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Associations of subjectively and objectively measured sedentary behavior and physical activity with cognitive development in the early years

Valerie Carson [a, *], Aishah Abdul Rahman [b], Sandra A. Wiebe [b, c]

[a] Faculty of Physical Education and Recreation, University of Alberta, Edmonton, Alberta T6G 2H9, Canada
[b] Neuroscience and Mental Health Institute, University of Alberta, Edmonton, Alberta T6G 2E1, Canada
[c] Department of Psychology, University of Alberta, Edmonton, Alberta T6G 2E9, Canada

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A B S T R A C T

Purpose: To examine the associations of subjectively and objectively measured sedentary behavior and physical activity with cognitive development in a sample of 30–59 month olds.
Methods: Cross-sectional findings are based on 100 early years children (43.4 ± 9.4 months; 53% female) from Edmonton, Canada that were part of the Physical Activity and Cognition in Early Childhood (PACE) study. Sedentary time and physical activity (light-intensity, moderate- to vigorous-intensity, total) were objectively measured with an accelerometer. Sedentary behavior (television, video/computer games, screen time) and physical activity (organized, non-organized, total) were also subjectively measured with a parental questionnaire. Vocabulary was measured with the Peabody Picture Vocabulary Test, Fourth Edition, working memory was measured with the Nebraska Barnyard task, and response inhibition was measured with the Fish-Shark Go/No-Go task. Correlations and linear regression were used to examine associations.
Results: Total subjective physical activity ($r = 0.31$; $p = 0.018$) and non-organized physical activity ($r = 0.27$; $p = 0.035$) were significantly positively correlated with vocabulary. Conversely, television viewing ($r = -0.21$; $p = 0.046$) was significantly negatively correlated with vocabulary. These significant associations remained in linear regression models after adjusting for age. Objectively measured sedentary time and physical activity were not significantly associated with any cognitive development measure and no sedentary behavior or physical activity measure was associated with working memory or response inhibition.
Conclusions: Television viewing may be detrimental and physical activity, especially non-organized, may be beneficial for vocabulary in early years children. Future research with larger sample sizes and longitudinal and experimental study designs are needed to confirm these findings and determine the mechanisms.

1. Introduction

Human brains experience rapid growth and development during gestation (Lenroot & Giedd, 2006) but the brain is not fully developed at birth, with development continuing in some regions through the early 20s (Christakis, 2009). The early years, the first five years of life, are characterized by significant growth and development of the brain (Khan & Hillman, 2014; Lenroot & Giedd, 2006). By age 2 the human brain has reached approximately 80% of its adult weight and by age 5 it has reached 90% of it adult weight (Lenroot & Giedd, 2006). Furthermore, the production of synapses rapidly increases from birth to 2 years (Lenroot & Giedd, 2006) followed by pruning of synapses at varying rates in different regions of the brain (Huttenlocher & Dabholkar, 1997; Lenroot & Giedd, 2006). This rapid period of brain maturation in the early years (Khan & Hillman, 2014) makes it more sensitive to the

* Corresponding author. University of Alberta, 8840-114 Street, Van Vliet Complex, Edmonton, Alberta T6G 2H9, Canada.
E-mail addresses: vlcarson@ualberta.ca (V. Carson), siti@ualberta.ca (A.A. Rahman), sandra.wiebe@ualberta.ca (S.A. Wiebe).

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immediate environment (Knudsen, 2004). As a result, early life experiences can have beneficial or detrimental long-term effects on brain structure and function (Greenough, Black, & Wallace, 1987). For instance, healthy brain development in the early years enables optimal cognitive development, including the growth of abilities and skills in domains such as language (Tomasello, 2010) and executive functions (Garon, Bryson, & Smith, 2008). Therefore, identifying and targeting the factors that are beneficially associated with healthy brain development during the early years is critical to facilitating optimal cognitive development across domains.

Physical activity may be one factor to consider for optimal brain and cognitive development in the early years, given its association with cognitive outcomes in older age groups. For instance, evidence from several reviews indicates physical activity in school-aged children and youth is beneficially associated with cognitive functioning (Biddle & Asare, 2011). Additionally, a number of mechanisms to explain this relationship have been identified primarily in animal models and older adults (Khan & Hillman, 2014; Voss, Car, Clark, & Weng, 2014). However, evidence in the early years is limited and has notable limitations. More specifically, a recent systematic review only identified seven studies in early childhood (birth to 6 years) among apparently healthy children that had examined the relationship between physical activity and cognitive development (Carson, Hunter, et al., 2016). While some preliminary evidence was found for a positive relationship, the majority of studies were rated as weak in quality (Carson, Hunter, et al., 2016) and only two studies included an objective measure of physical activity (Becker, McClelland, Loprinzi, & Trost, 2014; Campbell, Eaton, & McKeen, 2002). Similar findings were observed in a subsequent review (Tandon et al., 2016) on physical activity, gross motor skills, diet and cognitive development, which included two additional physical activity studies (Draper, Achmat, Forbes, & Lambert, 2012; Mavilidi, Okely, Chandler, Cliff, & Paas, 2015) that were not included in the earlier review.

In comparison to physical activity, more research has examined the association between sedentary behavior, in particular screen-based sedentary behavior, and cognitive development in the early years (Carson et al., 2015). It is thought that television viewing may have a detrimental impact on brain development in the early years due to the overstimulation of the developing brain and reduced interaction with caregivers (Christakis, 2009). A recent systematic review on sedentary behavior and cognitive development in early childhood observed primarily null or detrimental effects for screen time (Carson et al., 2015). However, the majority of studies were rated as weak in quality and none of the studies included contemporary forms of screen time beyond television viewing as an exposure. Furthermore, no study included an objective measure of sedentary behavior (Carson et al., 2015). It is important to consider both objective and subjective measures as objective measures can more accurately measure total sedentary time and subjective measures can provide information on type and context of sedentary behavior (Lubans, Hesketh, et al., 2011).

Future research examining the association between sedentary behavior, physical activity, and cognitive development that addresses current gaps and limitations is needed to strength the evidence base in this area. Understanding these relationships is of particular importance given current trends of high sedentary behavior, in particular screen-based sedentary behavior, and low physical activity, in particular moderate- to vigorous-intensity physical activity (MVPA), in the early years (Colley et al., 2013; Hinkley, Salmon, Okely, Crawford, & Hesketh, 2012). Therefore, the objective of this study was to examine the associations of subjectively and objectively measured sedentary behavior and physical activity with cognitive development in a sample of early years children.

2. Methods

2.1. Participants

Participants were 100 children aged 30–59 months from the *Physical Activity and Cognition in Early Childhood* (PACE) study. Data were collected between April, 2015 and December, 2016 in Edmonton, Canada. Families were recruited from existing databases, local media, online advertising, and flyers distributed to businesses serving families such as child care centers and doctor's offices. Inclusion criteria for the study were: (1) children aged 30–59 months and (2) English-speaking and English-reading parents. The exclusion criteria for the study were: (1) children who are non-ambulatory; (2) children diagnosed with a new or recent chronic disease (e.g., Type 1 diabetes) where physical activity may be limited during the initiation of treatment; (3) children with a disability/impairment that limits their ability to be physically active; and (4) children with a developmental delay, diagnosed neurological or psychiatric disorder, or children with pre- or perinatal risk factors known to affect brain development (e.g., fetal alcohol spectrum disorder, preterm birth, low birth weight). Families that met eligible criteria and agreed to participate attended a laboratory appointment where cognitive development measures were conducted. At the appointment, parents completed a questionnaire and families were also given an accelerometer for their child to wear for 7 consecutive days. Verbal and written accelerometer instructions were provided to families. Ethics approval was obtained from the University of Alberta Human Research Ethics Board and all participating parents provided written informed consent.

2.2. Objective measures of sedentary time and physical activity

Sedentary time, light-intensity physical activity (LPA), and moderate- to vigorous-intensity physical activity (MVPA) were objectively measured with Actigraph wGT3X-BT accelerometers worn on an elastic waistband over the right hip for 7 consecutive days. Parents were instructed to only remove the accelerometer for overnight sleep and during swimming and bathing. Data was collected in 15 s epochs. To be included, participants were required to have $\geq$4 days with $\geq$1440 total 15 s intervals (equivalent to 6 h) of wear time each day (Hinkley, O'Connell, et al., 2012). A weekend day was not required for the 4 days. Non-wear time was defined as $\geq$80 consecutive 15 s intervals of zero counts (equivalent to $\geq$20 min of consecutive zeros counts). Daytime naps were assumed to be removed with non-wear time. Sedentary time was defined as 0–25 counts per 15 s, LPA as 26–419 counts per 15 s, and MVPA as $\geq$420 counts per 15 s (Janssen et al., 2013). Minutes per day of sedentary time, LPA, and MVPA were derived by dividing the number of 15 s intervals classified as wear time by 4 and then dividing the total minutes in each intensity by the total number of valid days. To adjust for wear time, sedentary time, LPA, and MVPA variables were standardized by using the residuals obtained when regressing sedentary time, LPA, and MVPA separately on wear time (Willett & Stampfer, 1986).