strategy was developed and run by a librarian with expertise in systematic reviews (LS; see Supplementary material A for complete search strategies). No study design, date, or language limits were imposed on the search. In databases that included non-scholarly literature, such as trade publications and popular magazines (SPORTDiscus and Child Development & Adolescent Studies), publication type limits were applied to limit results to scholarly literature. Articles were extracted as text files and imported into EndNote software. Duplicate articles were removed using Endnote.

Titles and abstracts of potentially relevant articles were scanned by two independent reviewers (SH and NK). Full text copies of articles were then obtained for those meeting initial screening. If an article was included by one reviewer, and not the other, the article was obtained for further review. Two independent reviewers examined all full text articles (SH and NK). For discrepancies between reviewers, eligibility was decided based on discussion among the reviewers or by a third reviewer (VC) if it was required. Studies published in languages other than English were included if the article could be translated with Google Translate.<sup>27</sup> Reference lists of included articles and relevant reviews were also checked for additional relevant studies. Five key informants, identified through the literature search, were contacted by e-mail and asked to list the five most important papers that they were aware of that related to the systematic review.

Included studies had to be published, peer reviewed articles that satisfied the a priori determined population, intervention, comparator, and outcome (PICO) study criteria.<sup>28</sup> **Population:** apparently healthy (i.e., no diagnosed disease) young children aged birth to 5 years (mean age of less than 6 years) who had not entered elementary/primary school. For prospective cohort or experimental studies this criteria applied to the baseline age. **Intervention (exposure):** duration, intensity, frequency, or patterns of physical activity defined as any bodily movement generated by skeletal muscles resulting in increased energy expenditure above a resting level.<sup>29</sup> **Comparator:** various durations, intensities, frequencies, or patterns of physical activity. **Outcome:** cognitive development defined as growth in children's cognitive abilities in particular domains (e.g., language, executive function, memory, spatial cognition, visual cognition).<sup>30</sup>

Data extraction was conducted in October and November, 2014 by one of two reviewers (SH or NK) and verified by a third reviewer (VC). Information was extracted and recorded in Microsoft Excel for publication year, country, study design, sample size, age, sex, measurement of exposure, comparator, and outcome, and results. A fourth reviewer (SAW) assigned a cognitive domain to each cognitive outcome. A *p*-value of <0.05 was used across studies to denote statistical significant findings. See Supplementary material B for full details on included studies.

Study quality and risk of bias were assessed in December 2014 by two independent reviewers (SH and NK) using a modified version of the National Collaborating Centre for Methods and Tools

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