



2015

A Multi-Method Analysis of Body Mass Index, Physical Activity, and Executive Functions Among Urban Minority Girls

Amanda K. Ward
Loyola University Chicago

Follow this and additional works at: https://ecommons.luc.edu/luc_diss



Part of the [Clinical Psychology Commons](#)

Recommended Citation

Ward, Amanda K., "A Multi-Method Analysis of Body Mass Index, Physical Activity, and Executive Functions Among Urban Minority Girls" (2015). *Dissertations*. 1657.
https://ecommons.luc.edu/luc_diss/1657

This Dissertation is brought to you for free and open access by the Theses and Dissertations at Loyola eCommons. It has been accepted for inclusion in Dissertations by an authorized administrator of Loyola eCommons. For more information, please contact ecommons@luc.edu.



This work is licensed under a [Creative Commons Attribution-NonCommercial-No Derivative Works 3.0 License](#).
Copyright © 2015 Amanda K. Ward

LOYOLA UNIVERSITY CHICAGO

A MULTI-METHOD ANALYSIS OF BODY MASS INDEX, PHYSICAL ACTIVITY,
AND EXECUTIVE FUNCTIONS AMONG URBAN MINORITY GIRLS

A DISSERTATION SUBMITTED TO
THE FACULTY OF THE GRADUATE SCHOOL
IN CANDIDACY FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

PROGRAM IN CLINICAL PSYCHOLOGY

BY

AMANDA K. WARD

CHICAGO, IL

AUGUST 2015

Copyright by Amanda K. Ward, 2015
All rights reserved.

TABLE OF CONTENTS

LIST OF TABLES	iv
LIST OF FIGURES	v
ABSTRACT	vi
CHAPTER ONE: INTRODUCTION	1
The Influence of Summertime	2
Changes in Physical Activity and Body Mass Index.....	7
Body Mass Index, Physical Activity, and Executive Functions	8
Examining the Fit of Two Models: Changes in Physical Activity as a Moderator and Mediator	21
Specific Aims and Hypotheses.....	22
CHAPTER TWO: METHOD	24
Study Design and Procedure.....	24
Participants.....	25
Intervention	28
Measures	28
CHAPTER THREE: RESULTS	33
Data Preparation	33
Descriptives: Changes in BMI, Physical Activity, and Executive Functions.....	33
What is the Relation Between Changes in Physical Activity and BMI, and Does This Relation Depend on Age?	35
What is the Relation Between BMI and Executive Functions, and Does This Relation Depend on Age?.....	36
What is the Relation Between Changes in Physical Activity and Executive Functions, and Does This Relation Depend on Age?.....	37
Do Changes in Physical Activity Serve as a Moderator or a Mediator in the Relation Between BMI and Executive Functions?.....	39
CHAPTER FOUR: DISCUSSION.....	42
Physical Activity and Body Mass Index.....	43
Body Mass Index and Executive Functions.....	47
Physical Activity and Executive Functions	48
Physical Activity as a Moderator or Mediator Between BMI and Executive Functions.....	55
Limitations	56
Significance.....	57
REFERENCES.....	60
VITA.....	71

LIST OF TABLES

Table 1. Means, Standard Deviations, and Change Scores for BMI, Physical Activity, and Executive Functions using <i>t</i> -test Equality of Means	27
---	----

LIST OF FIGURES

Figure 1. Proposed Moderational Model of the Relation Between Changes in PA, age, and BMI	4
Figure 2. Proposed Moderational Models of the Relations Between BMI and Changes in PA on Executive Functions.....	5
Figure 3. Proposed Moderational and Mediational Models.....	6

ABSTRACT

Recent evidence suggests that the summer months represent an especially vulnerable time of year for weight gain, inactivity, and cognitive decline, particularly among adolescent girls. To explore these issues, this study examined the relations between changes in physical activity (PA), body mass index (BMI), and executive functions (EFs) among a sample of sixty-eight, 10-to 14-year-old girls participating in a four-week, community-based summer camp. Objectively measured PA data (i.e., accelerometer), BMI measurements, and EF neuropsychological assessments were conducted prior to the first week of camp and during the last week of camp. Results revealed that girls increased in all measurements of PA, as well as maintained stable *z*BMI and BMI percentile across the camp. Findings related to the influence of PA on EFs were somewhat mixed, as increases in specific aspects of PA were related to both lower *z*BMI and improvement in inhibition skills at the end of camp, but poorer performance on the shifting and working memory tasks. Additionally, higher *z*BMI was associated with improved working memory performance for participants who demonstrated larger increases in PA throughout the camp. Findings suggest that summertime physical activity programs may be one cost-effective avenue through which policy makers and educators might intervene to buffer negative physical and cognitive health outcomes.

CHAPTER ONE

INTRODUCTION

Despite increased awareness of the obesity epidemic over the last decade, prevalence rates of overweight remain stable among US children and adolescents (Ogden, Carroll, Kit, & Flegal, 2014). With 80% of overweight youth going on to become obese adults (Lifshitz, 2008), the annual estimated cost of treating obesity has risen to \$168 billion, or 16.5% of the country's total medical care costs (Cawley & Meyerhoefer, 2011). Another recent study examining the direct costs associated with childhood obesity determined that obese children, relative to their healthy weight peers, incur a lifetime medical cost of \$19,000 (Finkelstein, Graham, & Malhotra, 2014). Given the significant financial strain and chronic course associated with obesity originating during childhood, researchers have focused on gaining a better understanding of the correlates of obesity in order to determine the most effective avenues for intervention. Furthermore, while the obesity epidemic has affected the population as a whole, incidence among young minority females has increased dramatically compared to other demographic groups (Ogden, Carroll, Kit, & Flegal, 2012). This accelerated weight gain may, in part, be due to the related and notable declines in physical activity (PA) that occur for girls during the adolescent years (Finne, Bucksch, Lampert, & Kolip, 2011). Numerous studies have documented that females are less active than their male counterparts, and that inactivity increases with age into adolescence (Finn et al., 2011; Wong et al., 2012).

In addition to a host of negative physical health outcomes (i.e., coronary heart disease, type 2 diabetes, hypertension) associated with sedentary behaviors and obesity, new lines of research have also begun to explore implications for cognitive health, including executive functions (EFs) (Davis et al., 2007, Hillman, 2014). EFs represent cognitive processes (i.e., planning, problem solving) involved in effortful and goal-directed behavior (Best, 2010), which have important implications for self-regulation, academic and learning achievement, and successful functioning across activities of daily life (Li, Dai, Jackson, & Zhang, 2008; Mischel et al., 2011). Youth become increasingly proficient in their EF ability as they traverse childhood and adolescence into young adulthood (Chaddock-Heyman, Hillman, Cohen, & Kramer, 2014; Huizinga, Dolan, & van der Molen, 2006), and emerging evidence has highlighted the dynamic relation between EF development and environmental experiences such as PA (Hillman, 2014). Still, while the link between BMI and EFs has also recently been substantiated through neuroimaging and neuropsychological studies (Batterink, Yokum, & Stice, 2010; Verdejo et al., 2010), little is known about the interactions or mechanisms through which PA contributes to the association.

The Influence of Summertime

While there is a comprehensive body of literature examining obesity and PA in the context of the school and after-school environment, relatively little work has addressed the health consequences associated with the summer months. Interestingly, increases in body mass index (BMI) tend to be largest during periods of unstructured, unsupervised time, when youth are less active and engage in more sedentary behaviors

(Baranowski et al., 2014; Mahoney, 2011; von Hippel, Powell, Downey, & Rowland, 2007). Specifically, research has shown that the summer months may be a particularly vulnerable period for inactivity and weight gain due these factors (Moreno, Johnston, & Woehler, 2013; Moreno et al., 2015; von Hippel et al., 2007), and again, these risks are more pronounced for minority and overweight youth (Franckle, Adler & Davison, 2014). Additionally, these physical health declines, in conjunction with limited opportunities to participate in mentally engaging and structured academic activities, may contribute to poorer EFs and learning loss (Downey, von Hippel, & Broh, 2004; Hanes, Rife, & Laguna, 2005) across summer break.

Relying on a sample of elementary and middle school-aged urban minority girls, this study sought to gain a better understanding of relations between changes in PA, BMI, and EFs in the context of a community-based summer camp. Given the potential bidirectional nature of relations between these variables, several pathways were explored to further delineate these associations. Specifically, the link between changes in PA and BMI was examined, as well as whether this relation varied for younger and older adolescent girls (Figure 1). This study also expanded on the emerging literature that suggests a relation between BMI and EFs, as well as PA and EFs, by examining whether relations varied as a function of age (Figure 2). Lastly, to better understand the interactions and mechanisms that explain the link between BMI and EFs, changes in PA were examined in two models as both a moderator and a mediator (Figure 3).

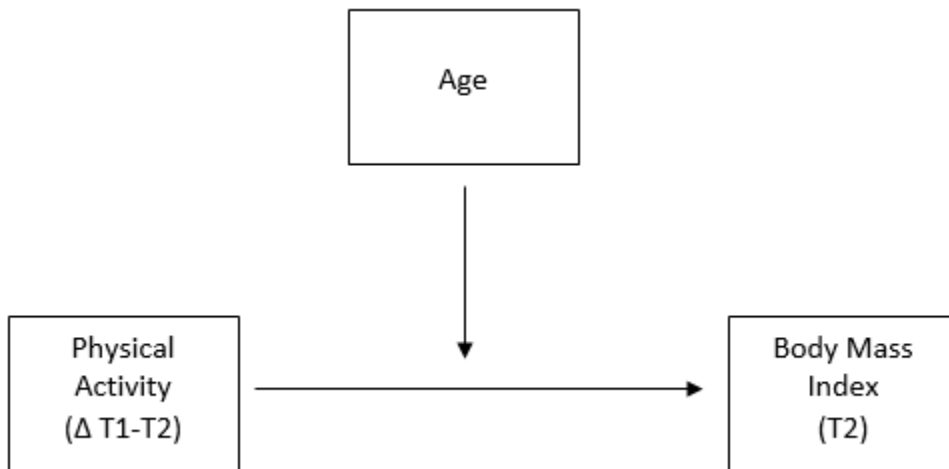


Figure 1. Proposed Moderational Model of the Relation Between Changes in PA, age, and BMI

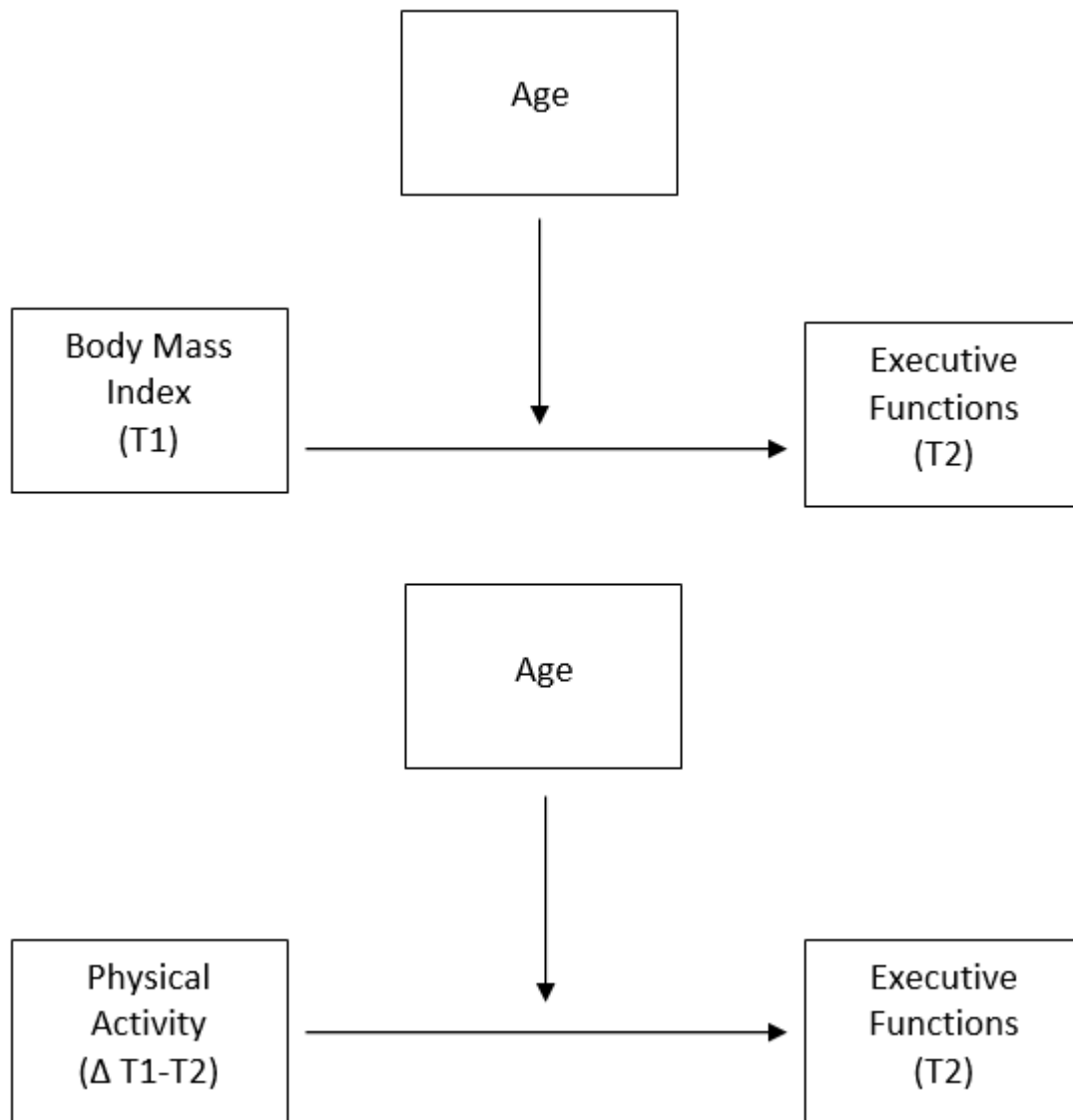


Figure 2. Proposed Moderational Models of the Relations Between BMI and Changes in PA on Executive Functions

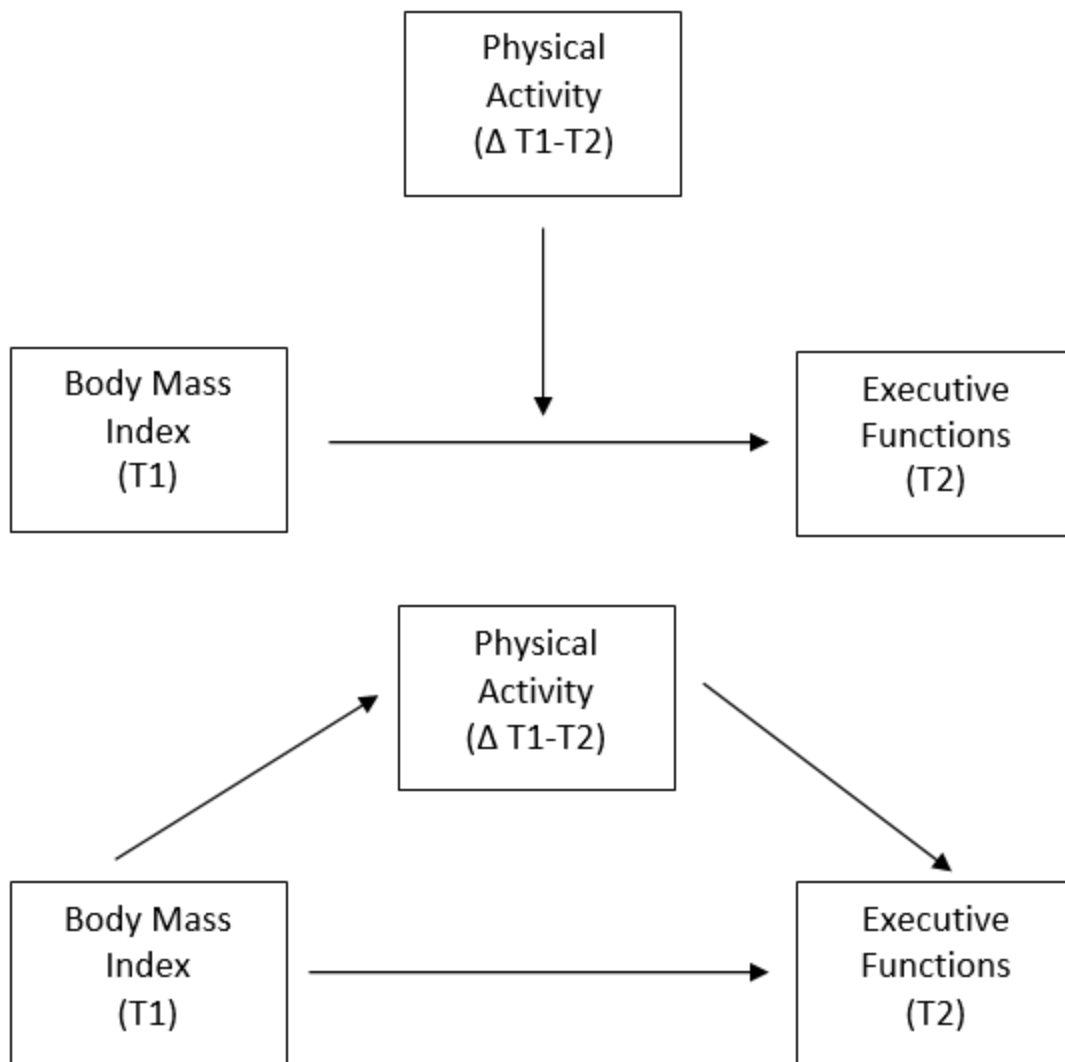


Figure 3. Proposed Moderational and Mediation Models

Changes in Physical Activity and Body Mass Index

The rise in childhood overweight has compelled researchers to consider the influence of various factors contributing to the energy expenditure imbalance implicated in weight gain. Particularly for low-income minority females, the well-documented decrease in PA that occurs during adolescence appears to play a significant role (Kimm et al., 2002; Treuth et al., 2009). One recent study documented that underserved, urban minority children do not achieve the 60 minutes of moderate-to-vigorous PA (MVPA) recommended by the US Department of Health and Human Services (Wong et al., 2012). Additionally, the researchers found that minutes of MVPA/day decreased with age, and females, specifically minority girls, experienced the decline more rapidly compared to males. Furthermore, while Latino populations represent the country's largest and most rapidly growing minority group (U.S. Census Bureau, 2013), Latino youth are more likely to be overweight than both Black and White children (NCLR, 2006). Latina girls have been found to spend less time engaging in physical activity and expend fewer calories than White girls in childhood and early adolescence (Butte, Puyau, Adolph, Vohra, & Zakeri, 2007; Grieser et al., 2006). Given that sedentary patterns established during childhood are more resistant to intervention in later years (Zook, Saksvig, Wu, & Young, 2014), encouraging an active lifestyle earlier is critical for young girls. In fact, African American girls who engaged in regular physical activity during early and later adolescence (ages 9-19 years) had a mean BMI 3kg/m² lower than girls who were consistently inactive (Kimm et al., 2005). Unfortunately, minority girls in urban environments have few opportunities to be physically active during discretionary time

periods (Sandercock, Angus, & Barton, 2010), and as such, public health initiatives should focus intervention efforts on establishing high quality programs in which urban youth can participate.

Age as moderator. While the link between lower levels of PA and increased BMI is well-documented, the relation may depend on various demographic factors. Given the notable decline in PA among adolescent girls, age may be particularly important to examine as a moderating variable across earlier and later adolescence. The adolescent years are also marked by significant physical change and maturation, and the role of physical activity is critical for maintaining healthy weight during this time (Kimm et al., 2005). This is especially true for girls as they enter puberty, the time period in which the most dramatic declines in PA occur (Belcher et al., 2010). Not only does resting energy expenditure decrease during puberty, but energy expended while engaged in physical activity declines as well, highlighting the importance of sustaining or increasing activity levels during this time (Sun et al., 2001; Wong et al., 1999). The decline in PA, coupled with significant changes in physiological processes, suggests PA may be more closely linked to BMI at certain ages.

Body Mass Index, Physical Activity, and Executive Functions

Body mass index and executive functions. Research exploring the consequences of obesity has more recently begun to focus on deficits in cognitive functions. Specifically, EFs have recently been linked to youth weight status, and a review of obesity and cognitive function across the lifespan revealed that obesity is consistently associated with EF deficits in children, adolescents, and adults (Smith, Hay, Campbell, &

Trollor, 2011). This set of functions is involved in planning and organization including “planning, set-shifting or cognitive flexibility, inhibition, working memory, generativity, strategy formation, and self-monitoring” (Wong, Mayberry, Bishop, Maley, & Hallmayer, 2006 p. 562). EFs, when present and typically developing, allow a person to use their abilities and problem solving skills to plan for and achieve goals (Solomon, Goodlin-Jones, & Anders, 2004).

Studies of overweight children, adolescents, and adults have identified several domains of EFs that may be impaired, including (1) shifting/cognitive flexibility and (2) inhibition. Shifting refers to the ability to quickly and flexibly adjust behavior in response to situational demands, while inhibition refers to the ability to constrain a prepotent response or impulse (Davidson, Amso, Cruess, & Diamond, 2006). Several theories exist to explain the association between overweight and these domains of EF, particularly that poor cognitive flexibility and response inhibition among overweight individuals is associated with unhealthy eating behaviors (Fagundo et al., 2012; Maayan, Hoogendoorn, Sweat, & Convit, 2011). This framework of EF deficits among overweight youth has been examined by comparing normal weight and overweight children on a wide range of neuropsychological EF tasks, and results have revealed that overweight children perform consistently worse on tasks related to both shifting (Cserjesi, Luminet, Molnar, & Lenard, 2009) and inhibition (Braet, Claus, Verbeken, & Vierberghe, 2007; Nederkoorn, Braet, Van Eijs, Tanghe, & Jansen, 2006; Pauli-Pott, Albayrak, Hebebrand, & Pott, 2010). Neuroimaging methods have also confirmed differences in brain structure (e.g., basal ganglia) and functions (e.g., increased activity in the prefrontal cortex) involved in EF

performance between normal and overweight children, including shifting, inhibition and working memory (Chaddock, Pontifex, Hillman, & Kramer, 2011). Additional evidence from neuroimaging research suggests that obese and aging brains look similar in their patterns of white matter deterioration in frontal-subcortical regions (Stanek et al., 2013). These findings suggest that overweight youth may differ from their healthy weight counterparts in EF abilities at both a neural and behavioral level, with EFs such as shifting and inhibition most affected. Still, although research in this area is growing, relatively little is known about the direct association between body mass and brain function (Khan, Raine, Donovan, & Hillman, 2014). This study will expand upon the current body of literature by exploring the link between BMI and shifting and inhibition skills among a community sample of urban, adolescent girls.

In addition to the above mentioned domains of EFs, working memory (e.g., updating and monitoring of information) represents another aspect of cognition that should be further explored given the role it plays in more complex mental processes (Miyake et al., 2000; Huizinga et al., 2006). Working memory/updating is characterized by the ability to hold information in one's mind and manipulate it as needed (Davidson et al., 2006), and recent work has demonstrated impairment among overweight children and adolescents. Very few studies have focused on this aspect of EF, but initial studies with children and adolescents suggest that interventions targeting overweight youth should incorporate curriculum focusing on working memory ability (Kamijo et al. 2011). Additionally, preliminary research has indicated that the relationship between obesity and EFs is likely to be bidirectional in nature (Khan et al., 2014), and as such, this study also

explored the reverse path (i.e., influence of EFs on BMI) to clarify the direction of relations.

Physical activity and executive functions. Given that EFs are fundamental for successful functioning in many domains of life, researchers, educators, and health care providers have begun to explore how to optimize the development of these skills. PA and aerobic exercise represent potential environmental factors that may contribute to brain changes implicated in the improvement of EF skills. Fortunately, human brain development extends well into the young adult years, creating an opportunity for PA to enhance brain health during childhood, as well as permanently alter the trajectory of brain function in adulthood (Khan & Hillman, 2014). PA refers to bodily movement that requires energy expenditure above normal physiological demands, while aerobic exercise/fitness refers to the maximal capacity of the cardiorespiratory system to use oxygen (Chaddock et al., 2011). The authors explain that aerobic fitness belongs to a set of health and skill-related attributes necessary to perform physical activities, and thus, aerobic fitness should be interpreted as attributes, and PA as the behavioral manifestation of these attributes.

PA and brain function. The executive function hypothesis proposes that aerobic exercise leads to improvements in EF through corresponding increases in prefrontal cortical activity (Chaddock et al., 2011; Colcombe, et al., 2004; Hillman, Erickson, Kramer, 2008). The neural circuitry within the prefrontal cortex is critical to EF performance, and the maturity of this brain region is particularly sensitive to PA (O'Hare & Sowell, 2008). Innovative research designs utilizing fMRI techniques have also

demonstrated that PA appears to alter the neural circuitry underlying EF performance (Khan & Hillman, 2014). In line with the executive function hypothesis, several other theories have been put forth to explain the relation between PA and EFs. These models all suggest that cognitive demands are integral to aerobic exercise as they require goal-directed behavior and complex motor skills, which result in increases in O₂ levels that are linked to increases in PFC activity (Best, 2010). Given this framework, researchers have begun to examine whether PA interventions may enhance EF abilities in children. In fact, a comprehensive review of EF interventions for children and adolescents found that curriculum focusing on physical and aerobic activity has been effective in improving EF skills (e.g., shifting/cognitive flexibility, inhibition, and working memory/updating) (Diamond & Lee, 2011).

Two experimental designs have typically been employed in order to study the relation between PA and EFs: (1) measuring EFs before and after participants engage in acute sessions of aerobic exercise, and (2) measuring EFs before and at the conclusion of chronic or extended bouts of aerobic exercise (e.g., over a period of several weeks). In general, it is believed that acute exercise increases cerebral blood flow, which accounts for the exercise-induced brain changes (Hillman et al., 2009b). Specifically, the increase in blood flow produces an immediate neurochemical response and increased brain metabolism, which has been linked to improved cognitive functions. On the other hand, chronic exercise programs are believed to bolster cardiorespiratory functioning, which is believed to be involved in the modulation of cognitive operations and EF skills (Best, 2010; Pontifex et al., 2011).

Acute experimental designs. Initial studies examining the effects of PA on EF through acute, laboratory-based assessments have yielded mixed results. One study of overweight 7-to 11-year-old children required participants to attend two laboratory sessions (i.e., experimental and control), and then complete a task assessing shifting abilities at each visit (Tompsonowski, Davis, Lambourne, Gregorski, & Tkacz, 2008). Children were required to participate in a 23-minute treadmill walking session, as well as a 23-minute video watching session. There were no differences in shifting scores after the PA session compared to the video session. Similar results were found in an experiment that required 13-to 15-year-old children to cycle or watch a video for 20 minutes, and then complete a modified version of the Eriksen flanker task (Stroth et al., 2009). The Eriksen flanker task is used as a measure of executive control, which assesses inhibition, working memory, and cognitive flexibility. Children's performance on the EF task was not differentially enhanced after the cycling condition.

Although both of these studies revealed non-significant effects of acute PA on EFs, other studies utilizing similar designs have yielded more positive results. In another treadmill walking test, children ($M = 9.5$ years) completed an inhibition task (e.g., modified flanker task) and measure of academic achievement on two occasions, one after walking for 20 minutes and one after resting for 20 minutes (Hillman et al., 2009b). Results revealed beneficial effects of walking on inhibitory processes. Ellemberg and St. Louis-Deschenes (2010) also saw improvements in cognitive flexibility and inhibition in their randomized experiment. Boys who were 7 and 10 years of age were assigned to either a 40-minute cycling condition or a 40-minute sedentary television viewing

condition. Participants were administered a simple reaction and choice response task assessing aspects of shifting/cognitive flexibility and inhibition prior to and at the conclusion of the intervention, with improvements in EF performance following the cycling condition only.

While several studies have examined the effects of acute PA on shifting/cognitive flexibility and inhibition, few have explored the relation with working memory/updating. Pontifex, Hillman, Fernhall, Thompson, and Valentini (2009) examined the influence of both aerobic exercise and resistance training on working memory among a sample of undergraduate students. Participants attended four laboratory sessions in order to obtain baseline measurements, as well as to participate in three, thirty-minute experimental trials of aerobic exercise, resistance exercise or rest, respectively. The Sternberg working memory task was completed before, immediately after, and 30 minutes after each experimental condition, with results revealing enhanced performance on the working memory task immediately after and 30 minutes after the aerobic exercise condition only. This suggests a differential effect of aerobic exercise on EF, specifically working memory, compared to other types of activity such as resistance exercise (Pontifex et al., 2009). Although findings related to acute PA and EF were mixed, there is growing support that acute PA may at least temporarily bolster youth's EF skills (Best, 2010; Verburch, Konigs, Scherder, & Oosterlaan, 2013), and may also have the potential to influence cognition over the lifespan (Chaddock et al., 2011). It is, however, important to be aware of differences in sample characteristics, research methodology, and domains of EF assessed across each study that may contribute to differences in findings.

Chronic experimental designs. While acute designs examine the immediate effects of PA on EF, chronic or extended PA programs explore the enduring influence of PA through increased cardiorespiratory fitness. Cardiorespiratory fitness is assessed by measuring the maximum capacity to use oxygen through VO₂ max testing or through the PACER tests of the Fitnessgram (Chaddock et al., 2011). A recent two-phase randomized controlled trial (RCT) assigned overweight 7-to 11-year old children to participate in either a 20-minute/day or 40-minute/day exercise group, or a sedentary control group each day after school for approximately three months (Davis et al., 2007; Davis et al., 2011). Participants completed the Planning subtest from the Cognitive Assessment System, which yields an inhibition/self-regulation score, at pre-and post-intervention. The low-and-high-dose (e.g., 20 and 40 minutes, respectively) exercise groups participated in activities such as running, jump rope, or various sports that were focused on fun and enjoyment. Results revealed a dose-response effect of PA on EF, with the high-dose group (e.g., 40 minutes) performing significantly better on EF tasks assessing inhibition than the no activity control group. Similarly, another RCT demonstrated a dose-response relationship between PA and EFs (i.e., brain function and behavioral performance) based on both attendance and task complexity (Hillman et al., 2014). The researchers assigned two hundred twenty-one 7-to 9-year old children to either a 9-month afterschool PA program or a wait list control group. Improvements in shifting and inhibition were observed on behavioral indices of EFs and measurements of brain function for the intervention group only, and the largest effects emerged during tasks requiring greater cognitive engagement and for participants who attended most regularly.

Further evidence of the beneficial effect of PA on inhibition comes from studies comparing youth with higher and lower aerobic fitness levels, as a number of studies have demonstrated that higher-fit children display better cognitive functioning than lower-fit children. In a study of children 7 to 11 years of age, researchers found greater childhood aerobic physical fitness (as measured by aerobic capacity) was associated with better inhibition performance on the Stroop Color-Word task (Buck, Hillman, & Castelli, 2008). Similar results were found in two studies of higher-fit children ($M = 9.4$ years, $M = 10.1$ years) for inhibition performance as measured by a flanker task, respectively (Hillman, Buck, Themanson, Pontifex, & Castelli, 2009a; Wu et al., 2011), as well as for higher-fit children ($M = 10.0$ years) for inhibition measured by both a flanker task and through an ERP recording (Pontifex et al., 2011). The researchers note that lower-fit children not only demonstrate poorer behavioral performance on EF tasks, but neuroelectric data also suggest lower cardiorespiratory fitness may be associated with less maturation of neural networks involved with EFs.

In another nine-month randomized physical activity controlled trial, 7-to 9-year-old children were assigned to participate in a physical activity after-school program (ASP) or a waitlist control group (Kamijo et al., 2011). The ASP met every school day for two hours, with 70 minutes devoted to moderate-to-vigorous PA as measured by heart rate monitors. Participants completed a modified Sternberg working memory task and a cardiorespiratory fitness assessment before and after the intervention, and only the ASP group demonstrated significant improvements in working memory and cardiorespiratory fitness over the course of the intervention. These findings suggest regular PA is

associated with documented increases in cardiorespiratory fitness that seem to be related to improved EFs, particularly aspects of working memory/updating.

Lastly, a recent 10-week exercise-based video game intervention program randomized overweight 15-to 19-year old African American adolescents to participate in a competitive exercise condition, cooperative exercise condition, or a no-play control group (Staiano, Abraham, & Calvert, 2012). The program session was offered every school day and lasted for approximately 30 minutes/day. Participants in the competitive condition were encouraged to beat other participants, burn the most calories, and compare scores with other players, while those in the cooperative condition were told to earn the highest score possible and burn the most calories together with a teammate. Participants also completed select subtests (e.g., design fluency, trail-making) from the Delis-Kaplan Executive Function System (D-KEFS) measuring shifting/cognitive flexibility and inhibition. Results revealed that participants in the competitive exercise condition performed significantly better on the EF tasks than both the cooperative exercise condition and the control group. Interestingly, there were no significant differences between the cooperative play and no play conditions. The authors suggest that conditions of PA that increase the demands on the prefrontal cortex, such as an emphasis on competition, may enhance skill development as youth are pushed to utilize great mental capacity.

Collectively this body of research highlights the contribution of PA to EF development during childhood and adolescence, as this period is marked by significant neural development. Establishing and maintaining healthy PA practices in the early years

is critical, as the negative effects of inactivity and sedentary behavior are more resistant to change in the later adolescent years (Chaddock et al., 2011; Zook et al., 2014). This may be especially relevant for overweight minority girls who historically engage in less PA than other demographic groups. Still, the research among community samples of children/adolescents is limited, and few community-based studies have incorporated high quality neuropsychological and PA assessment tools. This study will address the current gap in the literature by examining the association between changes in PA, measured objectively by accelerometry, and EFs (e.g., shifting, inhibition, working memory) among a community sample of urban minority girls.

Age as a moderator of BMI, changes in PA, and EFs. Although research examining relations between both BMI and EFs and PA and EFs continues to grow, little is known about variables that may affect these relations such as age. Because childhood and adolescence is a critical period for the emergence of EFs, the relations between BMI, changes in PA, and EFs may differ among younger and older adolescents as a function of growth and brain maturation. In general, youth exhibit greater proficiency on tasks assessing EFs as they move through childhood and into adolescence (Best, 2010). Additionally, EFs appear to develop more rapidly in childhood, and then continue to mature at a slower, yet consistent rate through adolescence (Huizinga et al., 2006). Developmental studies examining children's EFs highlight that these skills do not emerge synchronously, rather each aspect of EF emerges on a unique trajectory (Best et al., 2009; Brocki & Bohlin, 2004, Pauli-Pott et al., 2010). That is, adult-level performance for specific EFs appears to be achieved at different times throughout the adolescent years

(Huizinga et al., 2006). While working memory develops throughout childhood and into late adolescence, switching, and specifically inhibition, are thought to be present in a more sophisticated capacity earlier in adolescence. Not only may relations between BMI, PA, and EFs vary as a function of age, but age-related findings may differ for shifting, inhibition, and working memory as well.

BMI, age and EFs. While several studies have highlighted the importance of considering age and development as a factor that may influence the relation between BMI and EFs (Guxens et al., 2009; Pauli-Pott et al., 2010), very few studies have analyzed age differences. However, one study examined the inverse relation (e.g., EF influence on BMI) and found that age moderated the association between inhibition (i.e., impulsivity) and BMI among a sample of 8-to 15-year-old children and adolescents (Pauli-Pott et al., 2010). Specifically, a positive relation emerged such that the association between increased impulsivity and higher BMI was more pronounced for younger than older children. The authors hypothesize that inhibitory control and BMI may be more closely linked at younger ages, in part, because as children get older, additional environmental factors become more predictive of eating behaviors and activity levels. Still, more work is needed in order to thoroughly examine how EF interventions for overweight youth should be tailored for adolescents at different developmental stages.

PA changes, age and EFs. Although studies examining the relation between PA and EFs have yielded mixed results, a recent meta-analysis found an overall small, yet positive relation across 79 studies utilizing acute designs (Chang, Labban, Gapin, & Etnier, 2012). Still, variations in findings may be related to differences in sample

characteristics, highlighting the need to examine potential moderators of the relation. Best (2010) suggests that the link between PA and EFs may depend on age, particularly because certain aspects of EFs may be differentially susceptible to the influence of PA at different developmental periods. Caterino and Polak (1999) were the first to examine age effects and found 4th graders experienced EF benefits from an acute session of walking, while 2nd and 3rd graders did not. More recently, Ellemberg & St. Louis-Deschenes (2010) explored the combined influence of PA and age on shifting and inhibition. The study revealed no differences in the association between PA and EFs based on age among a sample of 7- and 10-year-old children participating in a cycling task. Similar results emerged in a study of task switching utilizing a sample of overweight children 7 to 11 years of age, as PA did not differentially influence EF abilities in older or younger children (Tompson et al., 2008).

Despite these variable results, the childhood development and neuroscience literature both suggest age may be a critical factor to consider when developing PA interventions designed to influence EFs. Particularly for children, the brain is highly plastic and very susceptible to environmental influences (Chaddock-Heyman et al., 2014; Hillman, 2014). For instance, several studies have found the association between PA and EFs differs depending on the cognitive complexity of the activity curriculum (Budde, Voelcker-Rehage, Pietrabyk-Kendziorra, Ribeiro, & Tidow, 2008; Pesce, Crova, Cereatti, Casella, & Bellucci, 2009), and as such, older children may benefit more from PA that involves complex rule structure compared to younger children (Best, 2010). The authors suggest that PA requiring greater cognitive engagement has a stronger impact on EFs;

however, these benefits may be less apparent for youth whose cognitive infrastructure is less established. To date, very few studies have examined age as a moderator of PA and EFs, and additional work is needed to determine the dynamic relation between the variables.

Examining the Fit of Two Models: Changes in Physical Activity as a Moderator and Mediator

As research has begun to substantiate the link between BMI and EFs, exploring moderational and mediational models may be the next step in gaining a more thorough understanding of the relation. While several studies have demonstrated associations between the two variables, results are equivocal and little is known about the specific contributions of PA as either a moderator or mediator. A recent investigation noted that the majority of the research in this area has focused on the independent contributions of both BMI and fitness factors (e.g., PA) on cognition, while very few have explored the influence of the “inter-relationship” in association with EFs (Pontifex et al., 2014). One method for answering questions related to mechanisms and influence is to examine the same variable in a moderator and mediator role (Rose, Holmbeck, Coackley, & Franks, 2004). This approach provides a better conceptualization of the relation between BMI and EFs, as well as informs future research and program development efforts.

Within this framework, one potential model hypothesizes that BMI has a more negative influence on EFs when a child or adolescent exhibits smaller increases in PA (i.e., moderator). This moderator model suggests that the strength of the relation between BMI and EFs will differ depending on the amount of changes observed in PA. On the

other hand, an alternative explanation may be that BMI is related to EFs through PA (i.e., mediation). That is, PA may be the mechanism through which BMI influences EFs. For instance, higher BMI might be associated with smaller increases in PA, which is in turn related to deficits in EFs. As health care providers, educators, and policy makers search for evidence-based and theoretically driven intervention techniques, this data has implications for decisions related to curriculum development and will shed light on factors that are likely to enhance program outcomes.

Specific Aims and Hypotheses

Utilizing a sample of 10-to-14 year old low-income, urban minority girls participating in a community-based summer camp, this study seeks to gain a better understanding of the relations between changes in PA, BMI, and EFs. Specifically, this study will address the following objectives:

1. To examine the relation between changes in PA levels across the camp and BMI at T2. An inverse relation between PA changes and BMI was hypothesized, such that greater increases in PA over the course of the camp would be associated with lower BMI at the end of camp.
 - 1a. To determine whether the relation between changes in PA and BMI differed depending on age. It was hypothesized that the relation between PA changes and BMI would be strongest for older participants.
2. To examine the relation between BMI at T1 and EFs at T2. It was hypothesized that higher BMI would be associated with poorer EF

performance, including EF domains of shifting, inhibition, and working memory. The model was run separately for each domain of EF.

- 2a. To determine whether the relation between BMI and EFs differed depending on age. It was hypothesized that the relation between higher BMI and poorer EF performance would be strongest for younger participants in the sample.
3. To examine the relation between changes in PA levels and EFs at T2. It was hypothesized that greater increases in PA would be positively associated with improved EF performance, including EF domains of shifting, inhibition, and working memory. The model was run separately for each domain of EF.
 - 3a. To examine whether the relation between changes in PA levels and EFs differed depending on age. It was hypothesized that the relation between PA changes and enhanced EFs would be strongest for older participants in the sample.
4. To conduct analyses examining the fit of moderational and mediational models of changes in PA to explain the relation between BMI at T1 and EFs at T2. Although no studies to date have examined the moderating or mediating role of changes in PA in the relation between BMI and EFs, it was hypothesized that the mediation model would demonstrate a better fit (i.e., BMI would influence EFs through a lack of PA).

CHAPTER TWO

METHOD

Study Design and Procedure

Data for this investigation was taken from a larger study designed to evaluate the effectiveness of an intensive 4-week community-based summer camp taking place over the course of three summers. The first wave of data was collected during the summer of 2012 (year one), the second during the summer of 2013 (year two), and the third during the summer of 2014 (year three). Pre-test data (Time 1; T1) was collected several weeks prior to the start of the camp at a camp orientation day, and end-of-camp data (Time 2; T2) was collected during the final week of the program. Participants were recruited through two methods: (1) a Girls in the Game (GIG) mailing to parents/guardians of all 10-14 year old girls enrolled in the program and (2) announcements at the GIG summer camp orientation meeting. Participants already enrolled in the summer camp were sent an informational packet about the study along with their camp registration materials. The packets provided consent forms in either English or Spanish and a cover letter explaining the study. The cover letter also invited participants and their families to attend a camp orientation day prior to the start of camp where campers could come to learn more about the community organization and their programs, as well as complete T1 measures if they chose to participate. Participants had the option of returning their consent forms by mail with their camp registration forms to the community organization, or to bring it directly

to the orientation day. Families who did not attend the camp orientation day and had eligible daughters enrolled in the program were also called and invited to participate in a second T1 data collection session held several days later. The Institutional Review Board of Loyola University Chicago approved this study.

A multi-method assessment strategy utilizing questionnaires, anthropometric measures, individually administered neuropsychological tests and accelerometers was used at T1 and T2. Participants completed questionnaires in small groups with a trained research assistant, individually completed neuropsychological tests, and had their anthropometric measurements taken in a semi-private location. In addition, participants wore accelerometers for one week at T1 and one week at T2.

Participants

Of the 231 girls who were eligible to participate and sent recruitment packets, 91 participants were enrolled in the camp in either the summer of 2012, 2013, or 2014. Though 91 participants ($n = 43$ in 2012, $n = 26$ in 2013, $n = 22$ in 2014) enrolled in the study, only 68 girls ($n = 22$ in 2012, $n = 26$ in 2013, $n = 20$ in 2014; M age = 11.95 years, $SD = 1.09$) were still enrolled and/or attended both data collection sessions and were included in this analytic sample (29 percent of recruited participants). Participants left the study for several reasons including dropping out of the summer program ($n = 3$ in 2012, $n = 4$ in 2013, $n = 2$ in 2014), and the remaining missing data ($n = 11$ in 2012, $n = 3$ in 2013, $n = 0$ in 2014) was the result of either being absent from camp during T2 data collection, invalid accelerometer data or device malfunction, or declining to be weighed

or wear an accelerometer. Finally, one accelerometer was lost each year in 2012 and 2013 at follow-up, and thus, no activity data was available for those participants.

Identification of participants' racial/ethnic background was obtained through parent/caregiver report on camp enrollment forms, and parents/caregivers indicated participants were African American (64.2%), Latina (29.9%), Asian American (3.0%), Caucasian (1.5%), or other identified (1.5%). The average BMI for participants at T1 was 22.49 ($SD = 5.16$), and a standardized z BMI score was also computed, with the average being 0.90 ($SD = 1.01$) (see Table 1). When measured in children, BMI can be plotted on BMI-for-age growth charts to obtain a percentile ranking, which is used to assess the relative position of the child's BMI number among children of the same sex and age. Girls in this sample had an average BMI percentile ranking of 73.84 ($SD = 26.86$), indicating normal weight status (<85th percentile). Still, based on BMI for-age percentiles over half of the sample was overweight or obese with 25.0% of girls falling in the overweight category (≥ 85 th percentile <95th percentile) and 27.9% (≥ 95 th percentile) meeting criteria for obesity.

Analyses were run to compare participants with and without complete data, and those who completed data collection at both time points did not differ from those with missing data in terms of basic demographic characteristics including age, z BMI or BMI percentile. However, girls without complete data did have significantly higher BMI ($M = 25.18$, $SD = 6.46$) at T1 than those who participated at both time points ($M = 22.49$, $SD = 5.16$), $t(88) = 1.99$, $p = .05$.

Table 1. Means, Standard Deviations, and Change Scores for BMI, Physical Activity, and Executive Functions using *t*-test Equality of Means

	Time 1 <i>M</i> (<i>SD</i>)	Time 2 <i>M</i> (<i>SD</i>)	Average Change <i>M</i> (<i>SD</i>)	<i>t</i>
Body mass index variables				
BMI	22.49 (5.16)	22.81 (5.38)	0.32 (1.01)	-2.57*
zBMI	0.90 (1.01)	0.93 (1.02)	0.03 (.16)	-1.63
BMI Percentile	73.84 (26.86)	74.57 (26.46)	0.73 (4.33)	-1.39
Physical activity variables				
Sedentary Min/day	713.28 (137.22)	563.03 (112.19)	150.25 (149.58)	8.28***
Moderate PA Min/day	12.52 (17.19)	39.30 (29.54)	26.78 (33.19)	-6.65***
Vigorous PA Min/day	1.59 (3.89)	2.96 (3.27)	1.37 (4.98)	-2.27*
MVPA Min/day	14.11 (19.52)	42.26 (31.47)	28.15 (35.78)	-6.49***
# of MVPA 5-min Bouts/day	0.27 (.78)	1.11 (1.35)	0.84 (1.46)	-4.74***
Min/day Spent in MVPA Bouts	3.82 (11.57)	16.46 (18.60)	12.64 (20.94)	-4.98***
Total PA Min/day	367.89 (124.51)	510.85 (137.62)	142.96 (154.54)	-7.63***
Executive function variables				
Shifting Time (seconds)	76.43 (17.68)	69.87 (20.69)	6.55 (15.97)	3.31**
Shifting Errors	2.13 (.71)	1.45 (.82)	0.68 (.77)	7.23***
Shifting Problems	7.05 (3.33)	7.01 (3.42)	0.03 (2.61)	0.10
Inhibition Time (seconds)	70.88 (17.98)	65.53 (18.05)	5.35 (11.70)	3.72***
Inhibition Errors	1.93 (.77)	1.40 (.87)	0.53 (1.00)	4.35***
Inhibition Problems	6.54 (4.31)	7.48 (5.14)	0.94 (3.75)	-2.02*
Working Memory (Digit recall)	15.30 (2.92)	15.70 (3.85)	0.40 (3.48)	-0.95
Working Memory Problems	8.22 (4.11)	8.44 (4.79)	0.22 (4.18)	-0.42

Note. PA=physical activity, MVPA=moderate-to-vigorous physical activity. Total PA includes light, moderate, and vigorous physical activity.

p* < .05. *p* < .01. ****p* < .001.

Intervention

The Girls in the Game (GIG) summer camp program serves girls who reside in low-income Chicago neighborhoods. Programming was provided for four weeks with six hours of activities each day. Each session provided instruction and PA through a variety of traditional and non-traditional sports and fitness activities, developmentally appropriate education in health and nutrition topics, as well as incorporated a focus on developing self-control and leadership skills.

Throughout the camp day program participants were divided into smaller teams (e.g., 20 campers) based on age and developmental level, and three camp coaches supervised each small team. The daily schedule included three 50-minute morning sessions (i.e., two sports-based, PA lessons and one health/leadership activity), a 40-minute lunch break, 60 minutes of pool time, 45 minutes of team physical activity, as well as an additional 10-minute snack break. Program participants were provided transportation to and from the camp.

Measures

Demographics. Demographic information was obtained via questionnaires and included date of birth and age. Ethnicity information was obtained from the after-school program demographic database completed by parents/caregivers.

Anthropometry. Weight of the participant was measured without shoes and dressed in light clothing to the nearest 0.1 kilogram (kg) using a digital scale (Seca 770, Hamburg Germany). Height was measured using a Seca 214 mobile stadiometer without shoes and head held in the Frankfort plane to the nearest 0.1 centimeter. These data were

then used to calculate BMI according to the following formula: $BMI = \text{kg}/\text{m}^2$. BMI is an indicator of weight divided by height and is considered a reliable indicator of body fatness for children and teens (Ogden & Flegal, 2010). The BMI-for-age percentile was determined using the Centers for Disease Control and Prevention (CDC) national norms using age to the nearest month and gender-specific median, SD, and power of the Box-Cox transformation. BMI-for-age percentile is used to interpret the BMI number because it is age- and sex-specific for children and teens. These criteria are different from those used to interpret BMI for adults, which do not take into account age or sex. BMI-for-age weight status categories were created based on BMI percentiles as outlined by the CDC: underweight (less than 5th percentile), normal weight (5th percentile to less than the 85th percentile), overweight (85th to less than the 95th percentile), or obese (equal to or greater than the 95th percentile). BMI *z*-scores were also calculated based on CDC growth charts using The Children's Hospital of Philadelphia online calculator, and these scores were used in all analyses (Kuczmarski et al., 2002). Researchers have used *z*BMI scores as a standardized way to assess overweight because there is no ceiling at the upper limit of percentiles where values are collapsed (Daniels, 2009).

Physical activity. Physical activity (PA) was measured using an accelerometer (Actigraph 3GTx), worn at the waist, positioned just behind the right hip. Participants were monitored both in and out of camp for a total of six days, including two weekend days. Participants were instructed to remove accelerometers when bathing and during the 60 minutes of pool time per day at camp. Accelerometer data were passed through a customized Visual Basic EXCEL macro designed to infer non-wear time and to

determine the amount of time spent in sedentary, light, moderate and vigorous physical activity (Troost, McCoy, Very, Mallya, Duffy, & Foster, 2013). A valid day of physical activity monitoring was defined as having 9 or more hours of wear time. Sedentary, moderate and vigorous activity levels were defined using published cut-points for children and adolescents, as well to determine moderate and vigorous bouts of PA (Rice & Trost, 2014).

Data are reported as total PA (min/day; e.g., light, moderate, vigorous), total minutes in moderate-and-vigorous PA (MVPA, min/day), the number of 5-minute bouts spent in MVPA (MVPA Bouts), and the number of minutes in MVPA in bouts of 5 or more minutes (MVPA Bout Minutes, min/d). Physical activity change variables were calculated utilizing both time points of data (e.g., T2 – T1), with positive scores representing an increase in minutes or bouts of PA and negative scores representing a decrease in minutes or bouts.

Executive functions. *Delis-Kaplan Executive Function System, (D-KEFS)*. The D-KEFS consists of nine standardized tests designed to evaluate cognitive functions in children and adults ages 8 to 89 years (Delis, Kaplan, & Kramer, 2001). This study utilized the Color-Word Interference Test to measure inhibition of an automatic response (word reading) in favor of a novel response (color naming) that was first developed by Stroop (1935). The Color-Word Interference Test includes color, word, and interference conditions like the Stroop test, but also includes a fourth interference/switching condition. This additional condition assesses cognitive flexibility or shifting by requiring participants to switch back and forth between naming dissonant ink colors and reading

conflicting words. Raw scores were utilized in all analyses and reflect the speed at which participants completed the task, as well as an error score (i.e., number of errors made while completing the task), with higher scores on both time and errors denoting worse performance. The test evidences strong psychometric properties with internal consistency coefficients ranging from 0.62 to 0.77 for children 10-to-14 years of age, and test-retest reliability from 0.77 to 0.90 across the four conditions included in the test (Delis et al., 2001).

Wechsler Intelligence Scale for Children- Fourth edition (WISC-IV).

Participants completed the Digit Span subtest from the Working Memory Index of the WISC-IV (Wechsler, 2003). Digit Span is composed of two parts, including Digit Span Forward (DSF) and Digit Span Backward (DSB), which was used to create a raw score for total digit span with higher scores indicating better working memory performance. The test is designed to measure auditory short-term memory, sequencing skills, attention, and concentration, with DSB specifically assessing working memory ability, transformation of information, and mental manipulation. The WISC-IV is well validated with an overall reliability coefficient of 0.97, and the specific Digit Span subtest at 0.87. The test-retest reliability coefficient for Digit Span is also 0.83 (Wechsler, 2003).

Behavior Rating Inventory of Executive Function, Self-Report, (BRIEF).

Participants completed three subtests of the BRIEF, which assess self-reported problems with several domains of EFs. The BRIEF is an 80-item measure in which the respondent is asked to identify whether each statement is true never, sometimes, or often. Examples of BRIEF statements include “I have trouble getting used to new situations”, “I interrupts

others”, and “I forget instructions easily.” While the measure assesses eight domains of EFs, the current study focused on the 35 items included in the Inhibit, Shift, and Working Memory indices, with higher raw scores indicating more EF problems. Previous examination of the psychometric properties of the BRIEF subscales has demonstrated a good internal consistency for the eight domains ($\alpha = .96$) and for the scales ($\alpha = .72 - .96$) (Guy, Isquith, & Gioia, 2004). Cronbach’s α in the current study was .90.

CHAPTER THREE

RESULTS

Data Preparation

Initially, the data were examined for outliers and skewness (Tabachnick & Fidell, 1996), and all EF variables that had a skewness statistic greater than 1.2 were transformed using a square root transformation (e.g., Inhibition Total Errors and Switching Total Errors). Additionally, preliminary descriptive analyses were run with all study variables at T1 and T2, including means, standard deviations, and average change scores and can be found in Table 1. Post-hoc power analysis using the G*Power program (Faul, Erdfelder, Lang, & Buchner, 2007) determined that the sample size of 68 was adequately powered to detect large effects, but was underpowered to detect both small and medium effect sizes through regression analyses.

Descriptives: Changes in BMI, Physical Activity, and Executive Functions

Paired samples *t*-tests were utilized in order to determine the nature of changes in BMI, PA and EF variables as a result of camp participation (e.g., response to intervention). Analyses indicated that participants' BMI at the end of camp was significantly higher than scores at baseline, while *z*BMI and BMI percentile scores did not significantly increase (see Table 1). Additionally, all PA variables significantly increased from T1 to T2, while sedentary time significantly decreased from T1 to T2 by over 150 min/day on average (see Table 1). Total PA (i.e., light, moderate & vigorous)

significantly increased by over 142 min/day, and MVPA increased by 28 min/day. Participants also significantly increased their MVPA Bouts, as well as increased their MVPA Bout Minutes. In terms of EFs, participants significantly improved in their time to complete the inhibition and shifting tasks at the end of camp compared to prior to camp, as well as made fewer errors while completing the shifting and inhibition tasks. Interestingly, participants indicated an increase in inhibition problems on the BRIEF self-report measure at T2.

Correlational analyses indicated that age was not significantly associated with any PA variables at T1, but was significantly negatively correlated with several PA change scores and PA variables at T2. Specifically, older girls demonstrated smaller increases in moderate PA changes ($r = -.25, p = .036$), MVPA minute changes ($r = -.26, p = .034$), and MVPA Bout Minute changes ($r = -.24, p = .049$). Similarly at T2, age was negatively associated with moderate PA ($r = -.24, p = .049$), vigorous PA ($r = -.28, p = .019$), MVPA Bout Minutes ($r = -.26, p = .036$), and MVPA minutes ($r = -.25, p = .037$), with older girls spending fewer minutes per day engaged in activity.

Age was also significantly negatively associated with several EF variables at both time points, including inhibition time ($r = -.33, p = .006$), shifting errors ($r = -.24, p = .049$), and self-reported problems with shifting ($r = -.28, p = .024$) at T1. That is, older girls completed the inhibition task faster, made fewer shifting errors, and reported fewer problems with shifting prior to camp. Similar relations emerged at T2, with age being negatively associated with inhibition ($r = -.31, p = .012$) and shifting ($r = -.29, p = .019$) time. Again, this suggests that older girls in the sample completed both the inhibition and

shifting tasks faster than younger girls at the end of camp. In addition to being significantly correlated with completion time on the neuropsychological tasks, age was also negatively associated with inhibition errors ($r = -.28, p = .022$) and switching errors ($r = -.33, p = .007$), demonstrating that older girls were more accurate in their performance while completing the task at T2.

Finally, z BMI at T1 was positively correlated with switching at both T1 ($r = .33, p = .007$) and T2 ($r = .25, p = .039$), and negatively correlated with vigorous PA at T1 ($r = -.25, p = .039$). Findings indicate that higher z BMI was associated with longer completion time on the shifting neuropsychological task before and at the end of camp, and lower z BMI was associated with more minutes spent in vigorous activity at T1. No other significant correlations emerged between z BMI and any other EF, PA change variables, or PA at either time point.

What is the Relation Between Changes in Physical Activity and BMI, and Does This Relation Depend on Age?

Multiple regression analyses were utilized to examine the relation between changes in PA over the course of the camp and z BMI at T2, as well as whether the relation differed depending on age. First, the PA change variables and age were centered by subtracting the mean from the variables. T1 z BMI was entered in the first step as a covariate, PA change variables and age were entered in step 2 to account for main effects of these variables, and the two-way interaction terms in Step 3 (PA X Age). Separate regressions were run for each of the six PA variables. When significant interactions were detected, post-hoc probing via tests of simple slopes was conducted.

Conditional moderating variables were created, and regressions were run incorporating the main effect of PA, the conditional variable, and the interaction between the two (Holmbeck, 2002).

For regression analyses examining relations between changes in PA and zBMI at the end of camp, analyses revealed a significant main effect of vigorous PA changes on zBMI, $B = -.01$, $\beta = -.04$, $t(64) = -2.06$, $p = .043$. This suggests that greater increases in vigorous PA over the course of the camp were related to lower zBMI scores at T2. No other significant main effects were found, and relations did not vary as a function of age.

What is the Relation Between BMI and Executive Functions, and Does This Relation Depend on Age?

Multiple regression analyses were also run to examine the relation between zBMI at T1 and EFs (e.g., shifting, inhibition and working memory) at T2, as well as whether the relation differed depending on age. T1 EFs were entered in the first step as a covariate, T1 zBMI and age were entered in step 2 to account for main effects of these variables, and the two-way interaction terms in Step 3 (e.g., zBMI X Age). Separate regressions were run for each of the EF variables at T2. When significant interactions were detected, post-hoc probing via tests of simple slopes was conducted. Conditional moderating variables were created, and regressions were run incorporating the main effect of PA, the conditional variable, and the interaction between the two (Holmbeck, 2002). No significant main effects emerged for relations between BMI and any of the

EFs. In addition, age did not moderate any of these relations.¹ Analyses exploring the reverse path (i.e., the influence of EFs on BMI) were also conducted.

What is the Relation Between Changes in Physical Activity and Executive Functions, and Does This Relation Depend on Age?

Relations between changes in PA, age and EFs (e.g., shifting, inhibition and working memory) at T2 were also examined through multiple regression analyses. All T1 outcome variables were entered as covariates in step 1 (e.g., T1 EFs), main effects were entered in step 2 (e.g., PA change variables, age), followed by the interaction terms in step 3 (e.g., PA change X Age). Results are presented separately for each EF outcome.

Shifting. For regression analyses examining relations between changes in PA and time to complete the shifting neuropsychological task, results revealed a significant main effect of MVPA Bout Minutes on shifting performance, $B = .26$, $\beta = .26$, $t(61) = 2.81$, $p = .007$. This suggests that greater increases in minutes spent in MVPA Bouts over the course of camp were actually related to slower completion time on the shifting task. No other significant main or interaction effects emerged between PA, age, and EFs.

Inhibition. Results revealed a significant main effect of Moderate PA changes on time to complete the inhibition neuropsychological task, $B = .09$, $\beta = .17$, $t(62) = 2.18$, $p = .033$, suggesting that greater increases in PA were related to participants taking longer to complete the task. However, changes in moderate PA were also significantly related to the number of inhibition errors on the neuropsychological task at T2, $B = -.01$, $\beta = -.25$, $t(63) = -2.17$, $p = .034$, such that greater increases in PA were related to participant's making fewer errors in their performance. Results also revealed a significant main effect

¹ Analyses exploring the relation between EFs and zBMI also revealed non-significant results.

of MVPA Bout Minute changes on inhibition time, $B = .17, \beta = .20, t(62) = 2.58, p = .012$, as well as changes in MVPA minutes on inhibition time, $B = .09, \beta = .17, t(62) = 2.14, p = .037$, again suggesting that greater increases in PA were related to longer time to complete the task. A similar pattern of results emerged demonstrating that increases in MVPA minutes, as well as total minutes of PA were associated with fewer inhibition errors at T2, $B = -.01, \beta = -.24, t(63) = -2.04, p = .045$; $B = -.01, \beta = -.24, t(63) = -2.13, p = .037$, respectively. In general, across all analyses of PA changes and inhibition there was a pattern of findings whereby greater increases in PA were associated with slower completion times, but also fewer errors and a more accurate performance.

Working memory. Changes in minutes of both moderate PA, $B = -.03, \beta = -.28, t(62) = -2.40, p = .019$, as well as MVPA, $B = -.03, \beta = -.27, t(62) = -2.33, p = .023$ were significantly related to performance on the working memory neuropsychological task, suggesting that greater increases in PA were associated with poorer working memory performance (i.e., fewer digits recalled). There was also a significant MVPA Bout Minute change X Age interaction on working memory performance, $B = -.04, \beta = -.21, t(62) = -2.02, p = .048$. While there were no significant relations between MVPA Bout Minute changes and working memory performance at T2 for younger girls, $B = -.01, \beta = -.06, t(62) = -.42, p = .676$, there was a significant relation between MVPA Bout Minute changes and working memory for older girls, $B = -.10, \beta = -.54, t(62) = -2.97, p = .004$. Older girls who increased the number of minutes spent in MVPA Bouts recalled fewer digits at T2.

In addition to MVPA Bout Minutes, there were parallel findings with changes in the number of MVPA Bouts indicating a significant MVPA Bout change X Age interaction on working memory performance, $B = -.96, \beta = -.31, t(62) = -3.28, p = .002$. The same pattern of results held in which there was a non-significant relation between MVPA Bout changes and working memory for younger girls, $B = .22, \beta = .08, t(62) = .52, p = .605$, and a significant inverse relation between MVPA Bout changes and working memory for older girls, $B = -1.87, \beta = -.71, t(62) = -4.79, p = .001$.

Do Changes in Physical Activity Serve as a Moderator or a Mediator in the Relation Between BMI and Executive Functions?

Physical activity as a moderator. Multiple regression was also utilized to examine the role of changes in PA as a moderator of the relation between zBMI and EFs at T2 (e.g., shifting, inhibition, and working memory). T1 EFs were entered in the first step as a covariate, T1 zBMI and PA change variables were entered in step 2 to account for main effects of these variables, and the two-way interaction term in Step 3 (e.g., zBMI X PA changes). Separate regressions were run for each of the EF variables at T2.

While no significant interactions emerged between zBMI, PA changes and shifting, regression analyses examining the relation between zBMI and performance on the inhibition task revealed a significant zBMI X MVPA Bout change interaction on numbers of inhibition errors at T2, $B = .15, \beta = .26, t(62) = 2.18, p = .033$. Still, simple slope analyses indicated a non-significant relation between zBMI and inhibition errors for girls with both greater increases in MVPA Bout changes, $B = .20, \beta = .23, t(62) = 1.42, p$

= .161, as well as for girls with smaller increases in their MVPA Bouts, $B = -.24$, $\beta = -.27$, $t(62) = -1.61$, $p = .112$.

For regression analyses examining relations between zBMI and performance on the working memory neuropsychological task, analyses revealed a significant zBMI X MVPA Bout change interaction on working memory performance, $B = .76$, $\beta = .30$, $t(62) = 3.16$, $p = .002$. For participants who had greater increases in MVPA Bouts, there was a significant positive relation between zBMI and working memory, $B = .15$, $\beta = .39$, $t(62) = 3.07$, $p = .003$. That is, higher zBMI was related to improved working memory performance among those participants who demonstrated greater increases in the number of MVPA Bouts achieved. The relation between zBMI and working memory was non-significant for participants with smaller changes in MVPA Bouts, $B = -.71$, $\beta = -.19$, $t(62) = 1.39$, $p = .170$. There was also a significant zBMI X MVPA Bout Minute change interaction on working memory performance, $B = .04$, $\beta = .21$, $t(62) = 2.04$, $p = .046$. A similar pattern of results emerged during follow-up analyses indicating a significant positive relation between zBMI and working memory for participants demonstrating greater increases in minutes spent in MVPA Bouts, $B = 1.27$, $\beta = .33$, $t(62) = 2.24$, $p = .029$, and a non-significant relation between zBMI and working memory for those with smaller increases in minutes spent in MVPA Bouts, $B = -.36$, $\beta = -.09$, $t(62) = -.67$, $p = .514$.

Physical activity as a mediator. A bootstrapping approach was utilized in order to examine the role of PA changes as a mediator between zBMI at T1 and EFs at T2. The bootstrapping approach is considered the most valid and powerful test of mediational

effects (Hayes, 2009) and included four main steps (Shrout & Bolger, 2002). First, the original sample n was used as a population reservoir to create a pseudo (bootstrap) sample of N people by randomly sampling observations with replacement from the original n . Next, for each bootstrap sample, a and b were estimated and the product of the path coefficients were recorded. The third step involved repeating Steps 1 and 2 for a total of k times (where $k = 5,000$ as recommended by Hayes, 2009). When completed, this procedure resulted in k estimates of the indirect effect and the distribution of this indirect effect functioned as an approximation of the sampling distribution of the indirect effect. Finally, the k estimates were used to generate a percentile-based bootstrap confidence interval, for which the cut points exclude $(\alpha/2) \times 100\%$ of the values from each tail of the empirical distribution. If zero was not between the lower and upper bound, then it was acceptable to claim that the indirect effect was not zero (Hayes, 2009; Shrout & Bolger, 2002). No significant findings emerged, suggesting that PA changes did not mediate the relation between z BMI and any of the EFs.

CHAPTER FOUR

DISCUSSION

A growing body of literature has demonstrated the association between declines in PA and increases in youth BMI (McCue, Marlatt, Sirard, & Dengel, 2013), and more recently correlates of PA have also included cognitive functions (Hillman, 2014), specifically EFs (Davis et al., 2007). In addition to examining the relation between both PA and BMI and PA and EFs, recent research has also demonstrated associations between BMI and EFs across the lifespan (Smith et al., 2011). While examining the links between PA, BMI and EFs among underserved youth certainly warrants further attention given the disparity in overweight and decreases in PA among this population, these relations should also be explored during the summer months as recent evidence suggests this may be a high-risk period due to disproportionate weight gain (Moreno et al., 2013; Moreno et al., 2015; von Hippel et al., 2007) and cognitive decline and learning loss (Downey et al., 2004; Hanes et al., 2005) that occurs during summer break. A recent meta-analytic review of seven studies also suggested that the trend for increased weight gain during the summer seems to be especially pronounced for racial/ethnic minorities and for youth who are already overweight (Franckle et al., 2014). Given that this study utilized a sample of minority girls and that over half the sample was either overweight or obese, this study contributes to the relatively small body of literature addressing the health consequences associated with summertime. In addition to examining physical

health consequences, this study also incorporates PA, BMI and cognitive functions (i.e., executive functions) within the same model in the context of this high-risk time period.

Physical Activity and Body Mass Index

The first aim of this investigation was to examine the relation between changes in physical activity (PA) and body mass index (BMI) and to determine whether the relation differed depending on age. It should be noted that zBMI was utilized in all regression analyses in this study, which is suggested to be the most stringent indicator of adiposity, as well as the most difficult indicator in which to observe change (Cole, Faith, Pietrobelli, & Heo, 2005), highlighting the strength of findings that did emerge. Additionally, the researchers note that zBMI is the most reliable parameter to include in research studies examining change in adiposity over time.

Camp influences on changes in PA. Participants in this study decreased their sedentary time over the course of the camp and increased in all measurements (i.e., minutes, bouts) of PA. While the US Department of Health and Human Services recommends 60 minutes of MVPA per day, recent studies have demonstrated that underserved minority youth do not meet the recommended guidelines, that females engage in fewer minutes compared to males, and this disparity increases with age into adolescence (Wong et al., 2012). Girls participating in the camp achieved forty-two minutes of MVPA/day compared to only fourteen minutes/day prior to camp. Given that participants did not wear accelerometers during their daily pool instruction, this is likely an underestimate of sedentary and PA time at the end of camp. This pattern of findings suggests that adolescent girls may be amenable to interventions that are designed to

increase their PA. This is significant in light of the large body of research that has found, in general, that adolescent girls typically engage in more sedentary activities and spend less time being physically active (Finn et al., 2011; Grieser et al., 2006), particularly during the summer months when youth become more inactive due to lack of structured opportunities provided by the school day. While summer camp studies have found that day programs do in fact attempt to buffer sedentary behavior and promote activity engagement, effectively increasing PA and decreasing sedentary time among females remains a significant challenge (Zarrett, Sorensen, & Skiles, 2013). Still, participants in the current study were enrolled in a girl-specific PA intervention, suggesting that tailored, female focused programming may be key to combatting summer time activity declines among adolescent girls.

Community-based programs that incorporate curriculum that is sensitive to female physical and social development may be essential. Past research has indicated that both removing potential negative psychosocial barriers (i.e., male evaluation) that impede activity and sport participation, as well as enhancing positive psychosocial factors (i.e., female friendships) that encourage increased activity (Vorhees et al., 2005), are necessary in order to create a safe activity environment for young girls. Given that longitudinal studies have demonstrated that sedentary behaviors developed during earlier childhood and adolescence are more difficult to change in girls after they reach 14 years of age (Zook et al., 2014), it is especially important for future research to explore predictors of PA that are specific to young females.

Influence of changes in PA on BMI. Although data addressing change over time provide valuable information related to health outcomes during this understudied and vulnerable time of year, this investigation also examined the influence of changes in PA on zBMI (i.e., response to intervention) at the end of camp for older and younger girls. While a recent meta-analysis demonstrated the difficulty of altering BMI through PA interventions (Sun et al., 2013), greater increases in vigorous PA were related to decreased zBMI for all participants despite the short intervention period (i.e., four weeks) in this study. As such, the link between vigorous PA and zBMI may indicate a dose-response relation. Specifically, the only significant findings that emerged were for minutes spent in vigorous activity, suggesting that it may be more important for at-risk children to receive PA at a higher threshold of intensity in order to produce change. This finding is particularly powerful given that the increase in vigorous PA and the resulting decrease in zBMI occurred during summer break among a sample of urban, minority females, 52% of whom were overweight/obese prior to the start of camp. A recent study also revealed that although changes in zBMI are often the gold standard outcome variable for measuring program effectiveness, researchers should not overlook the beneficial effects of PA on other indicators of physical health (i.e., waist circumference, blood pressure) even when the magnitude of change in zBMI appears to be relatively small (Kolotourou et al., 2013). As such, future research should explore a wide range of physical outcome variables in conjunction with zBMI changes.

Although much of the literature examining health-based obesity and PA interventions has focused on after-school programming, recent studies found that fitness

improvements achieved during the school year are often lost during summertime (Baranowski et al., 2014; Carrel, Clark, Peterson, Eickhoff & Allen, 2007). Furthermore, while there was a small, but statistically significant increase in BMI at the end of camp (e.g., 0.32 increase) in this study, there were not statistically significant increases in either zBMI or BMI percentile. Again, this contradicts past research that has documented that children gain weight at twice the rate during the summer compared to the school year (von Hippel et al., 2007). In fact, a study by Moreno and colleagues (2013) found that elementary school children actually decreased their BMI by 1.5 percentile points during the school year, but increased by 5.2 points over the course of the summer. Thus, the current findings indicating relatively stable BMI among this at-risk population is encouraging not only for the immediate summer, but also has implications for maintaining healthy weight throughout the entire calendar year and across the elementary school years. A recent longitudinal study following children from kindergarten through fifth grade found that youth consistently decreased their zBMI during the school months and increased their zBMI during the summer months (Moreno et al., 2015). Additional work exploring summertime contributions to weight gain is needed in order to better understand seasonal variations in proliferations, as well as the cumulative effects of summer weight gain throughout childhood. Community-based summer programs may be one cost-effective antidote to childhood obesity as they provide structured daily schedules similar to that of the school day. Specifically, findings related to vigorous PA and zBMI in this study highlight that summertime PA interventions might be one feasible

approach to building upon health and fitness gains developed within the school environment.

Body Mass Index and Executive Functions

The next aim of this study was to examine the relation between zBMI and executive functions (EFs) and to determine whether these relations differed depending on age. While no significant main or interaction effects between zBMI, age and EFs emerged here, other recent studies have also failed to find a direct association between the two variables (Boeka & Lokken, 2008; Stanek et al., 2013). Still, these researchers did find a significant interaction between age and BMI on EFs in their sample of 18-to-88-year-old adults. Specifically, obesity-related deficits in EFs were observed with increasing age, and the authors highlighted that the relation between overweight status and EFs remains unclear with adolescents. This suggests that cognitive impairments, including executive dysfunction, may begin with a milder pattern of weaknesses (e.g., slower processing speed) in adolescents and younger adults that continues to progress and becomes more severe over time.

In general, it has been noted that while a small number of studies have demonstrated links between BMI and cognition, relatively little is known about the impact of body mass and composition on brain development and EFs (Khan et al., 2014). Furthermore, the authors' review of the literature also suggests that the relation between overweight and cognitive function may in fact be bidirectional, with characteristics of EF contributing to obesity. As such, the current study explored this path as well, but again, no significant results emerged. Khan and colleagues note that future research should

consider additional mechanisms or variables (e.g., nutrition) that may indirectly explain the relation between obesity and cognitive deficits. Despite the fact that data from this study did not support associations between zBMI and EFs, previous research has demonstrated the cumulative effect of obesity and aging on EF deficits (Stanek et al., 2013), further emphasizing the importance of additional research beginning during the childhood years.

Physical Activity and Executive Functions

The third aim of this study explored the relation between changes in PA and EFs (i.e., shifting, inhibition, working memory), as well as whether these relations differed among older and younger girls participating in the camp. Of note, girls improved in their ability to complete the shifting and inhibition tasks at the end of camp compared to prior to camp, both in terms of time to complete the task (i.e., faster completion), as well as in accuracy of performance (i.e., number of errors). While these results are encouraging given that children often experience cognitive decline and learning loss during the summer months (Cooper, Nye, Charlton, Lindsay, & Greathouse, 1996), particularly for children from underserved communities (Sandberg Patton & Reschly, 2013), they should be interpreted cautiously as practice effects may have contributed to improved performance. A recent meta-analysis indicated that it remains difficult to discern between changes influenced by practice effects versus actual improvements in performance, and the review indicated that effect sizes associated with multiple measurements have varied considerably as a function of test domain, age, and clinical sample characteristics (Calamia, Markon, & Tranel, 2012). Still, the researchers highlighted the effectiveness of

controlling for practice effects through statistical techniques, which were in fact utilized in all regression analyses in this study, but were not implemented in analysis of change scores.

Shifting. Analyses examining the association between changes in PA and shifting at the end of camp revealed that increases in minutes spent in MVPA Bouts were actually related to worse performance on the shifting task, that is, slower completion time. This finding contradicts prior research that has demonstrated improvements in shifting abilities following both acute (Elleberg & St. Louis-Deschenes, 2010) and chronic exercise (Staiano et al., 2012). Still, other researchers have failed to find significant effects of PA on the ability to flexibly shift between task sets (Stroth et al., 2009; Tomporowski et al., 2008). In many studies that do demonstrate a link between PA and shifting, the PA intervention often incorporates activities that place greater demands on the prefrontal cortex (e.g., emphasis on competition or rules) and require youth to utilize more mental capacity (Staiano et al., 2012). It is possible that the conditions of PA inherent within this particular camp do not engage cognition in ways that enhance shifting abilities similar to other PA studies.

Another potential factor contributing to the counterintuitive finding related to the role of PA and its influence on shifting may, in part, be due to the design of this study. For instance, much of the literature examining the link between PA and EFs examines the influence of either single, acute bouts of PA (i.e., treadmill studies) or chronic exercise (e.g., multiple bouts). When considering the theoretical underpinnings of *why* PA facilitates EF skills, this study does not fit neatly into either design. Participants' EFs

were not uniformly measured following a discrete period of activity, and as such, our research team may not have captured the benefits associated with increases in cerebral blood flow, the mechanism through which acute PA is hypothesized to exert an influence on cognitive function (Hillman et al., 2009). For instance, some participants may have been tested following their sedentary life skill lesson, while others may have been tested following their sport or swimming rotation. Similarly, chronic exercise programs are believed to facilitate cardiorespiratory functioning, leading to improvements in the regulation of cognitive processes such as EFs (Best, 2010; Pontifex et al., 2011). Thus, the duration of this intervention period may not have been lengthy enough to significantly impact cardiorespiratory fitness and facilitate EF development.

Inhibition. Interestingly, analyses examining the association between changes in PA and inhibition at the end of camp also revealed that increases in Moderate PA, MVPA, and minutes spent in MVPA Bouts over the course of the camp were linked to slower completion of the inhibition task. However, this finding was complemented by the fact that increases in Moderate PA, MVPA, and total PA were significantly related to participants making fewer errors during the task. Previous work has demonstrated the beneficial effect of engaging in single bouts of PA (i.e., acute) on inhibitory processes (Elleberg & St. Louis-Deschenes, 2010; Hillman et al., 2009b), with additional support for improved inhibitory abilities coming from the literature examining chronic or multiple bouts of training (Buck et al., 2008; Davis et al., 2011; Hillman et al., 2009a; Pontifex et al., 2011; Staiano et al., 2012; Wu et al., 2011). In the current study, participants who increased their PA took longer to perform the task, but those participants

also improved the accuracy of their performance (i.e., made fewer errors). This finding has important implications for children's performance in the educational environment where difficulties with inhibition often manifest in ways that negatively impact academic work (e.g., rushed completion of assignments, lack of attention to detail) and social interactions (e.g., blurting out, interrupting, difficulty with turn-taking). In fact, previous work has shown that EF gains acquired through PA and play translate to academic improvements (Trudeau & Shepard, 2008), as well as that PA interventions may actually be more beneficial for students who are most in need of EF support. Drollette and colleagues (2014) found differential effects of inhibitory control following acute episodes of PA (i.e., 20-minute treadmill walking) versus a seated condition for children who demonstrated relatively lower task performance initially. That is, children with higher inhibition abilities maintained performance accuracy before and after PA, while children who demonstrated lower inhibitory performance before engaging in PA significantly improved in their accuracy following the exercise condition only. This demonstrates that aerobic exercise and PA are critical for brain health during childhood and adolescence, but may be especially beneficial for youth who experience more difficulty with various aspects of EFs.

Working memory. In terms of the influence of changes in PA on WM at the end of camp, findings suggest that increases in both Moderate PA and MVPA minutes were related to poorer recall on the working memory task. This was also true for increases in MVPA Bouts and minutes spent in MVPA Bouts for older girls only. Literature reviewing the effects of PA on working memory is still limited compared to studies

examining shifting and inhibition, but several studies have found improvements in working memory performance following acute (Pontifex et al., 2009) and chronic (Kamijo et al., 2011) PA. As mentioned above in relation to shifting, the type of PA, as well as timing of measurement, may be particularly relevant in order to observe working memory benefits. Pesce et al., (2009) utilized an acute PA design and observed that exercise incorporating motoric problem solving yielded better working memory results than did a traditional exercise and a no activity control group. It is possible that the PA curriculum implemented within this camp may not engage mental faculties in ways similar to other interventions. The neural circuitry involved in working memory is also particularly complex, and imaging studies have demonstrated that children and adolescents do not activate the same brain regions as adults during working memory tasks (Chaddock-Heyman et al., 2014). Additionally, another study with 18–25 year-old females found working memory performance varied depending on when it was measured following intensive exercise (Bue-Estes, Willer, Burton, Leddy, Wilding, & Horvath, 2008). The authors observed that the working memory of participants decreased during and immediately after the exercise bouts, but increased following a recovery period. Again, this raises questions related to study design and the protocol for measurement of EFs. Given that girls were not uniformly assessed following the same activity (e.g., after the sports rotation), it is difficult to determine whether order effects influenced the current results.

Summary of changes in physical activity and executive functions. In general, while a somewhat counterintuitive and inconsistent pattern of findings emerged across

the various relations between changes in PA and aspects of EFs at the end of camp, this should be considered in the context of the literature examining the developmental trajectory of EFs. For instance, a clear pattern of results did emerge for PA changes and behavioral inhibition, whereby increases in PA were related to a slower, but more accurate performance. Developmental studies of EFs suggest that inhibition is the first area of EFs to grow rapidly, while the more complex processes including shifting and working memory begin later (Brocki & Bohlin, 2004). Considering the age of this sample (i.e., between 10-and 14-years-old), it is possible that participants may have experienced the initial, more rapid growth period related to inhibition skills, but not yet undergone equal development of processes that underlie shifting and working memory. In fact, fMRI studies examining brain functions involved in working memory performance for children and adolescents demonstrated different activation patterns than were observed during inhibition tasks (Chaddock-Heyman et al., 2014). In general, inhibition is the most widely studied domain of EF, as well as the area in which the most consistent and positive results have emerged (Verburgh et al., 2013).

Still, while EF improvement is certainly tied to brain maturation, a recent review highlighted the importance of considering environmental interactions with factors such as PA in relation to development (Chaddock-Heyman et al., 2014). EF skills do not come online immediately and simultaneously, but rather steadily improve over time with repeated exposure to situations that enhance development (i.e., practice) (Tompsonski, Lambourne, & Okumura, 2011). The researchers highlight the highly plastic nature of the brain and emphasize that the pruning process that occurs during childhood and

adolescence is incredibly responsive to experiences and interventions (e.g., physical activity) (Hillman, 2014). Within this framework of EF development, as well as consideration of the mechanisms through which PA and environmental experiences alter cognitive development, the current intervention may provide just one practice experience in the gradual acquisition of EF skills. Additionally, task complexity (i.e., attention-demanding tasks) within PA also appears to be implicated in the extent to which PA contributes to EF performance (Budde et al., 2008). A recent randomized control trial demonstrated improved EF performance for 7-to-9 year-old youth assigned to a PA intervention group versus a wait-list control for tasks that required greater cognitive demands only (Hillman et al., 2014). As such, community and academic providers involved in the development of PA interventions should be mindful of the type of PA incorporated into curriculums, as well as the importance of adapting the curriculum as youth exhibit EF gains. A review of EF interventions highlighted that PA programs are most effective in influencing change when youth are continually challenged and activities evolve in conjunction with participants (Diamond, 2012). Finally, it has also been suggested that the link between PA and EFs may not be best captured as a direct relation, but rather mediated by other variables (Tomporowski et al., 2011). The researchers point to various factors that should be explored in conjunction with PA and cognition, including psychosocial (e.g., self-concept) and health and fitness variables.

Physical Activity as a Moderator or Mediator Between BMI and Executive Functions

The final aim of the study was to examine the fit of a moderational and mediational model of PA changes to explain the relation between BMI and EFs. PA changes did not mediate the relation between z BMI and any of the EFs. As mentioned above, other mediators might better explain this relation and should be further explored, such as psychosocial factors or aspects of interpersonal skills (Li et al., 2008; Tomporowski et al., 2011). Additionally, while other researchers have been interested in exploring the additive influence of weight and fitness variables (e.g., activity) on cognition, a recent study demonstrated that each appears to be a separable factor in relation to EFs (Pontifex et al., 2014). There were, however, significant interactions in the moderational model between z BMI and both MVPA Bout changes and minutes spent in MVPA Bouts on working memory performance. In both cases, participants who had greater increases in MVPA Bouts and MVPA Bout Minutes demonstrated a positive relation between z BMI and working memory such that higher z BMI was associated with improved working memory performance (i.e., more digits recalled). There was no relationship between z BMI and working memory for participants with smaller increases in PA. Again, while it was unexpected that higher z BMI would be associated with better working memory, benefits were only observed for girls who demonstrated larger increases in PA. Future work is needed to determine the dynamic interplay between BMI and other variables as it relates to cognitive function (Khan et al., 2014).

Limitations

Despite several important contributions of this study, there remain considerable limitations that must be taken into account. Most notably, the small sample size and lack of control group significantly limit generalizability of findings, as well as the power to detect significant associations and interactions. While the community-based nature of this research expands on laboratory-based PA work, it also presents distinct challenges related to retention of data. In the current study, girls who dropped out of the camp had significantly higher BMIs than those who participated in both data collection points. Although not unique to this investigation, attrition rates in PA and obesity interventions continue to be problematic, particularly as the participants who are most at-risk (i.e., overweight) tend to be those who drop out (Skelton & Beech, 2011). Recent studies have demonstrated a dose-response relationship between program attendance and outcomes (Hillman et al., 2014). Specifically, higher attendance rates were associated with more improvement in both electrical brain activity (i.e., P3 amplitude) and behavioral performance on EF tasks in a nine month PA intervention. In order to improve attendance and retain participants, programming should be developed that addresses the needs of diverse populations through culturally and developmentally tailored programming.

In addition to issues related to external validity (e.g., sample size, drop-out), there are also factors that affect internal validity, namely study design and measurement techniques. As mentioned above, the current study did not strictly adhere to methodology utilized in either acute or chronic PA designs. Specifically, PA was not measured directly following discrete bouts of activity according to protocol for acute measurement.

Additionally, this study did not incorporate a measure of cardiorespiratory fitness, an integral component of chronic PA studies as the mechanism through which aerobic training facilitates cognitive functioning (Tomporowski et al., 2011). Finally, previous studies have emphasized that the relation between PA and body mass may be more complicated among adolescent females, emphasizing the importance of taking physical maturation into account when assessing BMI as an outcome measure (Blucher et al., 2013). Future research focusing on physical health among adolescent girls should include a measure of pubertal status to include as a covariate.

Significance

Despite these limitations, this investigation highlights the need to further explore the relations between PA, BMI, and EFs in children and adolescents, not only during the school year, but also during high-risk periods such as the summer months. Childhood obesity remains a significant public health issue, and obesity has been linked to poorer cognitive and physical functioning across the lifespan (Hillman, 2014; Pontifex et al., 2014), while higher fitness levels and aerobic activity are linked to more positive outcomes (Diamond & Lee, 2011) that appear to have year-round benefits. Additionally, sedentary time has been associated with chronic disease, declines in physical health, and poor social-emotional functioning even after controlling for time spent being physically active (Owen, Bauman, & Brown, 2009; Tremblay et al., 2011). Thus, the implications of developing PA intervention programs are twofold: 1) To provide physical health benefits, and 2) to bolster cognitive and EF abilities. A recent meta-analysis examining aerobic exercise and EFs in children, adolescents, and adults revealed that acute PA appears to

have a positive, moderate effect size on EFs (Verburgh et al., 2013). Positive effects also appeared to be more apparent for individuals with disorders characterized by EF deficits (e.g., ADHD) and for obese youth.

Although past research has typically found detrimental effects of summertime on BMI and cognitive outcomes (Hanes et al., 2005; Franckle et al., 2014; Moreno et al. 2013; Moreno et al., 2015), the results from the current study suggest both physical (i.e., stable z BMI and BMI percentile, increased PA) and EF benefits (e.g., inhibition) as a result of participation in a summer camp aimed at increasing PA. The EF skills that youth develop while engaged in play or exercise during the summer may also translate to performance in the educational environment and social settings (Trudeau & Shepard, 2008), as EF skills have proven to be vital for success in both of those domains (Diamond, Barnett, Thomas, & Munro, 2007).

The findings from this study have significant implications related to developing feasible and effective interventions for underserved, urban youth. While this study deviates from laboratory-based studies designed to measure the influence of PA on EFs and physical health, it represents an attempt to provide a culturally and developmentally sensitive community-based intervention for at-risk adolescent girls. Interventionists call for applications of research that go beyond treadmill running tests, to developing and examining programs that incorporate enjoyable PA that foster a sense of passion and belonging among participants (Diamond, 2015). Reviews of EF interventions have noted that the greatest EF benefits are observed not when the focus is solely on increasing PA, but when increasing PA is presented in a manner that is mindful of social and emotional

development as well (Diamond, 2012). Furthermore, although the data for this study was taken from a PA-focused summer program, research suggests that, in general, day camps provide health benefits through structured opportunities in which youth can spend their discretionary time (Zarrett et al., 2013). Given the limited opportunities for urban youth to access to high quality summer care arrangements, these findings are especially important for policy makers to consider. As the pressure to improve academic achievement rises, educators should consider avenues in which intervention is likely to be most effective. EF skills have proven to be related to academic success independent of intellectual functioning (St. Clair-Thompson & Gathercole, 2006), and summer PA programs may be one method for bolstering skills without reducing classroom instruction time.

REFERENCES

- Baranowski, T., O'Connor, T., Johnston, C., Hughes, S., Moreno, J., Chen, T. A., . . . Baranowski, J. (2014). School year versus summer differences in child weight gain: a narrative review. *Childhood Obesity, 10*(1), 18–24.
- Batterink, L., Yokum, S., & Stice, E. (2010). Body mass correlates inversely with inhibitory control in response to food among adolescent girls: An fMRI study. *NeuroImage, 52*(4), 1696–1703.
- Belcher, B. R., Berrigan, D., Dodd, K. W., Emken, B. A., Chou, C. P., & Spuijt-Metz, D. (2010). Physical activity in US youth: Impact of race/ethnicity, age, gender, & weight status. *Medicine and Science in Sports and Exercise, 42*(12), 2211–2221.
- Best, J. R. (2010). Effects of physical activity on children's executive function: Contributions of experimental research on aerobic exercise. *Developmental Review, 30*(4), 331–351.
- Blüher, S., Molz, E., Wiegand, S., Otto, K. P., Sergeev, E., Tuschy, S., . . . Holl, R. W. (2013). Body mass index, waist circumference, and waist-to-height ratio as predictors of cardiometabolic risk in childhood obesity depending on pubertal development. *The Journal of Clinical Endocrinology & Metabolism, 98*(8), 3384–3393.
- Boeka, A. G., & Lokken, K. L. (2008). Neuropsychological performance of a clinical sample of extremely obese individuals. *Archives of Clinical Neuropsychology, 23*(4), 467–474.
- Braet, C., Claus, L., Verbeken, S., & Van Vlierberghe, L. (2007). Impulsivity in overweight children. *European Child & Adolescent Psychiatry, 16*(8), 473–483.
- Brocki, K. C., & Bohlin, G. (2004). Executive functions in children aged 6 to 13: A dimensional and developmental study. *Developmental Neuropsychology, 26*(2), 571–593.
- Buck, S. M., Hillman, C. H., & Castelli, D. M. (2008). The relation of aerobic fitness to Stroop task performance in preadolescent children. *Medicine and Science in Sports and Exercise, 40*, 166–172.

- Bue-Estes, C. L., Willer, B., Burton, H., Leddy, J. J., Wilding, G. E., & Horvath, P. J. (2008). Short-term exercise to exhaustion and its effects on cognitive function in young women. *Perceptual and motor skills*, *107*(3), 933–945.
- Budde, H., Voelcker-Rehage, C., Pietraßyk-Kendziorra, S., Ribeiro, P., & Tidow, G. (2008). Acute coordinative exercise improves attentional performance in adolescents. *Neuroscience Letters*, *441*(2), 219–223.
- Butte, N. F., Puyau, M. R., Adolph, A. L., Vohra, F. A., & Zakeri, I. S. S. A. (2007). Physical activity in nonoverweight and overweight Hispanic children and adolescents. *Medicine and Science in Sports and Exercise*, *39*(8), 1257–1266.
- Calamia, M., Markon, K., & Tranel, D. (2012). Scoring higher the second time around: Meta-analyses of practice effects in neuropsychological assessment. *Clinical Neuropsychologist*, *26*(4), 543–570.
- Carrel, A. L., Clark, R. R., Peterson, S., Eickhoff, J., & Allen, D. B. (2007). School-based fitness changes are lost during the summer vacation. *Archives of Pediatrics & Adolescent Medicine*, *161*(6), 561–564.
- Caterino, M., & Polak, E. (1999). Effects of two types of activity on the performance of second-, third-, and fourth-grade students on a test of concentration. *Perceptual and Motor Skills*, *89*, 245–248.
- Cawley, J., & Meyerhoefer, C. (2011). The medical care costs of obesity: An instrumental variables approach. *Journal of Health Economics*, *31*, 219–230.
- Chaddock-Heyman, L., Hillman, C. H., Cohen, N. J., & Kramer, A. F. (2014). The importance of physical activity and aerobic fitness for cognitive control and memory in children. *Monographs of the Society for Research in Child Development*, *79*(4), 25–50.
- Chaddock, L., Pontifex, M. B., Hillman, C. H., & Kramer, A. F. (2011). A review of the relation of aerobic fitness and physical activity to brain structure and function in children. *Journal of the International Neuropsychological Society*, *17*(6), 1–11.
- Chang, Y., Labban, J., Gapin, J., & Etnier, J. (2012). The effects of acute exercise on cognitive performance: A meta-analysis. *Brain Research*, *1453*, 87–101.
- Colcombe, S. J., Kramer, A. F., Erickson, K. I., Scalf, P., McAuley, E., Cohen, N. J., . . . Elavsky, S. (2004). Cardiovascular fitness, cortical plasticity, and aging. *Proceedings of the National Academy of Sciences of the United States of America*, *101*(9), 3316–3321.

- Cole, T. J., Faith, M. S., Pietrobelli, A., & Heo, M. (2005). What is the best measure of adiposity change in growing children: BMI, BMI%, BMI z-score or BMI centile? *European Journal of Clinical Nutrition*, *59*(3), 419–425.
- Cooper, H., Nye, B., Charlton, K., Lindsay, J., & Greathouse, S. (1996). The effects of summer vacation on achievement test scores: A narrative and meta-analytic review. *Review of Educational Research*, *66*(3), 227–268.
- Cserjési, R., Luminet, O., Poncelet, A. S., & Lénárd, L. (2009). Altered executive function in obesity. Exploration of the role of affective states on cognitive abilities. *Appetite*, *52*(2), 535–539.
- Daniels, S. R. (2009). The use of BMI in the clinical setting. *Pediatrics*, *124*, S35–S41.
- Davidson, M. C., Amso, D., Anderson, L. C., & Diamond, A. (2006). Development of cognitive control and executive functions from 4 to 13 years: Evidence from manipulations of memory, inhibition, and task switching. *Neuropsychologia*, *44*(11), 2037–2078.
- Davis, C. L., Tomporowski, P. D., Boyle, C. A., Waller, J. L., Miller, P. H., Naglieri, J. A., & Gregoski, M. (2007). Effects of aerobic exercise on overweight children's cognitive functioning: A randomized controlled trial. *Research Quarterly for Exercise and Sport*, *78*(5), 510–519.
- Davis, C. L., Tomporowski, P. D., McDowell, J. E., Austin, B. P., Miller, P. H., Yanasak, N. E., . . . Naglieri, J. A. (2011). Exercise improves executive function and achievement and alters brain activation in overweight children: A randomized, controlled trial. *Health Psychology*, *30*, 91–98.
- Delis, D. C., Kaplan, E., & Kramer, J. (2001). *Delis-Kaplan executive function system (D-KEFS): Examiner's manual*. San Antonio, TX: Psychological Corporation.
- Diamond, A. (2012). Activities and programs that improve children's executive functions. *Current Directions in Psychological Science*, *21*(5), 335–341.
- Diamond, A. (2015). Effects of physical exercise on executive functions: Going beyond simply moving to moving with thought. *Annals of Sports Medicine and Research*, *2*, 1–5.
- Diamond, A., Barnett, W. S., Thomas, J., & Munro, S. (2007). Preschool program improves cognitive control. *Science*, *318*(5855), 1387–1388.
- Diamond, A., & Lee, K. (2011). Interventions shown to aid executive function development in children 4 to 12 years old. *Science*, *333*(6045), 959–964.

- Downey, D. B., Von Hippel, P. T., & Broh, B. A. (2004). Are schools the great equalizer? Cognitive inequality during the summer months and the school year. *American Sociological Review*, *69*(5), 613–635.
- Drollette, E. S., Scudder, M. R., Raine, L. B., Moore, R. D., Saliba, B. J., Pontifex, M. B., & Hillman, C. H. (2014). Acute exercise facilitates brain function and cognition in children who need it most: an ERP study of individual differences in inhibitory control capacity. *Developmental Cognitive Neuroscience*, *7*, 53–64.
- Elleberg, D., & St-Louis-Deschênes, M. (2010). The effect of acute physical exercise on cognitive function during development. *Psychology of Sport and Exercise*, *11*(2), 122–126.
- Fagundo, A. B., de la Torre, R., Jiménez-Murcia, S., Agüera, Z., Granero, R., Tárrega, S., . . . Rodríguez, R. (2012). Executive functions profile in extreme Eating/Weight conditions: From anorexia nervosa to obesity. *PloS One*, *7*(8), 1–9.
- Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175–191.
- Finkelstein, E. A., Graham, W. C. K., & Malhotra, R. (2014). Lifetime direct medical costs of childhood obesity. *Pediatrics*, *133*(5), 854–862.
- Finne, E., Bucksch, J., Lampert, T., & Kolip, P. (2011). Age, puberty, body dissatisfaction, and physical activity decline in adolescents. Results of the German health interview and examination survey (KiGGS). *The International Journal of Behavioral Nutrition and Physical Activity*, *27*(8), 119–133.
- Franckle, R., Adler, R., & Davison, K. (2014). Accelerated weight gain among children during summer versus school year and related racial/ethnic disparities: A systematic review. *Preventing Chronic Disease*, *11*, 1–10.
- Grieser, M., Vu, M. B., Bedimo-Rung, A. L., Neumark-Sztainer, D., Moody, J., Young, D. R., & Moe, S. G. (2006). Physical activity attitudes, preferences, and practices in African American, Hispanic, and Caucasian girls. *Health Education & Behavior*, *33*, 40–51.
- Guxens, M., Mendez, M. A., Julvez, J., Plana, E., Forns, J., Basagaña, X., . . . Sunyer, J. (2009). Cognitive function and overweight in preschool children. *American Journal of Epidemiology*, *170*(4), 438–446.
- Guy, S., Isquith, P., & Gioia, G. (2004). *Behavior rating inventory of executive Function—Self-report version professional manual*. Lutz, FL: Psychological Assessment Resources.

- Hanes, C., Rife, E. M., & Laguna, L. B. (2005). The impact of a summer camp program as a secondary prevention measure for at-risk youth. *Crime Prevention and Community Safety*, 7(3), 37–49.
- Hayes, A. F. (2009). Beyond Baron and Kenny: Statistical mediation analysis in the new millennium. *Communication Monographs*, 76(4), 408–420.
- Hillman, C. H. (2014). An introduction to the relation of physical activity to cognitive and brain health, and scholastic achievement. *Monographs of the Society for Research in Child Development*, 79(4), 1–6.
- Hillman, C. H., Buck, S. M., Themanson, J. R., Pontifex, M. B., & Castelli, D. M. (2009a). Aerobic fitness and cognitive development: Event-related brain potential and task performance indices of executive control in preadolescent children. *Developmental Psychology*, 45, 114–129.
- Hillman, C. H., Erickson, K. I., & Kramer, A. F. (2008). Be smart, exercise your heart: Exercise effects on brain and cognition. *Nature Reviews Neuroscience*, 9, 58–65.
- Hillman, C. H., Pontifex, M. B., Castelli, D. M., Khan, N. A., Raine, L. B., Scudder, M. R., . . . Kamijo, K. (2014). Effects of the FITKids randomized controlled trial on executive control and brain function. *Pediatrics*, 134(4), e1063–e1071.
- Hillman, C. H., Pontifex, M. B., Raine, L. B., Castelli, D. M., Hall, E. E., & Kramer, A. F. (2009b). The effect of acute treadmill walking on cognitive control and academic achievement in preadolescent children. *Neuroscience*, 159(3), 1044–1054.
- Holmbeck, G. N. (2002). Post-hoc probing of significant moderational and mediational effects in studies of pediatric populations. *Journal of Pediatric Psychology*, 27, 87–96.
- Huizinga, M., Dolan, C. V., & van der Molen, M. W. (2006). Age-related change in executive function: Developmental trends and a latent variable analysis. *Neuropsychologia*, 44, 2017–2036.
- Kamijo, K., Pontifex, M. B., O’Leary, K. C., Scudder, M. R., Wu, C. T., Castelli, D. M., & Hillman, C. H. (2011). The effects of an afterschool physical activity program on working memory in preadolescent children. *Developmental Science*, 14(5), 1046–1058.
- Khan, N. A., & Hillman, C. H. (2014). The relation of childhood physical activity and aerobic fitness to brain function and cognition: A review. *Pediatric Exercise Science*, 26(2), 138–146.

- Khan, N. A., Raine, L. B., Donovan, S. M., & Hillman, C. H. (2014). The cognitive implications of obesity and nutrition in childhood. *Monographs of the Society for Research in Child Development*, 79(4), 51–71.
- Kimm, S. Y., Glynn, N. W., Kriska, A. M., Barton, B. A., Kronsberg, S. S., Daniels, S. R., . . . Liu, K. (2002). Decline in physical activity in black girls and white girls during adolescence. *New England Journal of Medicine*, 347(10), 709–715.
- Kimm, S. Y., Glynn, N. W., Obarzanek, E., Kriska, A. M., Daniels, S. R., Barton, B. A., & Liu, K. (2005). Relation between the changes in physical activity and body-mass index during adolescence: A multicentre longitudinal study. *The Lancet*, 366(9482), 301–307.
- Kolotourou, M., Radley, D., Chadwick, P., Smith, L., Orfanos, S., Kapetanakis, V., . . . Sacher, P. M. (2013). Is BMI alone a sufficient outcome to evaluate interventions for child obesity? *Childhood Obesity*, 9(4), 350–356.
- Kuczmariski, R. J., Ogden, C. L., Guo, S. S., Grummer-Strawn, L. M., Flegal, K. M., Mei, Z., . . . Johnson, C. L. (2002). 2000 CDC growth charts for the United States: Methods and development. *Vital and Health Statistics Series 11, Data from the National Health Survey*, 246, 1–190.
- Li, Y., Dai, Q., Jackson, J. C., & Zhang, J. (2008). Overweight is associated with decreased cognitive functioning among school-age children and adolescents. *Obesity*, 16(8), 1809–1815.
- Lifshitz, F. (2008). Obesity in children. *Journal of Clinical Research in Pediatric Endocrinology*, 1(2), 53–60.
- Maayan, L., Hoogendoorn, C., Sweat, V., & Convit, A. (2011). Disinhibited eating in obese adolescents is associated with orbitofrontal volume reductions and executive dysfunction. *Obesity*, 19(7), 1382–1387.
- Mahoney, J. L. (2011). Adolescent summer care arrangements and risk for obesity the following school year. *Journal of Adolescence*, 34(4), 737–749.
- McCue, M., Marlatt, K., Sirard, J., & Dengel, D. (2013). Examination of changes in youth diet and physical activity over the summer vacation period. *The Internet Journal of Allied Health Sciences and Practice*, 11, 1–6.
- Mischel, W., Ayduk, O., Berman, M. G., Casey, B., Gotlib, I. H., Jonides, J., . . . Zayas, V. (2011). ‘Willpower’ over the life span: Decomposing self-regulation. *Social Cognitive and Affective Neuroscience*, 6(2), 252–256.

- Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex “frontal lobe” tasks: A latent variable analysis. *Cognitive Psychology*, *41*, 49–100.
- Moreno, J. P., Johnston, C. A., Chen, T. A., O’Connor, T. A., Hughes, S. O., Baranowski, J., . . . Baranowski, T. (2015). Seasonal variability in weight change during elementary school. *Obesity*, *23*(2), 422–428.
- Moreno, J. P., Johnston, C. A., & Woehler, D. (2013). Changes in weight over the school year and summer vacation: Results of a 5-year longitudinal study. *Journal of School Health*, *83*(7), 473–477.
- National Council of La Raza (2006). *Key facts about childhood obesity in the Latino Community* [Fact Sheet]. Retrieved from http://www.viveligero.org:8081/documents/file_FS_childObesity_FNL.pdf
- Nederkoorn, C., Braet, C., Van Eijs, Y., Tanghe, A., & Jansen, A. (2006). Why obese children cannot resist food: The role of impulsivity. *Eating Behaviors*, *7*(4), 315–322.
- Ogden, C. L., Carroll, M. D., Kit, B. K., & Flegal, K. M. (2014). Prevalence of childhood and adult obesity in the United States, 2011–2012. *Journal of the American Medical Association*, *311*(8), 806–814.
- Ogden, C. L., Carroll, M. D., Kit, B. K., & Flegal, K. M. (2012). Prevalence of obesity and trends in body mass index among US children and adolescents, 1999–2010. *Journal of the American Medical Association*, *307*(5), 483–490.
- Ogden, C. L., & Flegal, K. M. (2010). Changes in terminology for childhood overweight and obesity. *National Health Statistics Reports*, *25*, 1–10.
- O’Hare, E., & Sowell, E. (2008). Imaging developmental changes in gray and white matter in the human brain. In C. A. Nelson & M. Luciana (Eds.), *Handbook of developmental cognitive neuroscience* (2nd ed., pp. 23–28). Cambridge, MA: MIT Press.
- Owen, N., Bauman, A., & Brown, W. (2009). Too much sitting: A novel and important predictor of chronic disease risk? *British Journal of Sports Medicine*, *43*(2), 81–83.
- Pauli-Pott, U., Albayrak, Ö., Hebebrand, J., & Pott, W. (2010). Association between inhibitory control capacity and body weight in overweight and obese children and adolescents: Dependence on age and inhibitory control component. *Child Neuropsychology*, *16*(6), 592–603.

- Pesce, C., Crova, C., Cereatti, L., Casella, R., & Bellucci, M. (2009). Physical activity and mental performance in preadolescents: Effects of acute exercise on free-recall memory. *Mental Health and Physical Activity*, 2, 16–22.
- Pontifex, M., Hillman, C., Fernhall, B., Thompson, K., & Valentini, T. (2009). The effect of acute aerobic and resistance exercise on working memory. *Medicine Science in Sports Exercise*, 41(4), 927–934.
- Pontifex, M. B., Kamijo, K., Scudder, M. R., Raine, L. B., Khan, N. A., Hemrick, B., . . . Hillman, C. H. (2014). The differential association of adiposity and fitness with cognitive control in preadolescent children. *Monographs of the Society for Research in Child Development*, 79(4), 72–92.
- Pontifex, M. B., Raine, L. B., Johnson, C. R., Chaddock, L., Voss, M. W., Cohen, N. J., . . . Hillman, C. H. (2011). Cardiorespiratory fitness and the flexible modulation of cognitive control in preadolescent children. *Journal of Cognitive Neuroscience*, 23(6), 1332–1345.
- Rice, K. R., & Trost, S. G. (2014). Physical activity levels among children attending family day care. *Journal of Nutrition Education and Behavior*, 46(3), 197–202.
- Rose, B. M., Holmbeck, G. N., Coakley, R. M., & Franks, E. A. (2004). Mediator and moderator effects in developmental and behavioral pediatric research. *Journal of Developmental & Behavioral Pediatrics*, 25, 58–67.
- Sandberg Patton, K. L., & Reschly, A. L. (2013). Using curriculum-based measurement to examine summer learning loss. *Psychology in the Schools*, 50(7), 738–753.
- Sandercock, G., Angus, C., & Barton, J. (2010). Physical activity levels of children living in different built environments. *Preventive Medicine*, 50(4), 193–198.
- Shrout, P. E., & Bolger, N. (2002). Mediation in experimental and nonexperimental studies: New procedures and recommendations. *Psychological Methods; Psychological Methods*, 7(4), 422–445.
- Skelton, J. A., & Beech, B. M. (2011). Attrition in pediatric weight management: A review of the literature and new directions. *Obesity Reviews*, 12(5), e273–e281.
- Smith, E., Hay, P., Campbell, L., & Trollor, J. (2011). A review of the association between obesity and cognitive function across the lifespan: Implications for novel approaches to prevention and treatment. *Obesity Reviews*, 12(9), 740–755.
- Solomon, M., Goodlin-Jones, B. L., & Anders, T. F. (2004). A social adjustment enhancement intervention for high functioning autism, Asperger's syndrome, and pervasive developmental disorder NOS. *Journal of Autism and Developmental Disorders*, 34(6), 649–668.

- St. Clair-Thompson, H. L., & Gathercole, S. E. (2006). Executive functions and achievements in school: Shifting, updating, inhibition, and working memory. *The Quarterly Journal of Experimental Psychology*, *59*(4), 745–759.
- Stanek, K. M., Strain, G., Devlin, M., Cohen, R., Paul, R., Crosby, R. D., . . . Gunstad, J. (2013). Body mass index and neurocognitive functioning across the adult lifespan. *Neuropsychology*, *27*(2), 141–151.
- Staiano, A. E., Abraham, A. A., & Calvert, S. L. (2012). Competitive versus cooperative exergame play for African American adolescents' executive function skills: Short-term effects in a long-term training intervention. *Developmental Psychology*, *48*(2), 337–342.
- Stroop, J. (1935). Studies of interference in serial verbal reaction. *Journal of Experimental Psychology*, *18*, 643–662.
- Stroth, S., Kubesch, S., Dieterle, K., Ruchow, M., Heim, R., & Kiefer, M. (2009). Physical fitness, but not acute exercise modulates event-related potential indices for executive control in healthy adolescents. *Brain Research*, *1269*, 114–124.
- Sun, M., Gower, B. A., Bartolucci, A. A., Hunter, G. R., Figueroa-Colon, R., & Goran, M. I. (2001). A longitudinal study of resting energy expenditure relative to body composition during puberty in African American and white children. *The American Journal of Clinical Nutrition*, *73*(2), 308–315.
- Sun, C., Pezic, A., Tikellis, G., Ponsonby, A. L., Wake, M., Carlin, J. B., . . . Dwyer, T. (2013). Effects of school-based interventions for direct delivery of physical activity on fitness and cardiometabolic markers in children and adolescents: A systematic review of randomized controlled trials. *Obesity Reviews*, *14*(10), 818–838.
- Tabachnick, B. G., & Fidell, L. S. (1996). *Using multivariate statistics* (3rd ed.). New York, NY: HarperCollins College.
- Tomporowski, P. D., Davis, C. L., Lambourne, K., Gregoski, M., & Tkacz, J. (2008). Task switching in overweight children: Effects of acute exercise and age. *Journal of Sport & Exercise Psychology*, *30*(5), 497–511.
- Tomporowski, P. D., Lambourne, K., & Okumura, M. S. (2011). Physical activity interventions and children's mental function: an introduction and overview. *Preventive Medicine*, *52*, S3–S9.

- Tremblay, M. S., LeBlanc, A. G., Kho, M. E., Saunders, T. J., Larouche, R., Colley, R. C., . . . Gorber, S. C. (2011). Systematic review of sedentary behaviour and health indicators in school-aged children and youth. *International Journal of Behavioral Nutrition and Physical Activity*, *8*, 98–120.
- Treuth, M. S., Baggett, C. D., Pratt, C. A., Going, S. B., Elder, J. P., Charneco, E. Y., & Webber, L. S. (2009). A longitudinal study of sedentary behavior and overweight in adolescent girls. *Obesity*, *17*(5), 1003–1008.
- Trost, S. G., McCoy, T. A., Vander Veur, S. S., Mallya, G., Duffy, M. L., & Foster, G. D. (2013). Physical activity patterns of inner-city elementary school children. *Medicine and Science in Sports and Exercise*, *45*(3), 470–474.
- Trudeau, F., & Shephard, R. J. (2008). Physical education, school physical activity, school sports and academic performance. *International Journal of Behavioral Nutrition and Physical Activity*, *5*(10), 5868–5880.
- Verburgh, L., Königs, M., Scherder, E. J., & Oosterlaan, J. (2013). Physical exercise and executive functions in preadolescent children, adolescents and young adults: a meta-analysis. *British Journal of Sports Medicine*, *1*, 1–8.
- Verdejo-García, A., Pérez-Expósito, M., Schmidt-Río-Valle, J., Fernández-Serrano, M. J., Cruz, F., Pérez-García, M., . . . Campoy, C. (2010). Selective alterations within executive functions in adolescents with excess weight. *Obesity*, *18*(8), 1572–1578.
- von Hippel, P. T., Powell, B., Downey, D. B., & Rowland, N. J. (2007). The effect of school on overweight in childhood: Gain in body mass index during the school year and during summer vacation. *American Journal of Public Health*, *97*(4), 696–702.
- Voorhees, C. C., Murray, D., Welk, G., Birnbaum, A., Ribisl, K. M., Johnson, C. C., . . . Jobe, J. B. (2005). The role of peer social network factors and physical activity in adolescent girls. *American Journal of Health Behavior*, *29*(2), 183–190.
- Wechsler, D. (2003). *Wechsler intelligence scale for children—fourth edition (WISC-IV)*. San Antonio, TX: Psychological Corporation.
- Wong, W. W., Butte, N. F., Ellis, K. J., Hergenroeder, A. C., Hill, R. B., Stuff, J. E., & Smith, E. O. B. (1999). Pubertal African-American girls expend less energy at rest and during physical activity than Caucasian girls. *Journal of Clinical Endocrinology & Metabolism*, *84*(3), 906–911.

- Wong, D., Maybery, M., Bishop, D., Maley, A., & Hallmayer, J. (2006). Profiles of executive function in parents and siblings of individuals with autism spectrum disorders. *Genes, Brain and Behavior*, 5(8), 561–576.
- Wong, W. W., Ortiz, C. L., Lathan, D., Moore, L. A., Konzelmann, K. L., Adolph, A. L., . . . Butte, N. F. (2012). Underserved minority children are not meeting the US Public Health recommendation for moderate-vigorous physical activity. *Journal of Obesity and Weight Loss Therapy*, 2(4), 1–5.
- Wu, C. T., Pontifex, M. B., Raine, L. B., Chaddock, L., Voss, M. W., Kramer, A. F., & Hillman, C. H. (2011). Aerobic fitness and response variability in preadolescent children performing a cognitive control task. *Neuropsychology*, 25(3), 333–341.
- Zarrett, N., Sorensen, C., & Skiles, B. (2013). Environmental and social-motivational contextual factors related to youth physical activity: Systematic observations of summer day camps. *International Journal of Behavioral Nutrition and Physical Activity*, 10(1), 63–76.
- Zook, K. R., Saksvig, B. I., Wu, T. T., & Young, D. R. (2014). Physical activity trajectories and multilevel factors among adolescent girls. *Journal of Adolescent Health*, 54, 74–80.

VITA

Dr. Ward graduated summa cum laude from Loyola University Chicago in 2008, where she completed a Bachelor of Science in Psychology. Before beginning graduate school, she worked as the project manager of a grant-funded, community-based program evaluation project with Dr. Amy Bohnert at Loyola University Chicago. She also worked as a research assistant on Dr. Grayson Holmbeck's NICHD funded study examining the psychosocial adjustment in children and young adolescents with spina bifida.

Dr. Ward began her graduate studies in 2009 in the Clinical Psychology Doctoral Program at Loyola University Chicago. While in graduate school, she completed a psychotherapy practicum at Loyola's undergraduate psychological Wellness Center, as well as at the University of Illinois at Chicago's Child and Adolescent Psychiatry Clinic. She also completed pediatric neuropsychological assessment and pediatric health psychology practica at the Alexian Brothers Neurosciences Institute and Shriners Hospital for Children, respectively. Dr. Ward was a pre-doctoral intern at Stanford Children's Hospital / Children's Health Council in Palo Alto, CA where she received advanced training as a child psychologist. Dr. Ward's scholarly work with Loyola faculty advisor Amy Bohnert included program evaluation research examining the effectiveness of community-based interventions in combatting the childhood obesity epidemic. Dr. Ward has also developed a program of research focusing on the influence of physical activity on physical and cognitive health, namely executive function development. Dr.

Ward graduated from Loyola University Chicago in August of 2015 with a Ph.D. in Clinical Psychology.

