PHYSICAL ACTIVITY, STRUCTURED SPORT PARTICIPATION, EXECUTIVE FUNCTION IN PRESCHOOLS

by

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ABSTRACT

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Two studies explored the connections between physical activity, participation in structured open-skilled sports (e.g., soccer and basketball) and closed-skilled sports (e.g. running and swimming), and executive function (EF) among preschool-aged children. Study 1 included 197 preschool-aged children (mean age = 4.34 years, female = 48%, white = 83.5%). Study 2 included 1012 preschool-aged children (mean age = 51.59 months, white = 60.5%). Results from regression models indicated that parent-reported physical activity was not associated with direct assessments or parent reports of child EF (Studies 1 and 2). General sport participation was associated with one direct assessment (DCCS; Study 1), but was not associated with parent reports of child EF when controlling for physical activity (Studies 1 and 2); however, depending on the conceptualization of sport, some associations were significant. Future research is necessary to determine whether these associations exist when the constructs are conceptualized differently and when using different assessments.

INTRODUCTION

An established literature has emphasized the benefits of physical activity in adulthood (e.g., reductions in anxiety, increased self-worth, enhanced cognitive function; Biddle & Ekkekakis, 2005; Fox, 1999) and has positively linked physical activity to adult executive functioning (EF; Hillman, Erickson, & Kramer, 2008). Some of these connections between physical activity and EF are similar across middle childhood and adolescence as well (Ellemberg & St-Louis-Deschênes, 2010; Tomporowski, Lambourne, Davis, Gregoski, & Tkacz, 2008). It is thought that these links may be attributed to the cognitive demands of physical activity and/or shared neurological processes (Davis et. al, 2011; Diamond, 2000). Despite the attention given to the role of physical activity in older children and adults, only two studies have explored this association in preschool and these findings were inconsistent. Whereas Becker and colleagues (2014) found that active play during recess was associated with EF in preschoolers, Willoughby and colleagues (2018) found a negative association between moderate to vigorous physical activity and EF in preschoolers. Thus, more research is needed to elucidate these findings. Examining the extent to which physical activity is related to EF in preschool is important given that EF at this developmental stage is predictive of various outcomes throughout the life span (e.g., school readiness, academic success; Blair & Razza, 2007; Mägi, Männamaa, & Kikas, 2016; McClelland, Acock, Piccinin, Rhea, & Stallings, 2013).

Specific physical activities may be particularly important for the development of preschool children's EF. For example, some research has shown that older children and adults who participate in physical activities that include cognitive components (e.g., planning, concentrating) exhibit greater EF skills than those who do not engage in these activities (Best, 2010: Lakes & Hoyt, 2004). One type of physical activity that contains cognitive demands, and thus, may be more strongly related to EF is structured sports (i.e., physical activity with a goal or an objective; Burack, Campbell, Landry, & Huizinga, 2017). However, findings with regard to the association between structured sport participation and EF in older children is mixed (Davis et al., 2011; Becker, McClelland, Geldhof, Gunter, & MacDonald, 2018), and no studies have explored this relation in preschoolers.

This thesis consists of two studies that extend existing literature on physical activity and structured sport participation in a few key ways. Becker et al. (2014) found that physical activity during recess was related to preschoolers' EF, but they exclusively looked at physical activity within a school setting, and did not measure structured sport activity. Willoughby and colleagues (2018) did look at physical activity at home and at school, but their sample was drawn from a consortium of schools that had a focus on increasing physical activity, perhaps impacting the generalizability of their findings. Further, similar to Becker et al., Willoughby et al. did not consider structured sport participation. Thus, the present studies extend this work by looking at *both* physical activity and structured-sport participation in relation to EF in preschool children using two independent samples. One study examined these associations using parent reports of EF and direct assessments (Study 1), and the other utilized parent reports of EF (Study 2).

Executive Function and its Development

Executive functioning (EF) is the ability to use conscious, flexible and goal-oriented behaviors to control automatic thoughts and responses (Garon, Bryson, & Smith, 2008; McClelland et al., 2007). The preschool years are often considered a sensitive period for the development for EF because of structural changes that occur in the prefrontal cortex during this time (Carlson, 2005; Garon et al., 2008; Luria, Karpov, & Yarbuss,1966; Stuss & Benson, 1984). Development in the prefrontal cortex promotes EF because it continuously inhibits or activates other brain areas, and in doing so, facilitates one's ability to regulate automatic thoughts, behaviors, and responses (Garon et al., 2008; Knight & Stuss, 2002; Shallice et al., 2002). Although some research suggests that EF is a multidimensional construct in preschool (Lerner & Lonigan, 2014) and as children get older (Lee et al., 2012; Smith & Jonides, 1999; West, 1996), most of the literature indicates that EF is a unidimensional construct in preschool, consisting of the integration of three components (Bernier, Beauchamp, Carlson, & Lalonde, 2015; Willoughby, Blair, Wirth, & Greenberg, 2012): working memory, inhibitory control, and cognitive flexibility (Garon et al., 2008).

Working Memory. Working memory is conceptualized as the ability to hold information in mind while keeping it readily accessible for use (Baddeley, Logie, Bressi, Sala, & Spinnler, 1986). To illustrate, children use working memory skills when they are asked to remember multi-step instructions (e.g., grabbing their coat and their lunch before school). Research indicates that the manipulation of information in mind, which draws on working memory, occurs in the prefrontal cortex (Petrides, 2000), and that growth in the prefrontal cortex parallels growth in children's working memory (Garon et al., 2008). Some theoretical accounts suggest that the development of EF may be broadly due to a growing capacity to process incoming information while remembering old information (Olson, 1993). Many cross-sectional and longitudinal studies have found that working memory increases from 3 to 5 years old on a variety of tasks (Bull, Espy, & Senn, 2004; Davis & Pratt, 1995; Espy & Bull, 2005).

Inhibitory Control. Inhibitory control is the ability to hold back automatic thoughts and responses in favor of more adaptive ones (Garon et al., 2008). For instance, children utilize inhibitory control when they put their toys away in response to a parent's direction rather than continuing to play with them. Similar to working memory, growth in inhibitory control in early childhood is in line with growth in the prefrontal cortex (Luria et al., 1966) and develops rapidly between the ages of 3-and-5 years old (e.g., Lemmon & Moore, 2007; Moore, Barresi, & Thompson, 1998).

Cognitive Flexibility. Cognitive flexibility is defined as the ability to shift attention and focus on achieving an internal goal or meeting the demands of a task (Garon et al., 2008). Children demonstrate cognitive flexibility when they are able to effectively transition and adapt to varying routines and rules in home and school contexts. Similar to the other two components of EF, cognitive flexibility develops rapidly between the ages of 3 and 5, and this development coincides with the development of the prefrontal cortex (Garon et al., 2008). It is thought that cognitive flexibility builds on the development of working memory and inhibitory control (Garon et al., 2008). In order to shift attention from one "mental set" to another, the mind must first focus on the set, form a mental rule, and ignore distractors (i.e., holding this rule in working memory). The next phase of cognitive flexibility is incorporating this rule while shifting into a new "mental set" that conflicts with the first set, forcing children to inhibit their initial response (i.e., inhibitory control).

The development of EF is thought to be the result of a combination of biological and neurological changes (Garon et al., 2008) as well as contextual influences (Zelazo et al., 2003). The Cognitive Complexity and Control (CCC; Frye, Zelazo, & Burack, 1998) theory posits that EF develops through the use of hierarchical rule systems, such that as children get older, they are able to understand, utilize, and reflect upon more complex rules when problem solving, which in turn, integrates the three components of EF (Frye et al., 1998). Zelazo and colleagues (2003) proposed that as children age, their ability to add complexity to these rules increases, and as such, their ability to solve problems flexibly increases. Alternatively, the Relational

Developmental Systems (RDS) theory (Overton, 2013) suggests that development occurs within a bidirectional process between the individual and the context in which they exist. The notion that multiple contexts nested together may help explain the development of EF is borrowed from Bronfenbrenner's (1977) ecological systems theory. Taken together, these theories suggest that the development of EF is impacted by characteristics of the individual child as well as by the opportunities and limitations within his or her environment (McClelland, Geldhof, Cameron, & Wanless, 2015).

The interplay between the individual and context is important to consider in the development of EF, and children's engagement in certain activities within their proximal contexts may play a role in the development of this set of skills. Specifically, some research suggests that when children engage in classroom-based activities, such as stop-think-act games (e.g., freeze game), the development of EF is supported (Duncan et al., 2007; Tominey & McClelland, 2011; Schmitt, McClelland, Tominey, & Acock, 2015). Other activities, such as physical activity or participation in organized structured sports, may also be related to EF in young children, however, little research has explored this notion (Diamond & Lee, 2011).

The Importance of Executive Function

EF in early childhood has emerged as a key predictor of a number of developmental outcomes in the short- and long-term, such as physical health (e.g., BMI) and social-emotional outcomes (Denham, 2006; Schmitt et al., 2017). Research also shows that individuals with strong EF in early childhood demonstrate school readiness and later academic achievement throughout their schooling (Blair & Razza, 2007; Duckworth & Carlson, 2013; Duckworth & Seligman, 2005; McClelland et al., 2013; Morrison, Ponitz, & McClelland, 2010). Because of the ability to be flexible in planning and attention, EF in early childhood has been linked to success in specific academic areas, like mathematics and literacy (Blair & Razza, 2007; Mägi et al., 2016). For instance, Blair & Razza (2007) found that for 3-to-5-year-old children from low-income backgrounds, measures of EF in preschool were related to math and literacy ability in kindergarten. Another study demonstrated that strong EF in preschool was associated with growth in math and literacy in kindergarten and predicted the probability of completing college by the age of 25 (McClelland et al., 2013).

In contrast to strong EF in early childhood being a predictor of positive subsequent outcomes, weak EF during this time frame has been identified as an indicator of poor outcomes. In particular, previous research suggests that low levels of EF in early childhood predict negative adult outcomes, such as substance dependence, psychiatric disorders, and risk of unemployment as adults (Caspi, Moffitt, Newman, & Silva, 1996; Moffitt et al., 2011). Therefore, predictors of EF at early ages are important to investigate. Although emerging research suggests that early home and school environments and temperamental characteristics may predict EF in young children (Blair et al., 2011; Blair & Raver, 2012a; Lengua, 2002; McClelland et al., 2015; Rimm-Kaufman & Kagan, 2005; Sektnan McClelland, Acock, & Morrison, 2010), little is known about whether activities young children may engage in, such as physical activity and structured sport participation, may be related to EF. If a positive association between physical activity and EF in preschool is found, this could be an important point of intervention.

Physical Activity and Executive Function

Physical activity is defined as any form of leisure and/or non-leisure body movement using skeletal muscles that results in expending energy rather than being at rest (Caspersen, Powell, & Christenson, 1985; Warburton, Nicol, & Bredin, 2000). Physical activity is a broader construct than exercise (i.e., deliberately participating in activities to improve an individual’s fitness; Caspersen et al., 1985) and has four domains: occupational (work), domestic (household work), transportation (walking, biking), and leisure (sport participation, exercise, or hobbies; Warburton et al., 2000). The study will focus on the leisure domain of physical activity; however, this construct will be referred to as physical activity (rather than leisure physical activity) throughout for ease in readability.

A large body of evidence suggests that physical activity is beneficial to physical and psychological well-being across the life span. A number of studies have been conducted on the benefits of physical activity in adulthood (e.g., Fox, 1999; Netz, Wu, & Tenenbaum, 2005). Specifically, habitual physical activity has been associated with reductions in anxiety and depression, improved physical and general self-worth, and enhanced cognitive function in adults (Biddle & Ekkekakis, 2005). Further, there is correlational and causal evidence to support a link between physical activity and EF in adults **(**Chaddock, Pontifex, Hillman, & Kramer, 2011; Hillman et al., 2008). One study by Hawkins, Kramer, and Capalid (1992) demonstrated that, versus the control group, older adults who participated in a pool-based aerobic exercise group showed significant improvements in EF performance over the intervention period.

Research that examines the effects of physical activity in middle childhood and adolescence has found that regular physical activity is associated with positive outcomes in academic ability, cognitive tasks (e.g., response accuracy), and mental functioning (Dwyer, Sallis, Blizzard, Lazarus, & Dean, 2001; Ellemberg & St-Louis-Deschênes, 2010; Hillman et al., 2009; Tomporowski et al., 2008; Tomporowski, McCullick, Pendleton, & Pesce, 2015). For example, one study that focused on children ages 7-15 found a significant relation between multiple components of physical activity (i.e. paced walking, paced running, shuttle runs) and academic performance (Dwyer et al., 2001). Correlational studies also suggest that physical activity in middle childhood and adolescence is associated with EF (Hinkle, Tuckman, & Sampson, 1993; Tomporowski et al., 2015; Tuckman & Hinkle, 1986). Additionally, recent intervention work has demonstrated a causal relation between engaging in physical activity and improvements in EF for older children, although evidence is mixed. Whereas some research suggests that engaging in physical activity, and particularly aerobic exercise (e.g. running, basketball, soccer), for at least 40 minutes per day leads to improvements in EF for children ages 7-11 (Davis, et. al., 2011), other research has not found similar effects, particularly when physical activity is measured generally (e.g., when studies assign a dosage of aerobic exercise usually only using running games – sprinting, relays, and distance runs; Best, 2010; Tomporowski et al., 2015). As posited in a review by Diamond and Ling (2016), simply performing aerobic physical activity may not be enough to significantly improve EF; the *type* of physical activity may matter due to differences in cognitive demands. In particular, studies where children engage in physical activities that include cognitive challenges (e.g., planning, concentration) demonstrate greater gains in EF than those who engage in aerobic exercise alone (Diamond & Ling, 2016; Lakes & Hoyt, 2004).

Though the body of research around the impact of physical activity on outcomes for older children and adolescence has drastically grown in the last decade, few studies have explored associations between physical activity and developmental outcomes, and particularly EF, in early childhood (Biddle & Ekkekakis, 2005). Just two studies have explored possible relations between physical activity and EF in preschool children and findings were inconsistent. Results from one study demonstrated that preschool-aged children who participated in higher levels of active play during recess had better EF, which was then associated with higher scores on early mathematics and reading assessments (Becker, McClelland, Loprinzi, & Trost, 2014). Findings from a second study revealed an inverse association between physical activity and EF in preschool aged children (Willoughby, Wylie, & Catellier, 2018). Though these studies shed light on the existing gap in the literature, more studies are necessary to elucidate this association. In the Becker et al. (2014) study, physical activities were only measured within a school context. Physical activity likely happens outside of school, and this physical activity taking place in other contexts may also be related to EF development. And though Willoughby and colleagues (2018) did look at physical activity at home and at school, their sample was drawn from a consortium of schools that had a focus on increasing physical activity, which may mean these children represent a specific population where there was an inverse association between physical activity and EF. Or, these associations may be because children who are more active during the preschool period may actually be more hyperactive and have attention deficits (Biederman et al., 2004). Additionally, having a curricular emphasis on promoting physical activity may not engage children in activities that promote EF (e.g., circle time games, structured block play; Schmitt, Korucu, Napoli, Bryant, & Purpura, 2018; Schmitt et al., 2015; Tominey & McClelland, 2011).

Potential mechanisms. There are several explanations for potential mechanisms that may connect physical activity and EF including: 1) the cognitive demands associated with physical activity, 2) individual differences in children and environmental influences, and 3) shared neurological processes. Each of these provides a different perspective on why higher (or lower) levels of physical activity may be significantly associated with higher (or lower) levels of EF.

One mechanism that has been proposed to explain the potential association between physical activity and EF is rooted in the cognitive demands that physical activity often brings (Burack, Russo, Dawkins, & Huizinga, 2010). Scholars suggest that the use of higher order cognitive control processes that involve aspects of EF (e.g., attention, memory) are required during many forms of physical activity (Oberer, Gashaj, & Roebers, 2017). Thus, children may be indirectly practicing their EF skills when engaged in physical activity. Notably, studies have documented associations between martial arts participation (a form of physical activity that emphasizes inhibitory control and discipline within its practice; Diamond & Lee, 2011; Lakes & Hoyt, 2004) and EF in children from kindergarten to 5th grade (Lakes & Hoyt, 2004). This may be because while engaging in martial arts, children are asked to self-monitor their behavior, reorient their thoughts, and focus their attention on the current context while engaging in physical activity. Some theories even suggest that forms of physical activity embody cognition, suggesting that physical activity could play a role in memory, problem solving (aspects of EF; Barsalou, 1999; Boncoddo, Dixon, & Kelley, 2010) and EF development itself (Balcetis & Cole, 2009). For example, theoretical perspectives postulate that the mind uses perceptual and motor resources to represent and manipulate information (Balcetis & Cole, 2009). Balcetis and colleagues (2009) suggest that physical movements are a primary means to self-regulatory behaviors. Young children who are participating in physical activity are often being goal-oriented without being consciously aware. Even when playing games at recess like tag, children will run away from the person who is “it,” making their movements goal-oriented and related to memory and problem solving. Children have to remember who is “it” and also problem solve about where to go to stay “safe” from becoming the tagger. Similarly, when children participate in martial arts training, their movements are methodical and purposeful to achieve a certain pose or position that they need to remember and execute properly.

Another potential mechanism underlying the association between physical activity and EF stems from a socioecological lens (Oberer et al., 2017); individual differences in children and their environmental influences may also be at play. A child's individual interest in, as well as their opportunities for, physical activity may affect the association between physical activity and EF. For instance, children who are more interested in physical activities that involve aerobic exercise (e.g., running, swimming) may have fewer cognitive benefits from the physical activity in terms of their EF than children who are more interested in physical activities that include cognitive demands during play (e.g., structured sports: soccer, basketball). Environmental constraints may also play a role in what types of physical activity children may be able to participate in. Specifically, childhood sport participation seems to be more prevalent among children from higher-income families than children from lower-income homes (Clark, 2008; Holt, Kingsley, Tink, & Scherer, 2011). Researchers have found that financial barriers and less access to sport facilities are among the reasons low-income families have restricted access to sport participation (Gordon-Larsen, McMurray, & Popkin, 2000), perhaps limiting their choices in terms of which sports children are able to participate in.

A third potential mechanism that may explain an association between physical activity and EF has to do with shared neurological processes. Research using neuroimaging suggests that the brain areas involved in EF (cortical systems) are associated with the same areas involved in motor activity and coordination (e.g., cerebellum and basal nuclei; Davis et. al, 2011; Diamond, 2000). Research also finds that neural connections within the prefrontal cortex, an area critical to the development of EF (Luria et al., 1966; Shimamura, 2000; Stuss & Benson, 1984), are positively impacted by aerobic exercise, a component of physical activity (Best, 2010). Evidence suggests that the strength of these neural connections, as well their stimulation that results from physical activity, have been associated with EF in children ages 7-11 (Davis et al., 2011).

Structured Sport Participation and Executive Function

Scholars have started recognizing that specific types of physical activity may be more related to EF in children than others. For example, Best (2010) suggests that physical activities that include cognitive demands, such as structured sports (i.e., activities or games that have an end goal or objective), may be more strongly associated with EF than physical activities that do not include cognitive demands. One of these physical activities that includes cognitive demands and could facilitate EF growth in children is structured sport. Structured sports can be characterized as being open-skilled (externally paced) or closed-skilled (internally paced; Becker et al., 2018; Singer, 2000; van der Fels et al., 2015). Structured sports also include two types of rules, context specific rules (rules of the game that provide a framework for the competition) and general “guidelines” for success (the unspoken understanding of nuances that support success in the game; Burack et al., 2017); adherence to these rules likely involves all aspects of EF (Burack et al., 2017).

When children participate in a structured sport, they are expected to be able to hold on to these types of rules (i.e., working memory), inhibit impulses that align with the rules (i.e., inhibitory control), and adapt to changing rules and game contexts that continually shift (i.e., cognitive flexibility). As an illustration, when children participate in a soccer game they are implementing working memory and inhibitory control (e.g., scoring in one goal, but not the other; moving up and down a field, but staying within the confines of that field) as well as cognitive flexibility (e.g., transitioning from “offense” to “defense”). This management of multiple rules while reacting and adjusting to different contexts within a game may allow children to practice their EF skills while increasing activation in the cortical systems that involve EF (Lin et al., 2013; Saemi, Porter, Ghotbi-Varzaneh, Zarghami, & Maleki, 2012). Even though children aged 3-5 may be unable to consistently engage in the complex thought required to understand the nuances of structured sports, they *are* beginning to develop the capacity to understand rules and goal-oriented behaviors (Posner & Rothbart, 1998). This capacity may be particularly facilitated with adult support and scaffolding, which most structured sports at this age include.

The hypothesis that structured sport may be related to EF skills in early childhood is supported through evidence in older children and adults. For instance, one correlational study found that higher-level adult soccer players (i.e., high division players) had significantly stronger EF (measured using the D-KEFS test battery of executive functions) than lower-level adult soccer players (i.e., lower division players) and that both the higher and lower-level players had better EF than the group that did not play soccer at all (Vestberg, Gustafson, Maurex, Ingvar, & Petrovic, 2012). This finding suggests that participating in high-level soccer is associated with better EF skills (Vestberg et al., 2012); however, it is important to note that the reverse association may be true (higher EF skills may be related to high-level soccer). There is also emerging intervention work documenting a causal association between structured sport participation and EF for older children and adolescents. For example, one study found that 13-16 year olds who participated in structured sport exercises using modified sport and coordinative exercises adapted from soccer and the Munich Fitness Test (i.e., a tool used for scoring aspects of motor performance in healthy children using activities to asses several domains: power, endurance, strength, coordination, flexibility, speed, and coordination; Arikan et al., 2015) had enhanced EF (e.g., attention and concentration) relative to children who did not participate in these activities (Budde, Voelcker-Rehage, Pietraßyk-Kendziorra, Ribeiro, & Tidow, 2008). Similarly, Davis (et al., 2011) found that sedentary, overweight 7- to 11-year-olds who participated in high doses of structured sport activities (e.g., running, jump rope, basketball, and soccer) showed greater improvement on EF than those who did not perform the structured sport activities.

Despite the fact that both open- and closed-skilled sports include cognitive demands and may require varying levels of EF, the cognitive demands associated with open-skilled sports may be more complex than those required with close-skilled sports, therefore better facilitating EF growth. One study examining similar associations in children ages 8-9 found that there was a significant curvilinear association between EF and sport metabolic intensity (a physiological index that expresses energy expenditure during a given activity), but there was not a significant association between open-skilled sport participation and the Tower of Hanoi task used to assess general EF skills (Becker et al., 2018). Notably, this study only included children that played at least one sport, and it used participation in closed-skilled sports as a reference group. Investigating whether there are differential relations between open-skilled, closed-skilled, and mixed-skilled sport participation is important to fully examine how early sport participation may impact EF (Becker et al., 2018). These differential relations may appear because open-skilled sports require constant adaptation to changing contexts versus simply engaging in repetitive movement (e.g., closed-skilled sport; Becker et al., 2018; Burack et al., 2017). Furthermore, this study did not include whether mixed-skilled sport participation differed from closed- or open-skilled sport participation (Becker et al., 2018). In early childhood when sport participation is generally fun and exploratory, children may be participating in different types of sport activity. Thus, children who participate in interventions that combine aerobic activity with modified activities that elicit complex motor skills (e.g., kicking, throwing, or martial arts) have stronger EF skills than those who may just engage in aerobic activity (Budde et al., 2008; Davis et al., 2011). Therefore, those children engaging in both open- and closed- skilled structured sport may have stronger EF skills than those just participating in closed-skilled sports.

One important issue worth noting with regard to associations between structured sport participation and EF is that of directionality. In the current study, it was predicted that participation in structured sport will predict better EF rather than vice versa. Though there is a possibility that individuals with strong EF skills may engage in more structured sports than those with poor EF, there is reason to believe this would not be the case in early childhood. Children are often being exposed to structured sports for the first time during this development stage, and a majority of children participate in sports in childhood (Sabo, & Veliz, 2008). Because many children participate in sports during this time period as an attempt to be active and try new things, it is not likely that initial level of EF skills would be associated with specific sport participation. Also, in early childhood, strong EF skills are not *required* in order to be successful in structured sports like they may be in adolescence or adulthood as sport participation during this developmental stage is typically meant to be fun and non-competitive.

Previous research provides evidence to suggest that adults and older children may benefit from physical activity as well as structured sport participation, and particularly open-skilled sports, in terms of their EF skills. However, few studies have explored these associations in early childhood. The current studies sought to address these gaps in the EF literature. Two parallel studies were conducted that examined the associations between physical activity, structured sport participation, and EF in preschool.

Overview of the Present Studies

Both studies investigated the extent to which physical activity and structured sport participation is related to preschool children's EF skills. The first study examines this association with direct assessments of EF and parent-reported EF. The second study solely focuses on parent-reported assessments of EF. Specifically, the following research questions and hypotheses were addressed across both studies:

Research Question 1. Is level of physical activity (i.e., total number of minutes of physical activity on an average weekday; Dwyer et al., 2001) significantly related to preschool children's EF?

Hypothesis 1. Based on previous research demonstrating an association between physical activity and EF in adulthood (Hillman et al., 2008; Chaddock et al., 2011), middle childhood, and adolescence (Hinkle et al., 1993; Tomporowski et al., 2015; Tuckman & Hinkle, 1986; Uhrich & Swalm, 2007), and one study showing a significant relation between high levels of active play during recess and higher EF in preschool children (Becker et al., 2014), it was expected that children who engage in more frequent physical activity would have better EF.

Research Question 2. Is structured sport participation significantly related to preschool children's EF?

Hypothesis 2a. Based on prior work documenting a positive association between structured sport participation and EF in adults (Vestberg et al., 2012), adolescents (Budde et al., 2008) and children in middle childhood (Davis et al., 2011) it was hypothesized that preschool children who participate in structured sports would have stronger EF skills compared to children who do not participate in structured sports.

Hypothesis 2b. Due to evidence indicating an association between open-skilled sport participation and EF in adults (Vestberg et al., 2012), as well as evidence that older children who participate in open-skilled sports activities have stronger EF skills when compared to children who did not participate in any of those activities (Davis et al., 2011), it was predicted that children who participate in open-skilled sports would have higher EF skills than those children who participate in closed-skill sports or report no sport participation.

Hypothesis 2c. Deriving from prior studies that document an association between physical activity and EF in preschool aged children (Becker et al., 2014), structured-sport participation and EF in adults (Vestberg et al., 2012) and evidence that older children who participate in open-skilled sports activities have stronger EF skills when compared to children who did not participate in any of those activities (Davis et al., 2011) it was hypothesized that preschool children who participated in mixed-sport participation (both open and closed) would have stronger EF skills than those children who report no sport participation.

Hypothesis 2d. Based on previous literature suggesting children who engage in any type of aerobic activity still have stronger EF than those who do not (Hillman et al., 2008), and that older children who participate in closed-skilled-sport activities have stronger EF skills compared to children who do not participate in any sports (Davis et al., 2011), it was also predicted that children who participate in closed-skilled sports would have higher EF skills than those who report no sport participation.

Research Question 3. Is structured sport participation significantly related to preschool children's EF when accounting for physical activity?

Hypothesis 3a. Drawing on research showing that better EF is associated with open-skilled sport participation in adults (Vestberg et al., 2012), and older children who participate in open-skilled sport activities (Davis et al., 2011), it was predicted that children who participate in closed- and open-skilled sports would have higher EF skills than those children who report no sport participation, even after accounting for parent-reported physical activity.

Overview of Data Analysis for Both Studies

Data were analyzed using IBM SPSS Statistics 22. In each model, EF was used as a dependent variable as described below. The specific analyses for each proposed hypothesis are as follows:

Research Question 1. Is level of physical activity (i.e., total number of minutes of physical activity during an average weekday) significantly related to preschool children's EF?

Hypothesis 1a. To test the hypothesis that parent reports of greater physical activity would be positively related to EF, a series of regressions were conducted (Model 1). Control variables were entered along with parent report of physical activity. To determine whether physical activity was related to EF above and beyond the control variables, there needed to be a significant ($p < .05$) standardized β coefficient for physical activity. To examine this first hypothesis, separate regression models were run for each EF measure to test for differential relations among physical activity and the three components of EF as well as the various parent reports. Although a majority of the current literature suggests that EF is a unidimensional construct that is an integration of three components (working memory, inhibitory control, and cognitive flexibility; Bernier et al., 2015; Willoughby et al., 2012), in this study, we examined each EF component separately to explore potential differential relations across components and measures.

Research Question 2. Is structured sport participation significantly related to preschool children's EF?

Hypothesis 2a. To test the hypothesis that structured sport participation is associated better EF skills, a series of regressions were conducted (Model 2). Control variables were entered along with parent report of sport participation. To determine whether sport participation was related to EF above and beyond the control variables, there needed to be a significant ($p < .05$) standardized β coefficient for sport participation. Similar to research question 1, separate regression models were run for each EF measure.

Hypothesis 2b. To test the hypothesis that parent reports of children who participate in open-skilled sports would have higher EF skills than those children who participate in closed-skill sports or report no sport participation, regressions were conducted.

Hypothesis 2c. To test the hypothesis that children who participate in a mix of open- and closed-skilled sports (mixed-sport participation) would have higher EF skills than those who report no sport participation, regressions were conducted.

Hypothesis 2d. To test the hypothesis that children who participate in closed-skilled sports would have higher EF skills than those who report no sport participation, regressions were conducted.

Research Question 3. Is structured sport participation significantly related to preschool children's EF when accounting for physical activity?

Hypothesis 3a. To test the hypothesis that children who participate in structured sports would have higher EF skills than those children who report no sport participation, even after accounting for parent-reported physical activity, a series of hierarchical regressions were conducted (Model 3). Control variables were entered along with parent report of physical activity and parent reports of sport participation. To determine whether sport participation was related to EF above and beyond the control variables and above and beyond physical activity, there needed to be a significant ($p < .05$) standardized β coefficient for sport participation. Similar to the other hypotheses, separate regression models were run for each EF measure to test for differential relations among physical activity and the three components of EF.

STUDY 1

Study 1 focused on the extent to which physical activity and sport participation were associated with direct assessments and parent reports of EF in preschool.

Method

Participants

Data from this study came from a larger study exploring associations between aspects of the home and children's EF. Participants consisted of 197 parents and their preschool-aged children. This sample was recruited from local preschools, with over a third of the children attending a local Head Start program (33.5%). At the beginning of the study, children were approximately 4 years old (*M* = 4.34, *SD* = .68) and the sample was predominantly white (85%). The breakdown of family income was: <$40,000 = 35.0%; $41-75,000 = 17.3%; >$76,000 = 42.6%. Additionally, the breakdown for parent education levels was: high school and below = 24.9%; some college/Associates = 25.4%; Bachelor's and above = 49.7%.

Procedure

Participants were recruited during the 2017-2018 academic year. Consent forms were sent home to parents to review. Parents provided written consent for themselves and for their children to participate in the study. Following consent, parents completed a survey that included items assessing demographics, the home environment, children's physical activity and structured sport participation, and children's EF. Children participated in a short battery of direct EF assessments that took approximately 20 minutes. The assessment battery was administered by trained research assistants and took place in a quiet area at children's preschools.

Measures

Physical activity. Physical activity was assessed using parent report (see Appendix A). Parents were asked the following question about typical physical activity during the week: "On a typical weekday, how many minutes does your child exercise?" Similar to previous studies measuring child physical activity using questionnaires, physical activity was represented using a continuous variable (Dwyer et al., 2001; Uhrich & Swalm, 2007). There were some responses that were not used in the final models for a variety of reasons (e.g., "all day", "hours", "non-stop"; see Appendix B). Additionally, for parents who reported extreme durations of child physical activity (n = 5), we scored their child's physical activity to a maximum of 311.99 minutes (three standard deviations above the mean, M duration in minutes = 72.49, SD = 55.93). This method is considered a form of winsorizing (Dixon & Yuen, 1974).

Structured sport participation. Structured sport participation was also measured using parent report (see Appendix A). Specifically, parents were asked a question that was modified from the National Institute of Child Health and Human Development study (Study of Early Child Care and Youth Development; NICHD Early Child Care Research Network, 2006): "During the past year, did your child participate in any children's sports or sports teams?" If parents' response was no, this item was coded 0 (no structured sport participation). If parents' response was yes, this item was coded 1 (participated in structured sport), and parents were asked, "What did he/she participate in?" Similar to Voss, Kramer, Basak, Prakash, & Roberts (2010) and Becker et al. (2018), sports were excluded if they did not include a level of continuous leg or arm movements (e.g., golf). Sports were also excluded if they were not included in the NICHD criteria (see Appendix B for excluded and included structured sports). Structured sport participation was then conceptualized in four different ways. The first conceptualization was focused on whether children participated in any type of structured sport. Similar to Becker (et al., 2018), another variable was created for the second conceptualization: whether the children participated in open-, closed- or mixed-skilled sports. These responses were coded as dummy variables to represent these categories. These criteria were based on previous literature examining differences in open-skilled (i.e., baseball/softball; martial arts; hockey: field, roller, ice; tennis; football; soccer; basketball; volleyball) and closed-skilled (i.e., swimming; cheerleading; skating: inline, ice; track and field; dance: team/group; skateboarding) structured sports as well as those involved in mixed-sport participation (Becker et al., 2018; Singer, 2000; van der Fels et al., 2015). The third conceptualization of sport participation examined whether children participated in a team sport, individual sport, or participation in both. These were coded as dummy variables for the final models. Finally, sport participation was categorized depending on whether the child participated in one sport or two or more sports. These variables were coded as dummy variables for analyses.

Parent-reported executive function. The inhibitory control and attention focusing subscales of the Children's Behavior Questionnaire-Short Form (CBQ-SF; Putnam & Rothbart, 2006) was used as a parent-reported assessment of EF.

Children's Behavior Questionnaire-Short Form (CBQ-SF). The CBQ-SF is a 25-item parent-report measure designed to assess multiple dimensions of 3- to 7-year-old children's temperament (Putnam & Rothbart, 2006). Of the 15 possible dimensions included in this measure, two subscales reflecting children's EF were used (i.e., inhibitory control and attention focusing), which include 12-items, with six items for each subscale. Parents rated the 12 items on a 7-point scale ranging from: "1 = *extremely untrue of your child*" to "7 = *extremely true of your child*." For example, within the inhibitory control subscale, parents were asked to state whether the child "[is] good at following instructions" or "can easily stop an activity when s/he is told 'no.'" Within the attention focusing subscale, parents are asked: "When practicing an activity, has hard time keeping her/his mind on it" and "Is easily distracted when listening to a story." The two subscales are reported to have good reliability (inhibitory control, α = .60; attention focusing, α = .70).

Direct assessments of executive function. The following direct assessments of EF were used: the Head-Toes-Knees-Shoulders (HTKS) task (McClelland et al., 2014), the Day/Night Stroop task (Gerstadt, Hong, & Diamond, 1994), the Dimensional Change Card Sort (DCCS; Frye, Zelazo, & Paflfai, 1995; Zelazo et al., 2003), and the Backward Digit Span task (Carlson, 2005; Davis & Pratt, 1996).

Head-Toes-Knees-Shoulders task. The HTKS is a behavioral measure that directly taps into all three components of EF (cognitive flexibility, inhibitory control, working memory), and is typically used with children ages 3-7 (McClelland et al., 2014). In the practice round, children are first asked to respond by following the directions naturally (e.g., Touch your head), and then they are asked to respond in the opposite way (e.g., children are asked to touch their heads when the research assistant says, "Touch your toes"). The testing portion consists of 30 items (three sections of ten), and the sections get increasingly complex as the child progresses. In order to progress to the second section, a child has to receive a score of at least 4 on the first section, and similarly, in order to progress to the third section, a child has to receive a score of at least 4 on the second section. Each correct response is worth two points, making the range of possible scores 0-60. Each item is scored as 0 (incorrect), 1 (self-correct), or 2 (correct). The total score of the test is the sum of all the correct items. This task takes approximately 5-10 minutes to complete. The interrater reliability, scoring agreement, and test-retest reliability is high and shows strong predictive validity (McClelland et al., 2014). The HTKS has moderate to strong effect sizes predicting achievement levels and gains across multiple studies in pre-k and kindergarten-aged children (McClelland et al., 2014; Ponitz et al., 2008; Wanless, McClelland, Acock, Chen, & Chen 2011).

Day-Night Stroop. The Day-Night Stroop task (DNS; Gerstadt et al., 1994) primarily assesses children's inhibitory control. During the DNS task, children are asked to inhibit instinctual responses when they are presented with 16 cards with images of a sun or moon. The children are instructed to say the opposite of what they see on the card by saying "night" when they are presented with the sun card and "day" when they are presented with the moon card. Each item is scored as 0 (incorrect/non-responses), 1 (correct), or 2 (self-corrected/similar), with a total score range of 0-32. The DNS has high internal consistency in preschool-aged children (Gerstadt et al., 1994).

Dimensional Change Card Sort. The Dimensional Change Card Sort (DCCS; Frye et al., 1995; Zelazo et al., 2003) primarily assesses children's cognitive flexibility and is a well-established measure for this component of EF. The DCCS task has up to 24 items, with each sorting trial containing 6 items. During the DCCS, children are introduced to colored picture cards that contain a dog, fish, or bird and are asked to sort these cards based on color, shape, and size. The children are given four sorting boxes that have target cards (e.g., a dog, fish, bird or frog) fixed to the front of the boxes. During the first trial, children are asked to sort on the basis shape (e.g., the fish cards go in the box with a fish fixed to the front). They are given a target card and asked, "Where does this one go?" For the next six items, children are asked to sort on the basis of color. For the third set of six items, children are asked to sort on the basis of size. If the children score five or more points on this third section, they are administered a fourth set of items with a new rule: when the card has a black border on it, children are asked to sort on the basis of size, and when the card does not have a black border, children are asked to sort on the basis of color. Children are given a score of 0 (incorrect response) or 1 (correct response) for each item, with the possible scores ranging from 0-24. This measure has strong reliability in previous research (Hongwanishkul, Happaney, Lee, & Zelazo, 2005).

Backward Digit Span. The backward digit span task (Carlson, 2005; Davis & Pratt, 1996) primarily assesses children's working memory. During this task, children are first introduced to a puppet (e.g., an elephant, hippo, hedgehog, or cat). Then, the research assistant says, "Sometimes my friend [animal name] likes to be silly and say the words I say backwards. If I say 1-2, [animal name] says 2-1. Let's try: 1-2. What would [animal name] say?" After this introduction, the children are invited to use the same example and say the string of numbers backward (e.g., saying "2, 1"). For the testing items, the string of numbers starts with two digits (e.g., "3, 2") and increases to up to seven digits, or until the child gets three consecutive items incorrect. Scores are calculated by using the number of correct trials completed. Children receive 0 (incorrect responses) or 1 (correct response) for each response. This measure has been reported to have good reliability for preschool aged children (ICC = .84; Müller, Kerns, & Konkin, 2012).

Covariates. Child age, parent education, race, income, and gender (male = 1) were used as control variables in all analyses because of their robust connections with EF (Bernier, Carlson, & Whipple, 2010; Frye et al., 1998; Hughes & Ensor, 2009; Matthews, Ponitz, & Morrison, 2009; Ponitz et al., 2008; Wanless, et al., 2011). Parent education was assessed by asking the parent to report their highest level of education: 1 = *8th grade or less*, 2 = *some high school*, 3 = GED, 4 = *high school diploma*, 5 = *some college*, 6 = *Associate's degree*, 7 = *Bachelor's degree*, 8 = *Master's degree*, and 9 = *Doctoral/postgraduate*. Parent education was then coded into three categories: High school and below, Some college/Associate's, Bachelor's and above. Parent income was also assessed by asking the parent to report their yearly income: 1 = *$5,000*, 2 = *$10,000*, 3 = *$15,000*, 4 = *$20,000*, 5 = *$25,000*, 6 = *$30,000*, 7 = *$31-40,000*, 8 = *$41-50,000*, 9 = *$51-75,000*, 10 = *$76-100,000*, 11 = *$101-125,000*, 12 = *$126-150,000*, 13 = *$151-175,000*, and 13 = *higher than $175,000*. Income was then coded into three categories: $40,000 and below, $41-75,000, and $76,000 and above.

Analytic Strategy

Data were analyzed using a series of regressions in IBM SPSS Statistics 22. In each model, EF was used as a dependent variable and child age, parent education, race, income, and gender were used as control variables in all analyses.

Results

Prior to conducting the main analyses, descriptive statistics were calculated for each variable in the analyses. On average, participants scored 15.79 points on the HTKS (*SD* = 17.42), 12.21 points on the DCCS (*SD* = 6.57), 17.71 points on the DNS (*SD* = 9.25), 0.56 points on the BDS (S*D* = 1.13), 4.86 points on the CBQ-AF (*SD* = .98), and 4.79 points on the CBQ-IC, (*SD* = .94). Full descriptive statistics for Study 1 are in Table 1.

Correlations of all key independent and dependent variables for Study 1 are presented in Table 2. Physical activity was not significantly correlated with any of the EF tasks, but was significantly correlated with gender ($r = .15$, $p = .035$). When sport participation was conceptualized as a dichotomous variable (whether children participated in sport or not), it was significantly correlated with all of the EF tasks, where the highest correlations were with DCCS ($r = .39$, $p < .001$), HTKS ($r = .30$, $p < .001$), and BDS ($r = .29$, $p < .001$).

Model 1 – Is level of physical activity significantly associated with executive function?

Model 1 examined whether physical activity significantly predicted EF scores across the tasks. It was hypothesized that parent reports of more physical activity would be positively related to EF skills. Contrary to our hypotheses, average physical activity on a typical weekday was not significantly associated with EF scores on any of the direct assessments or parent reports, after controlling for age, race, income, parent education, and gender (see Tables 4-9 for the full Study 1 results in Model 1 by assessment).

Model 2 – Is structured sport participation associated with executive function?

Model 2 examined whether structured sport participation (1 = child participated in a structured sport; 0 = child did not participate in a structured sport) was related to EF. It was hypothesized that participation in a structured sport would be associated with higher EF scores (Hypothesis 2a). It was also hypothesized that children who participated in open-skilled sports would have higher EF than those who participated in closed-skilled sports and those who reported no sport participation (Hypothesis 2b) The last part of the main hypotheses stated that children who participate in mixed-skilled sports would have higher EF skills than those who reported no sport participation (Hypothesis 2c), and that children who participate in closed-skilled sports will have higher EF than those who report no sport participation (Hypothesis 2d).

Partially as predicted, sport participation significantly predicted EF, but for just one of the direct assessments. Specifically, sport participation was significantly and positively related to the DCCS (β = .30, p = .026), but was not significantly related to any of the other EF tasks.

When sport was conceptualized as open, closed, or mixed, there was a significant association between sport participation and two of the EF tasks: the DCCS and BDS. As predicted, participation in open-skilled sports (vs. no sport participation) was associated with higher DCCS scores (β = .36, p = .022). Additionally, participation in mixed-skilled sports (relative to no sport participation) was associated with higher BDS scores (β = .59, p = .023). The association between open-skilled sport participation and EF scores was not found for the other EF tasks, nor was the association between mixed-skilled sport participation. Furthermore, none of the other hypothesized associations between sport participation and EF were significant.

Additional models were conducted to further investigate associations between specific aspects of sport participation and EF. Sport participation was conceptualized in two other ways: number of sports participated in (0, 1, 2+) and team or individual sport. When sport was conceptualized as looking at the number of sports a child participated in (0, 1, 2+), similarly to the other additional models, there was a significant association between sport participation and two EF tasks for Study 1: DCCS and BDS. Participation in one sport (relative to no sport participation) was significantly associated with DCCS scores (β = .31, p = .028); however, participation in two or more sports (relative to no sport participation) was significantly associated with BDS scores (β = .48, p = .027). When sport was conceptualized as team sport, individual sport, or participation in both team and individual sports, there was a significant association between sport participation and the DCCS and BDS tasks. Specifically, there was a significant association between participation in an individual sport and DCCS scores (β = .37, p = .025). Participation in both team and individual sports was significantly associated with BDS scores (β = .54, p = .033).

Model 3 – Is sport participation associated with executive function above and beyond physical activity?

Model 3 examined whether sport participation predicted EF skills above and beyond average physical activity. It was hypothesized that children who participate in closed- and open-skilled sports would have higher EF skills than those children who report no sport participation, even after accounting for parent-reported physical activity (Hypothesis 3a).

Similar to the second model for Study 1, we found that sport participation only predicted DCCS scores above and beyond physical activity (β = .30, p = .026). When conceptualizing sport in the other variations (open-skilled, closed-skilled, mixed; 0, 1, 2+; team, individual, both), none of the conclusions or findings from Model 2 changed with the inclusion of physical activity as a control variable for Study 1 (see Figure 1 for additional model results for Study 1). Like Model 2, the analyses indicated that the association between sport participation and DCCS scores seem to be linked with any type of participation, whereas BDS scores seemed contingent on greater sport involvement.

Discussion

The present study examined whether children who engaged in physical activity or participated in a structured sport in preschool had significantly higher levels of EF. Multiple OLS regressions were employed to test the associations between physical activity and EF (Model 1) and sport participation and EF (Models 2 and 3). Results for Model 1 indicated that physical activity was not significantly related to direct assessments or parent reports of EF. Results for Model 2 demonstrated that various conceptualizations of sport participation were significantly associated with cognitive flexibility (the DCCS task) and working memory (the BDS task), but were not associated with assessments examining inhibitory control or a global measure of EF. Results for Model 3 corroborated the results from Model 2, even with the inclusion of physical activity. Although there were some significant findings, in the majority of the models, physical activity and sport participation were not associated with any of the EF tasks. These findings contribute to an emerging body of literature that examines the associations between physical activity and EF in early childhood, suggesting that there may not be a relation between general physical activity and EF, but there may be links between sport participation and aspects of EF (i.e., cognitive flexibility and working memory). It will be critical for future research to continue to explore the connections between physical activity, sport participation, and EF in young children, as this study is among the first to do so in preschool-aged children.

Physical Activity and Executive Function

Results from the current study suggest that children who are more physically active do not necessarily have higher levels of EF, based on direct assessments and parent reports. This finding was contrary to our hypotheses and was inconsistent with research examining the same association in adulthood (Chaddock et al., 2011; Hawkins et al., 1992) as well as adolescence and middle childhood (Davis et al., 2011; Ellemberg & St-Louis-Deschênes, 2010; Tomporowski et al., 2008). These findings are also inconsistent with the few studies that have examined this association in early childhood (Becker et al., 2014; Willoughby et al., 2018). Whereas Becker et al. (2014) found a significant positive association between physical activity and EF, Willoughby et al. (2018) found a significant negative association between these domains. Differences in measurement of key constructs and samples across studies may contribute to the disparate findings.

In contrast to the present study, Becker and colleagues (2014) specifically examined physical activity during recess. Recess time usually takes place on playgrounds, which are specifically designed to promote physical activity (Broekhuzien, Scholten, & de Vries, 2014; Reimer & Knapp, 2017). Provision of equipment, size, and even playground density (children per square meter) are associated with higher levels of physical activity (Broekhuizen et al., 2014). Recess is a context that may elicit the types of physical activity that are more supportive of EF growth through specific types of play in a semi-structured environment. For example, recess is designed to support social interactions and to develop fundamental motor skills (Quigg, Reeder, Gray, Holt, & Waters, 2012), which are both associated with EF (Aadland et al., 2017; Cole, Usher, & Cargo, 1993; Hughes, White, Sharpen, & Dunn, 2000; Kamijo et al., 2011; Moyes, 2014). Thus, it may be that physical activity as measured during recess is embedded in these other domains which may then contribute to EF development (Curlik, Ii, & Shors, 2013; Koutsandréou, Wegner, Niemann, & Budde, 2016).

In the present study, physical activity was conceptualized more broadly, attempting to capture how active children are generally during a typical weekday. Assessing parents' perceptions of physical activity across a typical day may not capture the types of active play that occur during recess, and thus, this conceptualization of physical activity may not be associated with EF. Alternatively, parents perceptions of physical activity may be more representative of hyperactivity, which is related to poor EF (Makris, Biederman, Monuteaux, & Seidman, 2009; Pauli-Pott & Becker, 2011; Pennington, 2005). These differences in measurement may be a reason results in the present study did not point to significant associations between physical activity and EF like the Becker et al. (2014) study.

Our non-significant findings were also inconsistent with another recent study that examined the association between physical activity and EF in early childhood. In contrast to Becker et al. (2014), Willoughby and colleagues (2018) found that individual differences in sedentary behavior and light physical activity were unrelated to EF, but moderate to vigorous physical activity was inversely related to EF. Similar to the current study, Willoughby and colleagues assessed physical activity beyond recess. However, rather than asking parents to report on children's physical activity during a typical day, they assessed physical activity over a three-to-five-day span during school and at home, with the exception of bath-time, activities with water, and non-waking hours. As noted by the authors, children who were in the moderate-to-vigorous groups may have been disproportionally hyperactive and less likely to engage in activities that would facilitate EF growth (Willoughby et al., 2018). Further, Willoughby et al. recruited from preschools that were part of a public-private consortium seeking to increase physical activity and wellness of preschool children. Active recruitment of a specific consortium may mean that these children represent a specific population where the association between physical activity and EF may not exist. A curricular emphasis to promote physical activity may not translate into children engaging in physical activities that would also promote the development of EF. It is possible there was too much emphasis on physical activity and wellness and not a focus on activities that may promote EF (e.g., circle time games, structured block play; Schmitt et al., 2018; Schmitt et al., 2015; Tominey & McClelland, 2011).

Additionally, both Becker et al. (2014) and Willoughby et al., (2018) used accelerometers to detect activity patterns in young children, whereas the present study relied on parent reports of average physical activity during a typical weekday. Although there are benefits to using parent reports (e.g., low resource), these assessments also carry significant limitations (Ainsworth, Montoye, & Leon, 1994; Sallis & Saelens, 2000). For example, social desirability bias can lead to over-reporting of physical activity (Warnecke et al., 1997), and estimating physical activity is a challenging task, potentially leading to errors in accurate recall (Baranowski, 1988; Troiano et al., 2008). When comparing objective measures (accelerometer data) and subjective measures (parent reports) of physical activity, objective measures are usually a more accurate representation of energy expenditure (Troiano et al., 2008). Unlike the parent reports of physical activity in the current study, using objective measures of physical activity, like accelerometers, may be more useful in capturing how active children actually are in school and home settings (Bassett & Strath, 2002; Troiano, 2006).

Although measurement and sample differences may have played a role in discrepant findings across these studies, it is also possible that physical activity may not be related to individual differences in EF in young children. Acknowledging that there is correlational and causal evidence to support an association between physical activity and EF in adulthood (Chaddock et al., 2011, Hawkins et al., 1992; Hillman et al., 2008), evidence of this association in mid-to-late childhood is less clear. Developmental differences may be the reason for these discrepant findings. For adults, physical activity is typically intentional and is a known predictor of many positive health outcomes and enhanced cognitive function (e.g., reduced anxiety, depression, improved physical self-worth; Biddle & Ekkekakis, 2005; Chaddock et al., 2011; Hawkins et al., 1992). Further, adults who are inactive are more likely to have health problems and cognitive decline (e.g., increased cardiovascular disease risk, lower physical mobility; Gennuso et al., 2013; Seguin et al., 2012 Stamatakis et al., 2012; Weuve et al., 2004; Xu et al., 2011). Thus, the association between physical activity and EF in adults may be stronger. However, for young children, physical activity may be more natural and part of play and not necessarily as strongly linked with cognition.

Studies that have found an association between physical activity and EF in older children have often measured physical activity as varying aerobic activities (running, basketball, soccer; Davis et al., 2011), whereas the studies that have not found significant associations have often measured physical activity as general exercise or as running (e.g., sprinting, relays, and distance runs; Best, 2010; Tomporowski et al., 2015). Consequently, it also may be more important to consider the types of physical activities that young children are engaging in and what types of cognitive components (e.g., planning, concentrating) those physical activities demand when considering the association with EF. This argument is tied to a potential mechanism that may connect physical activity with EF: use of higher order cognitive processes that involve EF (e.g., attention, memory) are required during certain forms of physical activity (Oberer et al., 2017). Though we did not find an association with parent reports of EF and physical activity in this sample, future research should not only ask about time spent being active, but try to explore *how* children are being active.

Relatedly, it is important to re-evaluate other potential mechanisms that may link physical activity and EF, such as differences in children's individual interests and opportunities for physical activity. There is evidence to suggest that the built environment is an important determinant of physical activity (Gordon-Larsen, Nelson, Page, & Popkin, 2006). For example, lower quality built environments (e.g., safety issues, unappealing aesthetic) and lower access to high quality built environments (e.g., free parks, sidewalk connectivity, accessibility) are associated with physical inactivity (Heinrich et al., 2008). If a neighborhood park feels unsafe, even though it has free access, children are likely not going to be playing in that area. Research also suggests that sport participation is more common for children from higher-income families versus their lower-income counterparts, likely due to less access to sport facilities and/or less ability to pay to participate (Clark, 2008; Gordon-Larsen, et al., 2000; Holt et al., 2011). Though we cannot address these issues about safety concerns and the built environment with the current data, this could have played a role on how physically active children were in the present study. Future research should continue to examine the built environment and its impact on physical activity in early childhood.

Sport Participation and Executive Function

Results from the current study partially supported the hypothesis that sport participation is related to EF in preschoolers, and significant associations were dependent on how sport participation was conceptualized. Specifically, children who participated in a structured sport had higher cognitive flexibility, as measured by the DCCS, but this association did not hold across any of the other parent reports or direct assessments of EF. When sport was conceptualized as open, closed, or mixed, open-skilled sport participation was associated with DCCS scores and mixed-skilled sport participation was associated with children's working memory, as measured by the BDS task. Although these two associations partially confirmed our hypotheses, it is important to note that the majority of the models did not point to significant associations between sport participation and EF.

Additional exploratory models were conducted to probe whether other conceptualizations of sport participation were related to EF. When sport was conceptualized by number of sports a child participated in (0, 1, 2+), participation in one sport (relative to no sport participation) was significantly associated with DCCS scores and participation in two or more sports (relative to no sport participation) was significantly associated with BDS scores. When sport was conceptualized as team sport, individual sport, or participation in both team and individual sports, there was a significant association between participation in an individual sport and DCCS scores. Participation in both team and individual sports was significantly associated with BDS scores.

The significant associations between sport participation and EF tasks from the present study are congruent with theory suggesting that structured sport may facilitate EF development because it has context specific rules and it requires children to hold on to these rules (i.e., working memory) while adapting to changing rules and game contexts that continually shift (i.e., cognitive flexibility; Burack et al., 2017). Our significant findings are also consistent with research that has demonstrated similar associations in adulthood (Jacobson & Matthaeus, 2014; Vestberg et al., 2012) and are in line with intervention work in adolescents (Budde et al., 2008) and children ages 7-11 (Davis et al., 2011). For example, Davis et al. (2011) found that engaging in an intervention with structured sport activities (e.g., modified basketball and soccer) led to higher EF skills in children as measured by the Planning scale of the Cognitive Assessment System (Naglieri & Das, 1997). However, as noted, our significant findings were centered around two aspects of EF: cognitive flexibility and working memory.

Cognitive Flexibility. Cognitive flexibility is the ability to shift attention and focus on a goal or meeting the demands of a task (Garon et al., 2008), and is demonstrated when children are able to successfully transition and adapt to varying contexts (e.g., rules and routines in the home versus rules and routines at school). There are a few reasons why sport participation (i.e., participating in either a structured sport, an open-skilled sport, or at least one sport) may be related to young children's concurrent cognitive flexibility.

First, because structured sports are goal-oriented and have shifting contexts (e.g., transitioning from "offense" to "defense" or speeding up as an opponent gets closer), it is possible that participating in these activities allows children to practice their cognitive flexibility. As opposed to close-skilled sports, open-skilled sports may specifically relate to cognitive flexibility because there are typically more rule changes and shifts in context. For example, within a soccer game, children are asked to be concurrently aware of multiple shifting contexts: knowing who has possession of the ball (offense or defense), moving with the play across the field (to the opponent's offensive half, to the opponent's defensive half), and being aware of what their individual position is (i.e., defender, forward, midfielder). Alternatively, during a race in a cross-country meet (i.e., closed-skilled sport), there are fewer contexts that concurrently need attention: speeding up as an opponent gets closer or timing their pace in order to effectively maintain stamina throughout the race. Cognitive flexibility builds on the development of working memory and inhibitory control (Garon et al., 2008), and because open-skilled sports may be more cognitively complex than closed-skilled sports, participation in open-skilled sport may better facilitate the cognitive flexibility component of EF.

Working Memory. Results from the present study suggest that various conceptualizations of sport participation (i.e., mixed-skilled sport participation, participation in two or more sports) were significantly associated with working memory, as assessed by the BDS task. Working memory is the ability to hold information in mind while keeping it accessible for use and is demonstrated when children are able to remember multi-step instructions or rules. Open- and closed-skilled sports have multiple explicit and implicit rules that need to be followed and maintained (Burack et al., 2017). In order to remember all of those rules and keep them actively accessible for use, children need to engage their working memory. During a soccer game, for example, children have ample opportunity to use and practice their working memory skills. For example, they need to remember which direction they are going, the roles of their position, and the rules of the game. Similarly, children use their working memory in closed-skilled sports like swimming. Swimmers have to remember to stay in their lane, properly execute a specific stroke, time their breathing in the most efficient way, and keep track of what lap they are on in a relay. Working memory is likely used in a similar way across team (e.g., soccer, basketball, baseball) and individual sports (e.g., swimming, running). Participation in two or more could be particularly important for working memory given that a child would need to understand different rules and contexts *across* different sports, perhaps requiring a stronger set of working memory skills.

Interpretation of Nonsignificant Findings

Although a few of the findings were significant, the majority of the associations between structured sport and EF tasks were non-significant, and thus it is important for future research to continue to explore whether there is a relation between structured sport and EF in preschool. It is possible that, in contrast to adolescents (Budde et al., 2008) and older children (Davis et al., 2011), preschool-aged children are too young to experience the benefits of sport for EF. As noted in the introduction, preschool-aged children may be unable to consistently engage in the complex thought required to understand the nuances of a structured sport, even if they are beginning to understand these rules and goal-oriented behaviors (Posner & Rothbart, 1998). Additionally, these rules and goal-oriented behaviors may be enforced by scaffolding during sport, either by a parent or a coach. Therefore, a potential mechanism that could better inform the association between structured sport participation and EF in early childhood could be the use of scaffolding by parents and coaches.

The null findings could also be the result of measurement issues. For example, our measure of sport participation was limited in that we simply asked parents to report on whether their child participated in any sports in the last year. We did not ask parents to report on dosage (e.g., how often they practiced/played) or duration (e.g., how long each practice was) of sport participation, which may be important to consider. Furthermore, even if there were reports of dosage and duration of practices, there still could be individual differences among children in how they engage physically and cognitively at practices and games. Simply being at a practice or a game may not be enough for children to see benefits for their EF. Children may have to be actively engaged in all of the practices, drills, and game-time situations. Another methodological issue to consider is the role of parent reports. As noted in the physical activity section, social desirability bias can lead to over-reporting of physical activity in parent reports (Warnecke et al., 1997), which may also impact reporting of *types* of physical activity, like structured sport. Thus, future research should emphasize using objective measures of structured sports or including additional probing questions in parent reports about the type, duration, dosage of those activities (e.g., daily diaries, additional questions).

Despite the methodological limitations, these null findings are consistent with a recent study that examined a similar association in 3rd grade children (Becker et al., 2018). In a sample of 8-9-year-old children, Becker and colleagues examined whether sport metabolic intensity (a physiological index that expresses energy expenditure during a given activity; Ainsworth et al., 2011), open-skilled sport, or the interaction between metabolic intensity and number of open-skilled sports were related to EF, literacy, and math. Whereas, Becker et al. did find a significant curvilinear association between EF and sport metabolic intensity, there was not a significant association between open-skilled sport participation and the Tower of Hanoi task used to assess general EF skills (i.e., inhibitory control, set shifting, and working memory; Best & Miller, 2010; Borys, Spitz, & Dorans, 1982). However, it is important to note that Becker and colleagues used a different sample by only including children in the study who played at least one sport, using participation in closed-skilled sports as a reference group (if it was the only type of sport children participated in), and not including whether mixed-skilled sport participation differed from closed- or open-skilled sport participation. We attempted to replicate this approach by using closed-skilled sports as the reference group, and the null findings remained. We were not able to include metabolic intensity in our models, which will be important for future research.

STUDY 2

Study 2 explored the associations between physical activity, sport participation, and parent-reported EF in a larger sample of parents of preschool children.

Method

Participants

Data from this study came from a larger study exploring associations between aspects of the home and children's EF. Participants consisted of 1012 parents of preschool-aged children. At the beginning of the study, on average, children 4 years of age (*M* months of age = 51.59, *SD* = 9.94) and the sample was predominantly white (65%). The breakdown of yearly family income was: <$40,000 = 39.0%; $41-75,000 = 32.4%; >$76,000 = 28.6%. The breakdown of parent education levels: High school and below = 9.6%; some college/Associates = 36.1%; Bachelor's and above = 54.3%.

Procedure

The sample was recruited during the 2017-2018 academic year using an online tool, Amazon's Mechanical Turk (MTurk), which allows for an inexpensive and rapid sampling method that can provide high quality data using diverse and representative samples (Burhmester et al., 2011). Following consent, parents completed a comprehensive survey that included items assessing demographics, the home environment, children's physical activity and structured sport participation, and children's EF.

Measures

Physical activity. Physical activity was assessed the same way as in Study 1 (see above). Similar to Study 1, for parents who reported extreme durations of child physical activity (n = 40), we scored their child's physical activity to a maximum of 288.64 minutes (three standard deviations above the mean, M duration in minutes = 63.26, SD = 75.13). This method is considered a form of winsorizing (Dixon & Yuen, 1974).

Structured sport participation. The same assessment for structured sport participation was utilized across both studies (see above).

Parent-reported executive function. The following parent report assessments were used to assess children's EF: Ratings of Every Day Executive Function (REEF; Nilsen, Huyder, McAuley, & Libermann, 2017), the Childhood Executive Functioning Inventory (CHEXI; Thorell & Nyberg, 2008), and the inhibitory control and attention focusing subscales of the Children's Behavior Questionnaire-Short Form (CBQ-SF; Putnam & Rothbart, 2006).

Ratings of Everyday Executive Functioning (REEF). The REEF is a 76-item, parent-report questionnaire that captures every day, observable behaviors of preschool-aged children that reflect their global EF skills (e.g., all three components of EF; Nilsen et al., 2017). Example items include: "Waits for you to finish on the phone before seeking your attention", "Fetches all items requested by adult [e.g., Does not forget what he/she was asked to get]," "Rephrases language when another person doesn't understand what he/she is saying"), "Recovers quickly from a disappointment or change in plans)," and "Plans ahead when playing games [e.g., what he/she should do on the next turn])." Parents are asked to acknowledge if they have observed the particular behavior or not in their child's every day functioning. Parents are asked to respond based on a forced-choice scale: "0 = *is not able*," "1 = *never or almost never*," "2 = *sometimes*," or "3 = *always or almost always*." The REEF had high internal consistency in our sample (α = .98).

Childhood Executive Functioning Inventory (CHEXI). The CHEXI is a 24-item, parent-report measure of EF for children ages 4- to 12-years-old. Parents are asked to rate their child on items using a 5-point Likert scale consisting of the following choices: "1 = *Definitely not true,*" "2 = *Not true,*" "3 = *Partially true,*" "4 = *True,*" and, "5 = *Definitely true*." The CHEXI consists of two factors: Inhibition (11 items) and Working Memory (13 items). The Inhibition factor consists of two subscales (i.e., inhibition and regulation) and assesses a child's difficulty in stopping inappropriate behavior and maintaining on-task behaviors (e.g., "Gets overly excited when something special is going to happen [e.g., going on a fieldtrip, going to a party])." The Working Memory factor also consists of two subscales (i.e., working memory and planning) and assesses a child's ability to hold information in mind or plan/organize activities (e.g., "When asked to do several things, he/she only remembers the first or last;" Thorell & Nyberg, 2008). The CHEXI had high reliability for our sample (α = .95).

Children's Behavior Questionnaire-Short Form (CBQ-SF). As listed above in Study 1, the CBQ-SF is a 25-item parent-report measure designed to assess multiple dimensions of 3- to 7-year-old children's temperament (Putnam & Rothbart, 2006). Two subscales reflecting children's EF (i.e., inhibitory control and attention focusing) were used, which include 12-items, with six items for each subscale. Parents rated the 12 items on a 7-point scale ranging from: "1 = *extremely untrue of your child*" to "7 = *extremely true of your child*." The two subscales are reported to have good reliability and validity (inhibitory control, α = .72; attention focusing, α = .75; Putnam & Rothbart, 2006). In our sample, we found similar reliabilities (inhibitory control, α = .64; attention focusing, α = .72).

Covariates. Child age, parent education, race, and income were used as control variables in all analyses because of their robust connections with EF (Bernier et al., 2010; Frye et al., 1998; Hughes & Ensor, 2009; Matthews et al., 2009; Ponitz et al., 2008; Wanless, et al., 2011). Parent education was assessed by asking the parent to report their highest level of education using the same scale as Study 1: 1 = *8th grade or less*, 2 = *some high school*, 3 = GED, 4 = *high school diploma*, 5 = *some college*, 6 = *Associate's degree*, 7 = *Bachelor's degree*, 8 = *Master's degree*, and 9 =*Doctoral/postgraduate*. Parent education was then coded into three categories: High school and below, Some college/Associate's, Bachelor's and above. Parent income was also assessed by asking the parent to report their yearly income using the same scale as Study 1: 1 = *$5,000*, 2 = *$10,000*, 3 = *$15,000*, 4 = *$20,000*, 5 = *$25,000*, 6 = *$30,000*, 7 = *$31-40,000*, 8 = *$41-50,000*, 9 = *$51-75,000*, 10 = *$76-100,000*, 11 = *$101-125,000*, 12 = *$126-150,000*, 13 = *$151-175,000*, and 13 = *higher than $175,000*. Income was then coded into three categories: $40,000 and below, $41-75,000, and $76,000 and above.

Analytic Strategy

As discussed above, data were analyzed using a series of hierarchical regressions in IBM SPSS Statistics 22. In each model, EF was used as a dependent variable and child age, parent education, race, and income were used as control variables.

Results

Prior to conducting the main analyses, descriptive statistics were calculated for each variable in the analyses. On average, children scored 2.98 points on the REEF (*SD* = .47), 3.47 points on the CHEXI-WM (*SD* = .82), 3.09 points on the CHEXI-IC (*SD* = .78), 3.77 points on the CBQ-AF (*SD* = .97), and 4.50 points on the CBQ-IC (*SD* = .93). Full descriptive statistics for Study 2 are in Table 1.

Correlations of all key independent and dependent variables for Study 2 are presented in Table 2. Physical activity was significantly correlated with only one of the EF tasks, CHEXI-WM ($r = .07$, $p = .021$). Physical activity was significantly correlated with the following covariates: White ($r = .13$, $p < .001$), Income less than $40,000 ($r = -.12$, $p < .001$), Income between $41-75,000 ($r = .07$, $p = .025$), Parent Education at College/Associates ($r = .07$, $p = .034$) and Parent Education at Bachelor's and above ($r = -.09$, $p = .006$). When sport participation was conceptualized as a dichotomous variable (whether children participated in sport or not), it was significantly correlated with three of the EF tasks: REEF ($r = .13$, $p < .001$), CHEXI-WM ($r = .09$, $p = .004$), and CBQ-AF ($r = .07$, $p = .046$).

Model 1 – Is level of physical activity significantly associated with executive function?

Model 1 examined whether physical activity was significantly related to EF scores across the tasks. It was hypothesized that parent reports of more physical activity would be positively related to EF skills. Contrary to our hypotheses, average physical activity on a typical weekday was not significantly associated with EF scores on any of the parent reports, after controlling for age, race, income, and parent education (see Tables 10-14 for the full Study 2 results in Model 1 by assessment).

Model 2 – Is structured sport participation associated with executive function?

Model 2 examined whether structured sport participation (1 = child participated in a structured sport; 0 = child did not participate in a structured sport) was related to EF. The hypotheses were addressed in the same way across both Study 1 and Study 2 (see above).

Contrary to our predictions, sport participation was not significantly related to any of the EF assessments. When sport was conceptualized as open, closed, mixed, there was a significant association between sport participation and one of the EF tasks, the REEF. Specifically, children who participated in mixed-skilled sports had higher REEF scores than those who reported no sport participation ($\beta = .37$, $p = .044$). Participation in open-skilled sports (vs. no sport participation) was not significantly associated with any of the parent reports of EF.

There were no significant differences on EF scores between closed-skilled to open-skilled sport participation, which was contrary to one of the hypotheses. Additionally, there were no significant differences on EF scores from closed-skilled participation to mixed sport participation across any of the tasks. Our hypothesis related to closed-skilled sport vs. no sport participation was also not supported; children who participated in closed-skilled sports did not have significantly higher EF scores than those who reported no sport participation in any of the EF tasks.

Similar to Study 1, additional models were conducted to further investigate associations between specific aspects of sport participation and EF: number of sports participated in (0, 1, 2+) and team or individual sport. When sport was conceptualized as the number of sports a child participated in, there were no significant associations with the EF tasks. When sport was conceptualized as team sport, individual sport, or participation in both team and individual sports, there was a significant association with the REEF. Specifically, there was a significant association between participation in both team and individual sports and the REEF ($\beta = .46$, $p = .007$).

Model 3 – Is sport participation associated with executive function above and beyond physical activity?

Model 3 examined whether sport participation predicted EF skills above and beyond physical activity. It was hypothesized that children who participate in closed- and open-skilled sports would have higher EF skills than those children who do not participate in structured sports, even after accounting for parent-reported physical activity (Hypothesis 3a).

Similar to the second model for Study 2, we found that sport participation did not predict any of the parent reports of EF, above and beyond physical activity. When conceptualizing sport in the other variations (open-skilled, closed-skilled, mixed; 0, 1, 2+; team, individual, both), one of the findings from Model 2 changed with the inclusion of physical activity as a control variable. Mixed-sport participation was marginally significantly associated with REEF scores ($\beta = .36$, $p = .051$). See Figure 2 for additional model results for Study 2.

Discussion

As previously discussed, the current study examined whether children who engaged in physical activity or participated in a structured sport in preschool had significantly higher levels of EF above and beyond physical activity. Using multiple OLS regressions, the associations between physical activity and EF (Model 1) and sport participation and EF (Models 2 and 3) were tested in two separate samples. Results for Model 1 indicated that physical activity was not significantly related to parent reports of EF. Results for Model 2 demonstrated that sport participation (yes/no) was also not significantly associated with parent reports of EF; however, when conceptualized as open, closed, or mixed, participation in mixed-skilled sport (vs. no sport) was significantly associated with a measure of parent-reported global EF (the REEF). Results for Model 3 largely replicate the results from Model 2, even with the inclusion of physical activity. As previously stated, these results add to the current literature by demonstrating physical activity may not be associated with EF in early childhood, but specific types of sport participation may be related to parent reports of global EF (i.e., cognitive flexibility, working memory, and inhibitory control). Additionally, because these associations have not been studied extensively in early childhood, future research is necessary and may have implications for current physical activity policy and future intervention work. These implications are discussed further in the overall conclusions and limitations section.

Physical Activity and Executive Function

Similar to Study 1, the findings from the present study found that higher levels of physical activity were not associated with higher levels of parent-reported EF. Specifically, results suggested that physical activity was not associated with EF scores on any of the assessments (REEF, CHEXI-WM, CHEXI-IC, CBQ-AF, CBQ-IC). As previously mentioned, this result was contrary to our hypotheses and was inconsistent with research examining similar associations in adulthood (Chaddock et al., 2011; Hawkins et al., 1992), middle childhood, and adolescence (Davis et al., 2011; Ellemberg & St-Louis-Deschênes, 2010; Tomporowski et al., 2008). Results were also inconsistent with findings from an emerging body of research exploring these associations in early childhood (Becker et al., 2014; Willoughby et al., 2018). As noted in the interpretation for Study 1, discrepancies across studies may be due to measurement or sample characteristics (see pages 32-36). Alternatively, it could be that physical activity may emerge as a predictor of EF after the early childhood period as has been shown in previous research (Chaddock et al., 2011; Davis et al., 2011; Ellemberg & St-Louis-Deschênes, 2010; 2011; Hawkins et al., 1992; Tomporowski et al., 2008). Nonetheless, more work is clearly needed to explore these associations in young children.

Sport Participation and Executive Function

Somewhat congruent with Study 1, a few results from Study 2 supported the hypothesis that sport participation is related to parent-reported EF in preschoolers, but the majority of the models did not point to significant associations. Although there were no significant associations between sport participation (versus no sport participation) and parent-reported EF, when sport was conceptualized as open, closed, or mixed, there was a significant association between mixed-sport participation (participation in both open- and closed- skilled sports) and general EF, as measured by the REEF; however, when parent-reported physical activity was included in the model, the coefficient became non-significant. Additionally, when sport was conceptualized by number of sports a child participated in (0, 1, 2+), none of the variations were associated with any of the parent-reported EF tasks. Finally, when sport was conceptualized as team sport, individual sport, or participation in both team and individual sports, there was a significant association between participation in both team and individual sports and general EF, as measured by the REEF; however, this association was no longer significant after including physical activity in the model. Because the large majority of the findings were non-significant, it is possible that the significant findings presented here are spurious. As such, the following interpretation is with regard to the null associations.

As noted in the explanation for Study 1, inconsistencies across studies exploring physical activity and EF may be due to lack of evidence for an association between these variables. Additionally, this could be due to methodological, measurement, or sample characteristics (see pages 36-41). Unlike Study 1, Study 2 not only used parent-reported sport participation, but exclusively used parent reports for EF as well. Notably, some of the questions asked of the parents across the EF scales (CHEXI, CBQ-AF, CBQ-IC, REEF) may not necessarily map onto the types of EF skills children may be exhibiting at a sport practice or how EF may look in a physically active context. For example, the following items from the CBQ (Rothbart, 2006) may not make sense in the context of physical activity or sport: “Is easily distracted when listening to a story”; “Sometimes becomes absorbed in a picture book and looks at it for a long time”; “Prepares for trips and outings by planning things s/he will need.” This misalignment also applies to items from the CHEXI (i.e. “Has difficulty telling a story about something that has happened so that others may easily understand”; Thorell & Nyberg, 2008) and the REEF assessment (i.e., “Sits at dinner table for entire meal without fussing or getting up from table”; Nilsen et al., 2017). Thus, it will be important for future research to ensure that items directly align with the context they are evaluating (e.g., sport practices).

Additionally, parents may not be at children’s practices and, thus, may be unaware of the types of EF skills that are elicited during a structured sport. Coaches are implementing the practices and trying to facilitate skill growth (Fraser-Thomas, Côté, & Deakin, 2005) and may be better at observing children’s EF skills in this context. Thus, in future research, it may be important to have multiple informants (e.g., parents and coaches) reporting on EF skills due to differences in situation-specific behaviors (e.g., EF skills demonstrated at home or at soccer practice; Konold, Walthall, & Pianta, 2004).

Beyond explanations of measurement, it could also be that sport participation in early childhood is simply not a predictor of parent-reported EF (Budde et al., 2008; Davis et al., 2011; Jacobson & Matthaeus, 2014; Vestberg et al., 2012). As noted in Study 1, this could be due to preschool-aged children being unable to consistently engage in the complex thought required to understand the nuances of a structured sport (Posner & Rothbart, 1998), and the goal-oriented behaviors required to be successful in sport may be enforced by scaffolding by a parent or a coach. Notably, results *were* consistent with recent findings indicating a null association between open-skilled sport participation and general EF skills in older children (Becker et al., 2018). Nevertheless, more work is necessary to explore these associations in early childhood.

GENERAL LIMITATIONS, FUTURE DIRECTIONS, AND CONCLUSIONS ACROSS BOTH STUDIES

Despite the fact that these studies are the first to examine the relations among physical activity, sport participation, and EF in early childhood, limitations must be noted. Though several measures of EF were utilized (e.g., direct assessments of individual components, parent reports), one item was used to assess physical activity and one item was used to assess sport participation. It is possible that more objective and nuanced measures of physical activity and sport participation may be necessary to capture their associations with EF. For example, it may be important to utilize more objective measures of physical activity, rather than relying on retrospective, adult-report questionnaires. As noted above, parent reports of physical activity may suffer from recall bias and/or over-reporting (Ainsworth et al., 1994; Warnecke et al., 1997). Wearable devices like accelerometers are easy to administer and are able to capture large amounts of data (Sylvia et al., 2014). Studies have demonstrated how researchers can use accelerometer data to compute physical activity volume and rate as well as time spent in different intensities of exercise (Tudor-Locke, Brashear, Johnson & Katzmarzyk 2010). Furthermore, accelerometers are feasible to use with young children (Tudor-Locke et al., 2010). However, they are very expensive and require expertise in specialized software and programming (Dishman, 1994). An alternative option may be the use of direct observations, where an independent observer monitors and records physical activity (McKenzie, Marshall, Sallis & Conway, 2000; Sleap & Warburton, 1996). This method can tap into contextual information (e.g., time, location) and details of the physical activity (e.g., type and variations; Sylvia et al., 2014), or may be modified to measure different levels of scaffolding performed by parents and coaches in settings where children are physically active. Though this method is more flexible, there is a high cost of time and energy, and it may be difficult to obtain participant approval (Sylvia et al., 2014). Despite these challenges, future studies may benefit from the use of more objective measures of physical activity (e.g., accelerometers; Bassett & Strath, 2002; Troiano, 2006).

If direct observations and objective measures of physical activity and sport participation are not feasible, future studies could include additional, more comprehensive questions in parent surveys. One method that could be used in future research is daily diaries. Using daily diaries to assess how active kids are at home may help overcome some limitations of retrospective questionnaires because they may be less susceptible to recall errors (Tudor-Lock, van der Ploeg, Bowles et al., 2007; van der Ploeg et al., 2010).

Although the purpose of the present study was to examine overall physical activity during an average weekday, it may be important to ask questions about physical activity that reflect different contexts. It may also be important to assess different contexts of physical activity (e.g., school day, home, weekend, etc.) in order to parse apart what facilitates the highest levels and types of physical activity that may be most important for EF growth. Research around physical activity has demonstrated it is crucial to consider dosage (e.g., how often they were physically active in a week), duration (e.g., how long were they active for), intensity (e.g., were they engaging in light, moderate, vigorous activity), and mode (e.g., were they biking, running, playing tag). Due to metabolic intensity being related to EF (Becker et al., 2018), asking these types of questions, which may be proxies for met intensity, may be important. Similarly, this logic of examining contexts, dosage, intensity, and mode can also apply to the way researchers evaluate sport participation.

Moreover, an important future direction for similar research is to measure coaching techniques or scaffolding which may also be important to consider when assessing the relation between sport participation and EF. Scaffolding allows complex and difficult tasks to be more manageable for a child, placing that task/skill within a child's zone of proximal development (Vygotsky, 1978). This could aid in EF development by helping children remain goal-oriented. This potential association is supported by early childhood literature that examines the role parental scaffolding plays on EF development (Hammond, Müller, Carpendale, Bibok, & Liebermann-Finestone, 2012; Hughes & Esnor, 2009; Landry, Miller-Loncar, Smith, & Swank, 2002). Additionally, a body of literature examining coaching sports emphasizes that the coach is also an educator (Abraham & Collins, 1998; Jones, 2006). Both literature bases discuss how important indirect instructional strategies are to developing skills in young athletes, as well as young children (Abraham & Collins, 1998; Jones, 2006; Vygotsky, 1978). Future research should consider measuring scaffolding and coaching techniques in order to better understand these associations.

Finally, although both samples were diverse in terms of socioeconomic status, neither sample was very ethnically diverse. Relatedly, Study 1 had a small sample size, and the power to detect effects may be limited. Therefore, future research needs to replicate these findings using larger and more representative samples in order to determine the generalizability of the findings. Though we had a larger sample for Study 2, these data came exclusively from using Amazon's MTurk. This method allows for larger data collection at a considerably lower cost, but it still has some limitations. Using MTurk requires a reliance on self-reported measures (Holden, Dennie, & Hicks, 2013) and although it is designed to represent a diverse population, studies have shown that MTurk participants are more likely to have a college degree, be female, be younger, and have a lower salary than the general population (Paolacci & Chandler, 2014; Ross, Irani, Silberman, Zaldivar & Tomlinson, 2010), which potentially limits the generalizability of findings from MTurk samples (Stritch, Pedersen, & Taggart, 2017).

Conclusions

In sum, the present study sought to replicate and extend current literature exploring physical activity, sport participation, and EF. Unlike previous work, the present study examined physical activity in early childhood, outside the context of the school environment. Additionally, previous literature had not explored the extent to which sport participation in early childhood may be associated with EF. Our results suggest that children who are more physically active do not necessarily have stronger EF skills, based on direct assessment and parent reports. However, sport participation may be related to direct assessments of cognitive flexibility and working memory in preschoolers, depending on how sport participation is conceptualized. The current study has implications for future research and policy. Results suggest that researchers may need to consider using different types of measurement techniques (e.g., objective measures, direct observations, and modified self-reports) and consider other potentially relevant variables (e.g., metabolic intensity, context, scaffolding, etc.) in order to better understand the association between physical activity, sport participation, and EF in early childhood. Furthermore, the 2018 Physical Activity Guidelines Advisory Committee Scientific Report released, for the first time, recommendations for preschool children (2018 Physical Activity Guidelines Advisory Committee, 2018). The advisory committee included a target of at least three hours of activity per day, but this is not considered an official guideline (2018 Physical Activity Guidelines Advisory Committee, 2018). The present study could inform future guidelines by emphasizing that the inclusion of the structure of physical activity (in addition to the frequency) may be important.

Table 1. *Descriptive statistics of key study variables for Study 1 and Study 2*

	Study 1 (*N* = 197)					Study 2 (*N* = 1012)			
	n	*M*	*SD*	*Range*		*n*	*M*	*SD*	*Range*
Age (years)	197	4.34	0.68	3.00-6.20	**Age (months)**	1012	51.59	9.94	31.00-78.00
Parent education					**Parent education**				
High School and Below	49	24.9%			High School and Below	97	9.6%		
Some College/Associates	50	25.4%			Some College/Assoc.	365	36.1%		
Bachelor's and Above	98	49.7%			Bachelor's and Above	550	54.3%		
Race					**Race**				
White	165	83.8%			White	612	60.5%		
Non-White	30	15.2%			Non-White	392	38.7%		
Missing	2	1.0%			Missing	8	.8%		
Income[b]					**Income**[b]				
< $40,000	69	35.0%			< $40,000	395	39.0%		
$41-75,999	34	17.3%			$41-75,999	328	32.4%		
> $76,000	84	42.6%			> $76,000	289	28.6%		
Missing	10	5.1%			Missing	0	0.0%		
HTKS	192	15.79	17.42	0.00-59.00					
DCCS	194	12.21	6.57	3.00-23.00	**REEF**	1012	2.98	0.47	1.00-4.00
DNS	193	17.71	9.25	0.00-28.00	**CHEXI-WM**	1012	3.47	0.82	1.00-5.00
BDS	193	0.56	1.13	0.00-9.00	**CHEXI-IC**	1012	3.09	0.78	1.00-5.00
CBQ-AF	196	4.86	.98	1.33-7.00	**CBQ-AF**	1012	3.77	0.97	1.00-7.00
CBQ-IC	196	4.79	.94	1.00-6.50	**CBQ-IC**	1012	4.50	0.93	1.00-7.00
Physical Activity	197	72.49	55.93	0.00-312.00	**Physical Activity**	1012	63.26	75.13	0.00-288.64
Sport Participation					**Sport Participation**				
No	108	54.8%			No	742	73.3%		
Yes	88	44.7%			Yes	270	26.7%		
Open	45	51.3%			Open	182	67.4%		
Mixed	17	19.3%			Mixed	28	10.3%		
Closed	26	29.4%			Closed	60	22.3%		
Missing	1	0.5%			Missing	0	0.0%		
Male									
Male	102	51.8%							
Female	95	48.2%							

Note. [a]1 = 8th grade or less, 2 = some high school, 3 = GED, 4 = high school diploma, 5 = some college, 6 = associate's degree, 7 = bachelor's degree, 8 = master's degree, 9 = doctoral/postgraduate degree. Physical activity measured in minutes of physical activity on a typical weekday.

Table 2. *Correlations of key variables in Study 1*

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Age[a]	—															
2. Male	.05	—														
3. White	.06	-.13	—													
4. Income 1: ≤ $40,000	-.01	-.16*	-.08	—												
5. Income 2: $41-75,000	-.01	-.04	-.14*	-.34**	—											
6. Income 3: ≥ $76,000	.03	.17*	.23**	-.63**	-.39**	—										
7. Parent Education 1[b]	.04	-.16*	.05	.46**	.05	-.50**	—									
8. Parent Education 2[c]	.04	-.05	-.05	.28**	.01	-.27**	-.34**	—								
9. Parent Education 3[d]	-.07	.18*	.00	-.65**	-.05	.66**	-.57**	-.58**	—							
10. HTKS	.52**	.02	.16*	-.19**	-.02	.18*	-.15*	-.11	.23*	—						
11. DCCS	.53**	.01	.23**	-.30**	.04	.25**	-.16*	-.15*	.27**	.59**	—					
12. DNS	.38**	.09	.19*	-.20**	-.08	.26**	-.11	-.14*	.22**	.40**	.46**	—				
13. BDS	.38**	.09	.16*	-.12	-.06	.17*	-.15*	-.11	.22**	.55**	.42**	.34**	—			
14. CBQ-AF	.12	-.18	.09	-.10	.04	.06	-.04	-.19**	.20**	.11	.30**	.18*	.18*	—		
15. CBQ-IC	.19**	-.11	.18*	-.11	-.01	.08	-.07	-.17*	.09	.22*	.29**	.17*	.25**	.58**	—	
16. Physical Activity[e]	-.03	.15*	.00	-.03	.04	.01	-.01	-.04	.04	.00	.02	.01	.03	-.04	-.07	—
17. Sport Paricipation[f]	.27**	.03	.13	-.34**	-.12	.41**	-.26**	-.18*	-.38**	.30**	.39**	.24**	.29**	.15*	.15*	-.00

Note. [a]Child age measured in years; [b]Parent education 1 = high school diploma or less; [c]Parent Education 2 = some college/associate's degree; [d]Parent Education 3 = bachelor's/master's/doctoral/postgraduate degree. [e] Physical activity measured in minutes of physical activity on a typical weekday. [f]1 = child participated in a sport within the last 6 months, 0 = child did not participate in a sport. $*p < .05$, $**p < .01$

Table 3. *Correlations of key study variables in Study 2*

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Age[a]	—														
2. White	.03	—													
3. Income 1: ≤ $40,000	-.03	-.27**	—												
4. Income 2: $41-75,000	.01	.13**	-.55**	—											
5. Income 3: ≥ $76,000	.03	.15**	-.51**	-.44**	—										
6. Parent Education 1[b]	.00	.07*	.08**	.01	-.10**	—									
7. Parent Education 2[c]	.02	.15**	.10**	.09**	-.20**	-.25**	—								
8. Parent Education 3[d]	-.02	-.18**	-.15**	-.09**	.25**	-.36**	-.82**	—							
9. REEF	.29**	.11**	-.15**	.07*	.09**	.03	-.06*	.05	—						
10. CHEXI-WM	.13**	.11**	-.19**	.10**	.10**	.07*	.01	-.05	.54**	—					
11. CHEXI-IC	.07*	.05	-14**	.06	.10**	.07*	-.02	-.02	.44**	.78*	—				
12. CBQ-AF	.09**	.04	-.10**	.03	.08*	.03	-.10**	.07*	.40**	.47**	.48**	—			
13. CBQ-IC	.10**	.03	-.07*	.04	.03	-.00	-.10*	.09**	.49**	.33**	.38**	.36**	—		
14. Physical Activity[e]	-.01	.13**	-.12**	.07*	.06	.04	.07*	-.09**	.04	.07*	.03	.03	-.02	—	
15. Sport Participation[f]	.19**	.19**	-.22**	.01	.22**	-.07*	-.03	.07*	.13**	.09**	.05	.07*	.04	.10**	—

Note. [a]Child age measured in months; [b]Parent education 1 = high school diploma or less; [c]Parent Education 2 = some college/associate's degree; [d]Parent Education 3 = bachelor's/master's/doctoral/postgraduate degree. [e] Physical activity measured in minutes of physical activity on a typical weekday. [f]1 = child participated in a sport within the last 6 months, 0 = child did not participate in a sport. *$p < .05$, **$p < .01$.

Table 4. *Regression adjusted estimates from models for HTKS scores in Study 1*

	Model 1	**Model 2**	**Model 3**
	β (SE)	β (*SE*)	β (SE)
Physical Activity	.00 (.00)		.01 (.00)
Sport Participation			
No Sport Participation		Reference	Reference
Sport Participation		.13 (.14)	.13 (.14)
Age (Years)	.54 (.06)***	.52 (.06)***	.52 (.07)***
Income			
≤ $40,000	Reference	Reference	Reference
$41-75,000	.00 (.18)	.00 (.18)	.00 (.18)
$76,000+	-.15 (.20)	-.19 (.20)	-.19 (.20)
Parent education			
High School and below	Reference	Reference	Reference
Some college/Associate	.15 (.18)	.14 (.18)	.14 (.18)
B.A./B.S. and above	.74 (.21)***	.69 (.21)**	.69 (.21)**
Male	-.08 (.13)	-.06 (.13)	-.06 (.13)
White	.37 (.18)*	.36 (.18)*	.36 (.18)*
R^2	.37	.35	.35

Note. Standard errors are in parentheses. All continuous variables are standardized. All models control for age, gender, race, dummy variables for parent education, and dummy variables for income. Reference for sport participation = child did not participate in a sport. Reference for income = $40,000/year and below. Reference for education = high school education and below. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Table 5. *Regression adjusted estimates from models for DCCS scores in Study 1*

	Model 1	**Model 2**	**Model 3**
	β (SE)	β (*SE*)	β (SE)
Physical Activity	.02 (.00)		.02 (.00)
Sport Participation			
No Sport Participation		Reference	Reference
Sport Participation		.30 (.13)*	.30 (.13)*
Age (Years)	.52 (.06)***	.49 (.06)***	.49 (.07)***
Income			
≤ $40,000	Reference	Reference	Reference
$41-75,000	.29 (.17)	.29 (.17)	.29 (.17)
$76,000+	.10 (.19)	.04 (.19)	.04 (.19)
Parent education			
High School and below	Reference	Reference	Reference
Some college/Associate	.03 (.17)	.01 (.16)	.01 (.16)
B.A./B.S. and above	.59 (.19)**	.51 (.20)*	.51 (.20)*
Male	-.09 (.13)	-.07 (.12)	-.08 (.12)
White	.54 (.17)**	.52 (.16)**	.52 (.17)**
R^2	.42	.43	.43

Note. Standard errors are in parentheses. All continuous variables are standardized. All models control for age, gender, race, dummy variables for parent education, and dummy variables for income. Reference for sport participation = child did not participate in a sport. Reference for income = $40,000/year and below. Reference for education = high school education and below. **p* < 0.05; ***p* < 0.01; ****p* < 0.001.

Table 6. *Regression adjusted estimates from models for DNS scores in Study 1*

	Model 1	**Model 2**	**Model 3**
	β (SE)	β (*SE*)	β (SE)
Physical Activity	.00 (.00)		.00 (.00)
Sport Participation			
No Sport Participation		Reference	Reference
Sport Participation		.07 (.15)	.07 (.15)
Age (Years)	.39 (.06)***	.39 (.07)***	.39 (.07)***
Income			
≤ $40,000	Reference	Reference	Reference
$41-75,000	-.02 (.19)	-.02 (.19)	-.02 (.19)
$76,000+	.20 (.21)	.19 (.21)	.19 (.21)
Parent education			
High School and below	Reference	Reference	Reference
Some college/Associate	-.13 (.19)	-.13 (.19)	-.13 (.19)
B.A./B.S. and above	.27 (.22)	.25 (.23)	.25 (.23)
Male	.08 (.13)	.09 (.13)	.08 (.14)
White	.39 (.19)*	.39 (.19)*	.39 (.19)*
R^2	.25	.25	.25

Note. Standard errors are in parentheses. All continuous variables are standardized. All models control for age, gender, race, dummy variables for parent education, and dummy variables for income. Reference for sport participation = child did not participate in a sport. Reference for income = $40,000/year and below. Reference for education = high school education and below.
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Table 7. *Regression adjusted estimates from models for BDS scores in Study 1*

	Model 1	Model 2	Model 3
	β (SE)	β (*SE*)	β (SE)
Physical Activity	.00 (.00)		.00 (.00)
Sport Participation			
No Sport Participation		Reference	Reference
Sport Participation		.23 (.15)	.23 (.15)
Age (Years)	.39 (.07)***	.36 (.07)***	.36 (.07)***
Income			
≤ $40,000	Reference	Reference	Reference
$41-75,000	-.17 (.20)	-.17 (.20)	-.17 (.20)
$76,000+	-.28 (.22)	-.33 (.22)	-.33 (.22)
Parent education			
High School and below	Reference	Reference	Reference
Some college/Associate	.17 (.19)	.16 (.19)	.16 (.19)
B.A./B.S. and above	.77 (.23)**	.70 (.23)**	.70 (.23)**
Male	.11 (.14)	.14 (.14)	.13 (.14)
White	.47 (.19)*	.45 (.19)*	.45 (.19)*
R^2	.24	.24	.24

Note. Standard errors are in parentheses. All continuous variables are standardized. All models control for age, gender, race, dummy variables for parent education, and dummy variables for income. Reference for sport participation = child did not participate in a sport. Reference for income = $40,000/year and below. Reference for education = high school education and below. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Table 8. *Regression adjusted estimates from models for CBQ-AF scores in Study 1*

	Model 1	**Model 2**	**Model 3**
	β (SE)	β (*SE*)	β (SE)
Physical Activity	.00 (.00)		.00 (.16)
Sport Participation			
No Sport Participation		Reference	Reference
Sport Participation		.11 (.16)	.11 (.16)
Age (Years)	.15 (.07)*	.15 (.07)*	.15 (.07)*
Income			
≤ $40,000	Reference	Reference	Reference
$41-75,000	.01 (.21)	.00 (.21)	.00 (.21)
$76,000+	-.31 (.23)	-.32 (.23)	-.32 (.23)
Parent education			
High School and below	Reference	Reference	Reference
Some college/Associate	-.14 (.20)	-.15 (.20)	-.15 (.20)
B.A./B.S. and above	.61 (.24)*	.59 (.24)*	.59 (.24)*
Male	-.41 (.14)**	-.42 (.14)**	-.41 (.15)**
White	.25 (.20)	.24 (.20)	.24 (.20)
R^2	.13	.13	.13

Note. Standard errors are in parentheses. All continuous variables are standardized. All models control for age, gender, race, dummy variables for parent education, and dummy variables for income. Reference for sport participation = child did not participate in a sport. Reference for income = $40,000/year and below. Reference for education = high school education and below. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Table 9. *Regression adjusted estimates from models for CBQ-IC scores in Study 1*

	Model 1	**Model 2**	**Model 3**
	β (SE)	β (*SE*)	β (SE)
Physical Activity	.00 (.00)		.00 (.00)
Sport Participation			
No Sport Participation		Reference	Reference
Sport Participation		.13 (.17)	.13 (.17)
Age (Years)	.19 (.07)**	.18 (.08)*	.17 (.08)*
Income			
≤ $40,000	Reference	Reference	Reference
$41-75,000	.05 (.21)	.05 (.21)	.05 (.21)
$76,000+	.04 (.23)	.01 (.23)	.01 (.23)
Parent education			
High School and below	Reference	Reference	Reference
Some college/Associate	-.40 (.20)	-.40 (.20)	-.41 (.21)*
B.A./B.S. and above	.03 (.24)	-.02 (.25)	-.01 (.25)
Male	-.22 (.15)	-.23 (.15)	-.21 (.15)
White	.40 (.21)	.39 (.21)	.39 (.21)
R^2	.11	.11	.11

Note. Standard errors are in parentheses. All continuous variables are standardized. All models control for age, gender, race, dummy variables for parent education, and dummy variables for income. Reference for sport participation = child did not participate in a sport. Reference for income = $40,000/year and below. Reference for education = high school education and below. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Table 10. *Regression adjusted estimates from models for REEF scores in Study 2*

	Model 1	**Model 2**	**Model 3**
	β (SE)	β (*SE*)	β (SE)
Physical Activity	.00 (.00)		.00 (.00)
Sport Participation			
No Sport Participation		Reference	Reference
Sport Participation		.09 (.07)	.08 (.07)
Age (Years)	. 28 (.03)***	. 28 (.03)***	. 28 (.03)***
Income			
≤ $40,000	Reference	Reference	Reference
$41-75,000	.24 (.07)**	.23 (.07)**	.23 (.07)**
$76,000+	.23 (.08)**	.22 (.08)**	.21 (.08)**
Parent education			
High School and below	Reference	Reference	Reference
Some college/Associate	-.18 (.11)	-.18 (.11)	-.18 (.11)
B.A./B.S. and above	-.04 (.11)	-.06 (.11)	-.04 (.11)
White	.15 (.07)*	.14 (.07)*	.14 (.07)*
R^2	.11	.11	.11

Note. Standard errors are in parentheses. All continuous variables are standardized. All models control for age, race, dummy variables for parent education, and dummy variables for income. Reference for physical activity = did not meet daily recommended 60. Reference for sport participation = child did not participate in a sport. Reference for income = $40,000/year and below. Reference for education = high school education and below.

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Table 11. *Regression adjusted estimates from models for CHEXI-WM scores in Study 2*

	Model 1	**Model 2**	**Model 3**
	β (SE)	β (*SE*)	β (SE)
Physical Activity	.00 (.00)		.00 (.04)
Sport Participation			
No Sport Participation		Reference	Reference
Sport Participation		.06 (.07)	.06 (.03)
Age (Years)	.11 (.03)***	.11 (.03)**	.11 (.03)***
Income			
≤ $40,000	Reference	Reference	Reference
$41-75,000	.34 (.07)***	.34 (.07)***	.33 (.07)***
$76,000+	.38 (.08)***	.38 (.08)***	.37 (.08)***
Parent education			
High School and below	Reference	Reference	Reference
Some college/Associate	-.21 (.11)	-.21 (.11)	-.21 (.11)
B.A./B.S. and above	-.28 (.11)*	-.29 (.11)*	-.29 (.11)**
White	.09 (.07)	.09 (.07)	.08 (.07)
R^2	.06	.06	.06

Note. Standard errors are in parentheses. All continuous variables are standardized. All models control for age, race, dummy variables for parent education, and dummy variables for income. Reference for sport participation = child did not participate in a sport. Reference for income = $40,000/year and below. Reference for education = high school education and below.
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Table 12. *Regression adjusted estimates from models for CHEXI-IC scores in Study 2*

	Model 1	**Model 2**	**Model 3**
	β (SE)	β (*SE*)	β (SE)
Physical Activity	.00 (.00)		.00 (.00)
Sport Participation			
No Sport Participation		Reference	Reference
Sport Participation		.01 (.07)	.01 (.08)
Age (Years)	.06 (.03)*	.06 (.03)*	.06 (.03)*
Income			
≤ $40,000	Reference	Reference	Reference
$41-75,000	.27 (.08)***	.27 (.08)***	.27 (.08)***
$76,000+	.36 (.08)***	.36 (.08)***	.36 (.08)***
Parent education			
High School and below	Reference	Reference	Reference
Some college/Associate	-.24 (.11)*	-.24 (.11)*	-.24 (.11)*
B.A./B.S. and above	-.28 (.11)*	-.28 (.11)*	-.28 (.11)*
White	.00 (.07)	.00 (.07)	.00 (.07)
R^2	.03	.03	.03

Note. Standard errors are in parentheses. All continuous variables are standardized. All models control for age, race, dummy variables for parent education, and dummy variables for income. Reference for sport participation = child did not participate in a sport. Reference for income = $40,000/year and below. Reference for education = high school education and below.
**p* < 0.05; ***p* < 0.01; ****p* < 0.001.

Table 13. *Regression adjusted estimates from models for CBQ-AF scores in Study 2*

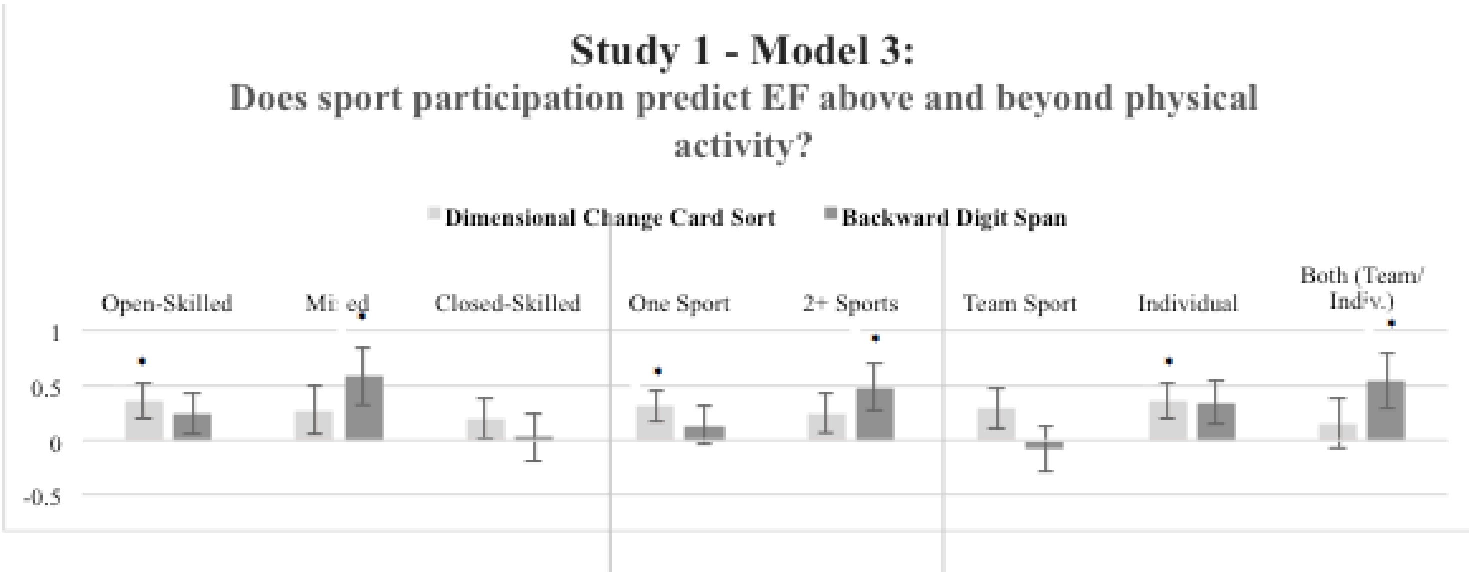
	Model 1	**Model 2**	**Model 3**
	β (SE)	β (*SE*)	β (SE)
Physical Activity	.00 (.00)		.00 (.00)
Sport Participation			
No Sport Participation		Reference	Reference
Sport Participation		.07 (.08)	.08 (.08)
Age (Years)	.09 (.03)**	.08 (.03)*	.08 (.03)*
Income			
≤ $40,000	Reference	Reference	Reference
$41-75,000	.16 (.08)*	.15 (.08)	.15 (.08)
$76,000+	.19 (.09)*	.17 (.09)*	.17 (.09)*
Parent education			
High School and below	Reference	Reference	Reference
Some college/Associate	-.23 (.12)*	-.24 (.12)*	-.24 (.12)*
B.A./B.S. and above	-.05 (.11)	-.05 (.11)	-.06 (.11)
White	.06 (.07)	.04 (.07)	.05 (.07)
R^2	.03	.03	.03

Note. Standard errors are in parentheses. All continuous variables are standardized. All models control for age, race, dummy variables for parent education, and dummy variables for income. Reference for sport participation = child did not participate in a sport. Reference for income = $40,000/year and below. Reference for education = high school education and below.
* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Table 14. Regression adjusted estimates from models for CBQ-IC scores in Study 2

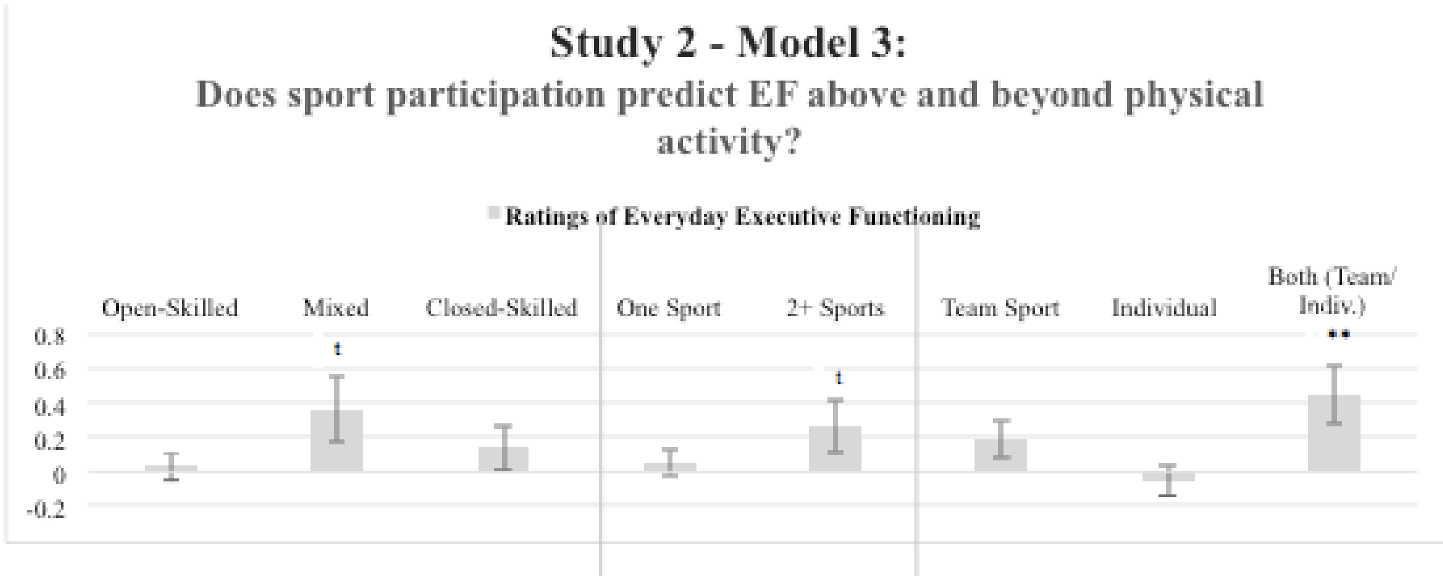
	Model 1	**Model 2**	**Model 3**
	β (SE)	β (*SE*)	β (SE)
Physical Activity	.00 (.00)		.00 (.00)
Sport Participation			
No Sport Participation		Reference	Reference
Sport Participation		-.01 (.08)	-.01. (.08)
Age (Years)	.10 (.03)**	.11 (.03)**	.10 (.03)**
Income			
≤ $40,000	Reference	Reference	Reference
$41-75,000	.13 (.08)	.13 (.08)	.13 (.08)
$76,000+	.05 (.08)	.04 (.09)	.05 (.09)
Parent education			
High School and below	Reference	Reference	Reference
Some college/Associate	-.14 (.12)	-.14 (.12)	-.14 (.12)
B.A./B.S. and above	.09 (.11)	.10 (.11)	.09 (.11)
White	.07 (.07)	.07 (.07)	.07 (.07)
R^2	.03	.03	.03

Note. Standard errors are in parentheses. All continuous variables are standardized. All models control for age, race, dummy variables for parent education, and dummy variables for income. Reference for sport participation = child did not participate in a sport. Reference for income = $40,000/year and below. Reference for education = high school education and below.
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.



Note. All continuous variables are standardized. Lines indicate separate analyses were performed for each model (i.e., open-skilled, mixed, and closed-skilled were in one model; one sport and 2+ sports were one analysis; team, individual, and both were one analysis). All models control for age, gender, race, physical activity, dummy variables for parent education, and dummy variables for income. Reference group for sport participation = child did not participate in a sport.
**p* < 0.05; ***p* < 0.01; ****p* < 0.001.

Figure 1. *Regression estimates for additional analyses for Model 3 predicting DCCS and BDS scores using physical activity and sport participation for Study 1*



Note. All continuous variables are standardized. Lines indicate separate analyses were performed for each model (i.e., open-skilled, mixed, and closed-skilled were in one model; one sport and 2+ sports were one analysis; team, individual, and both were one analysis). All models control for age, race, dummy variables for parent education, and dummy variables for income. Reference group for sport participation = child did not participate in a sport.

$^{t}p < .10$; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Figure 2. *Regression estimates for additional analyses for Model 3 predicting REEF scores using physical activity and sport participation for Study 1*

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APPENDIX A. BACKGROUND QUESTIONNAIRE

Background Questionnaire

Parent Survey Questionnaire

1. What is your race/ethnicity? ____________________What is your child's race/ethnicity? __________

2. Language(s) spoken at home: ___________________Child's primary language: __________________

3. Since your child's birth, how many times has your family moved? _______

4. How many total *adults* _________ and *children* __________ are living in your home?

5. What is your current marital status? (check one)

1 ❑ Single	2 ❑ Married (living with partner)	3 ❑ Separated (married, but not living with partner)	4 ❑ Divorced	5 ❑ Cohabiting / Living with partner	6 ❑ Widowed

6. What is your current employment status? **(check one)**

1 ❑ Employed (List Job:____) 2 ❑ Unemployed 3 ❑ Student

7. What is your partner's employment status (if living in the home)? **(check one)**

1 ❑ Employed (List Job:____) 2 ❑ Unemployed 3 ❑ Student

8. What is your <u>family income</u> to nearest $5,000 per year? **(circle number or range)**

$5,000	$10,000	$15,000	$20,000	$25,000	$30,000	$31,000 –$40,000
$41,000 – $50,000	$51,000 – $75,000	$76,000 – $100,000	$101,000-$125,000	$126,000-$150,000	$151,000-$175,000	Higher than $175,000

9. How many years of schooling have you completed? **(circle one)**

8th Grade or Less	Some High School	GED	High School Diploma	Some College
AA/AS Degree	BA/BS Degree	MA/MS	Doctoral/Postgraduate Degree	

10. How many years of schooling has your spouse/partner completed? **(circle one)**

8th Grade or Less	Some High School	GED	High School Diploma	Some College
AA/AS Degree	BA/BS Degree	MA/MS	Doctoral/Postgraduate Degree	

11. How high can your child count? _______

12. My child can identify the following numerals **(circle all that apply)**:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

13. My child can calculate simple sums (e.g., 1+1 =, 1+2 =): yes_______ no_______

14. On a typical weekday, how many minutes does your child exercise? _______ minutes

15. On a typical Saturday or Sunday, how many minutes does your child exercise? ________ minutes

16. During the past year, did your child participate in any children's sports or sports teams? yes______no_______

If YES, what did he/she participate in? ____

Was this sports participation an organized activity - like a team or class - or an informal activity? ____

17. During the past week, did your child spend any non-school time participating in structured activities, lessons or clubs (for example, music lessons)? yes______no_______

If YES, which activity(s)? ____

APPENDIX B. PHYSICAL ACTIVITY AND SPORT PARTICIPATION RESPONSES AND CRITERIA

Physical Activity: Criteria for Exclusion for Study 1 and Study 2

Not included:	**Study 1**	**Study 2**
If listed “1,2,3,4,5,6,7,8,” unless specified as minutes or hours	-	93
1-2	-	1
43388	-	1
5 TIMES	-	1
6.25E-2	-	1
If listed any response that included phrases/words (e.g., “All day”; “Hours”; “Non-stop” ; “Always moving”; “Every day” “Hours every day” ; “She runs all day”)	3	13
No response	12	0
Total	15	110

Physical Activity: Responses Included for Study 1 and Study 2

Included:	
If listed “10” was included as 10 min.	
If listed “at least” is entered as that number – the “at least” number	
If listed “no” – included as 0 minutes	
If listed “none” – included as 0 minutes	
If listed “Nil” – included as 0 minutes	
If listed “Never” – included as zero minutes	
If listed “no exercise” – included as 0 minutes	
If listed “an hour” – included as 60 minutes	
When there is a range, the average number in that range is used	
Study 1: 3+/- SD above the mean, replace with the 3SD mark: 0-311.99	5
Study 2: 3+/- SD above the mean, replace with the 3SD mark: 0-288.64	40

Sport participation: Responses Included for Study 1 and Study 2

Included	**Study 1**	**Study 2**
Open-Skilled		
Baseball	3	17
Basketball	6	12
T-Ball	10	32
Tennis	-	2
Football	-	4
Cricket	-	2
Wrestling/Boxing	-	2
Karate	4	13
Soccer	42	126
Softball	1	3
Hockey	-	6
Rugby	-	1
Martial Arts	5	3
Tae Kwon Do	-	7
Jiujutsu	-	1
Closed-Skilled		
Swimming	13	25
Cheerleading	2	4
Tumbling/Gymnastics	12	37
Dance/Tap/Ballet	14	24
Ice Skating/Skating	-	5

Sport participation: Not Included for Study 1 and Study 2

Not Included	Study 1	Study 2
0	-	1
1	-	2
1K race - ADD AS SP	-	1
3.5	-	1
50 meter running	-	1
Athletic	-	1
balloon football	-	1
Baton	-	1
carrom	-	1
Chess/chess competition	-	2
Children's Physical Training	-	1
children's sports competition	-	1
Clay making, drawing competition	-	1
Cycling	-	2
Drawing	-	1
game	-	1
Her School Running Race Competition	-	1
jogging	-	1
kids game sports	-	1
kinter garter running competition	-	1
lemon and spoon	-	2
local activities/local games	-	2
Local children park	-	1
Long jump	-	1
Mind games at play school, Running, jumping etc.	-	1
musical chair	-	1

Sport Participation: Not Included for Study 1 and Study 2 continued

My Child participated in individual sports like Running Race, Putting ball into a basket, Frog jumping and team games like Puzzle arranging and Building with small patterns.	-	1
My gym	2	-
no	-	1
obstacle running race	-	1
organized in school	-	1
Participate in a running/participate in running	-	2
playing games	-	1
playing tag	-	1
Racing/Race/	-	5
Run/Running/Running competition/Running race	-	45
S	-	1
school sports activities	-	1
scouts	-	1
She is participating in running race competating at school .	-	1
skipping	-	1
Skipping rope	-	1
Table Tennis	-	1
To do exercise and learn how to swim.	-	1
yes	-	4

Justification for non-inclusion of sport responses: Decisions about including certain sports were based on Becker et al., 2018. Becker and colleagues (2016) did not include cycling/running. However, they did include track, but parents did not specify track or type of sport within track. Additionally, NICHD questionnaire did not include running as a “sport” category.