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The Behavioral Effects of Increased Physical Activity on Preschoolers at Risk for Attention Deficit Hyperactivity Disorder

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THE BEHAVIORAL EFFECTS OF INCREASED PHYSICAL ACTIVITY ON PRESCHOOLERS AT RISK FOR ATTENTION DEFICIT HYPERACTIVITY DISORDER

A Thesis Presented

by

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ABSTRACT

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ATTENTION DEFICIT HYPERACTIVITY DISORDER

MAY 2011

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Physical activity (PA) has many health benefits, both physical and psychological. PA has been linked to improved cognitive functioning, superior overall health, and enhanced emotional well-being in populations ranging from school-age children to older adults. There has been less research, however, examining the benefits of PA in atypical preschool populations.

The present study examined the efficacy of a PA intervention in preschool-aged children at risk for attention deficit hyperactivity disorder (ADHD). ADHD symptomatology, response inhibition, and physical activity were measured at three time points over a 6-month period. Results provide support for the efficacy of PA as an alleviative tool in preschoolers with ADHD. This research is some of the first to use objective measures to examine PA as viable intervention in atypical preschool populations.

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CHAPTER 1

LITERATURE REVIEW

Introduction

Recent research into the benefits of physical activity has documented fairly consistent improvements in performance on cognitive tasks after acute exercise and chronic activity (e.g., Kramer, Erickson & Colcombe, 2006). These benefits have been seen in young adults and senior citizens, and are currently being evaluated in children (Davis, et al., 2007). However, there has been relatively little examination of these benefits in atypical populations, such as children with Attention Deficit Hyperactivity Disorder (ADHD). ADHD is characterized by developmentally deviant levels of hyperactivity, impulsivity, and inattention, and is estimated to affect 5% of school-age children (APA, 1994). Children with ADHD experience difficulty in a variety of settings, including social, academic, and family functioning (Wehmeier, Schacht & Barkley, 2010). Although the disorder is not typically diagnosed until school age, evidence suggests that the average age of onset of symptoms is three years (Applegate, 1997). While high activity and impulsive behavior are common among preschool-age children, those who demonstrate elevated levels of these behaviors appear to be at higher risk for developing ADHD when compared to peers (Harvey, Youngwirth, Thakar & Errazuriz, 2009).

The most common treatment for ADHD is the stimulant medication methylphenidate (MPH), which is known to enhance the activity of dopamine and noradrenaline in the nervous system (Murray, et al., 2008). MPH does, however, produce side effects in many patients (ranging from headaches and decreased appetite to blurred vision, slowing of growth, and psychotic symptoms such as auditory hallucination (Adler, et al., 2009; Rapport, et al., 2008). Recent research into long-term effects of continued use of medication has shown that children who start taking medication at an early age have an increased risk of substance abuse later in life (Mannuzza et al., 2008). Given the recent increase in the number of children diagnosed with ADHD and the potential negative effects of drug treatments, it is critical to explore alternative interventions for this disorder. The present study sought to investigate baseline levels of activity in children at increased risk for ADHD, and to examine the effects of increased activity on behavior and clinical symptoms.

Overview of the Benefits of Exercise

In recent years, we have seen a dramatic increase in exercise-related research, and the cognitive benefits of physical activity have begun to be examined in children, young adults and elderly populations. Most of the developmental exercise research to date has dealt with the effects of physical activity on academic achievement, cognition, and measures of IQ. One such study examined the physical fitness and body mass index (BMI) of 259 third and fifth grade public school students, in relation to academic achievement (Castelli, Hillman, Buck & Erwin, 2007). Analyses revealed significant positive correlations between measures of physical fitness and academic achievement scores, as well as a negative correlation between achievement and BMI (higher BMIs denoting higher proportions of body fat). These results suggest a positive relationship between physical fitness and academic achievement.

Research utilizing exercise as an intervention suggests a causal relationship between increased physical activity and cognitive ability. For example, acute bouts of physical activity as well as chronic activity have been associated with improved executive functioning, specifically working memory, multitasking, planning, and inhibitory control. This is evidenced by marked improvements in academic achievement, and performance on cognitive tasks such as the dual visual-auditory discrimination and Stroop tasks (Davis, et al., 2007; Hillman, Erickson & Kramer, 2008; Sibley & Etnier, 2003; Sibley, Etnier & Le Masurier, 2006; Tomporowski, Davis, Miller & Naglier, 2008).

Examination of this relationship at the physiological level has revealed that exercise may improve cognitive functioning by increasing production of brain-derived neurotrophic factor (BDNF). BDNF is a member of the neurotrophin family of growth factors—a set of proteins produced in the brain that are beneficial to the development of neurons, supporting the survival and growth of neurons and mediating neuronal connectivity and use-dependent plasticity (Cotman & Berchtold, 2002). The behavioral and physiological research into the benefits of exercise, taken together, strongly support the theory that physical activity helps improve cognitive functioning.

ADHD: General Diagnosis & Treatment

Attention Deficit Hyperactivity Disorder (ADHD) is defined by the Diagnostic and Statistic Manual of Mental Disorders, fourth edition (DSM-IV) as a set of maladaptive behaviors denoting inattention and/or impulsivity and hyperactivity, that are inconsistent with development and cause impairment in two or more settings (e.g., at school and at home). Such behaviors cause social, academic and/or occupational impairment, persist for at least six months, and do not occur exclusively during the course of any psychotic disorder, mental disorder, or pervasive developmental disorder. Symptoms include carelessness during school, work or leisure activities, excessive fidgeting or talking, difficulty in waiting situations, and inappropriate and disruptive behaviors such as blurting out answers before questions have been completed and butting into conversations and/or games (APA, 1994).

While the DSM-IV criteria for ADHD stipulates that symptoms of the disorder must be present before age 7, previous research suggests that symptoms of ADHD may manifest earlier. A study conducted by Applegate and colleagues (1997) examined the validity of the DSM's age-of-onset criterion for ADHD. Applegate and colleagues used the parent and teacher versions of the Diagnostic Interview Schedule for Children (DISC) to determine the age-of-onset of the first symptom of ADHD, as well as the age-of-onset of impairment due to symptoms in 380 children with ADHD. They found that, of the 380 youths in the study, over half displayed their first symptoms of ADHD at age 1, and the median age-of-onset of impairment due to symptoms of ADHD was 3.5. Applegate concluded that, while ADHD is generally diagnosed in school-aged children, symptoms often arise much earlier.

The most common treatment for school-aged children with ADHD is MPH. While there is extensive literature citing MPH as an effective method of treating ADHD in this age group, the literature on the use of MPH in preschoolers is less clear (Abikoff, et al., 2007). Although several studies have reported that preschoolers treated with MPH exhibit improved attention and decreased impulsivity (e.g., Byrne, DeWolfe & Bawden 1998; Monteiro-Musten, et al., 1997; Short, Manos, Findling & Schubel, 2004), others report less clear results. One study, a phase of the Preschoolers with Attention-Deficit/Hyperactivity Disorder Treatment Study (PATS) conducted by Abikoff et al., (2007), found that MPH effects varied greatly by outcome measure and informant. ADHD preschoolers whose behavior was improved with medication treatment during a previous phase of the PATS were randomized into a placebo group and a drug treatment group. Measures of social skills, classroom behavior, emotional status and parenting stress were recorded over a 4-week period. Results showed that parent measures and teacher Strengths and Weaknesses of ADHD-Symptoms and Normal Behaviors (SWAN) scores did not improve with MPH treatment. Additionally, while clinician ratings on the Clinical Global Impressions-Severity (CGI-S) scale—a measure of the child's current level of illness severity—and teacher social competence ratings did significantly improve, parent-rated depression and dysthymia actually worsened with MPH treatment. That is, results varied based on whether teachers, parents, or clinicians were reporting, and depending on the instrument used to assess ADHD behavior. Abikoff and colleagues concluded that, while MPH treatment did improve some aspects of functioning, more research is needed to determine the utility of MPH treatment in preschoolers.

Physical Activity and ADHD

There has been very little research into the effects of physical activity on children diagnosed with ADHD, but what does exist focuses primarily on behavioral outcomes (e.g., Azrin, Vinas & Ehle, 2007; Baker, 2005). In the most relevant study to date, Wendt (2000) encouraged daily running in adolescent boys diagnosed with ADHD. After a six-week period, the adolescents showed significant improvements, as evidenced by changes in scores on the Connor's Parent Rating Scale. Importantly, several of the children were able to reduce their medication levels during this six-week intervention period.

Azrin et al., discuss the benefits associated with using physical activity as a positive reinforcer in children with ADHD, specifically in a school setting. In their study, they rewarded a 4-year-old boy's attentiveness with a 1-minute break where the child was allowed to play in an adjacent playground. As the boy successfully maintained periods of attentiveness, the criterion for reinforcement (the amount of time for which the boy was required to remain attentive) was slowly increased, and the child was continuously able to conquer new time milestones. The participant showed marked improvements in attention, as well as a decrease in the number of outbursts and tantrums. Another school intervention study used martial arts as an intervention, and found that after 12 weeks, participants showed increases in percentage of homework completed and percentage of classroom preparation, as well as overall improvements in academic performance (Morand, 2004). The number of classroom rules broken decreased, as did the number of times participants inappropriately left their seats. These three studies, taken together, provide support for the use of physical activity as tool for improving behavior in children with ADHD.

In a related study, Reynolds and colleagues (Reynolds, Nicolson & Hambly, 2003) posited that exercise's influence on symptomatology in atypical populations may go beyond the behavioral, and may influence behavior through physiological changes in particular brain areas. They evaluated an activity-based treatment program for children at high risk for developing reading difficulties. The activity-based program, known as DDAT, is based on the idea that certain disorders arise out of deficits in cerebellar function (Reynolds, et al., 2003). The program uses balance and coordination exercises, theoretically to strengthen cerebellar function, and counteract pre-existing deficits. Reynolds and colleagues administered the program to junior high school students over a 6-month period. Twenty-five percent of participants had an existing diagnosis of dyslexia, dyspraxia, or ADHD. Various tests of cerebellar/vestibular function (e.g., the Sensory Organization Test, and the Dyslexia Screening Test) revealed significant improvements in participants' cerebellar function and reading ability. These results suggest that physical activity may play an important role in strengthening certain brain areas, and in ameliorating certain kinds of deficits.

Hyperactivity in ADHD

The primary goal of the current study was to further explore the efficacy of using exercise as an intervention for children at increased risk for developing ADHD. A secondary goal was to gain a better understanding of hyperactivity in ADHD. Although hyperactivity is an established symptom of ADHD, defining this type of behavior can often be difficult, especially in preschool-aged children (Vaughan, Wetzel & Kratochvil, 2008). An intriguing study by Antrop, Buysse, and Roeyers (2005) examined levels and types of activity in 6-11 year-old children with ADHD and matched controls during waiting and non-waiting situations in a school setting. They found that both the ADHD and control groups differed significantly in their behavior during waiting situations as compared to non-waiting situations. In addition, there was no significant interaction between group and waiting effects, despite children with ADHD being more restless, noisy, and disruptive overall. This result is contrary to patterns of increased activity suggested in other research studies (e.g., Antrop, Roeyers & Van Oost, 2000; Jacob, O'Leary & Rosenblad, 1978), pointing to the need for further exploration of hyperactivity in ADHD children. Antrop and colleagues (2005) go on to stress the importance of considering the environment in which ADHD children are observed, pointing out that they tend to display fewer hyperactivity symptoms in novel environments, and environments with high levels of stimulation. Given the findings of their study, and the fact that much of the literature on hyperactivity in ADHD deals with familiar environments and/or school settings, further research is needed to adequately assess the frequency and level of hyperactivity in children with ADHD. Are children with ADHD really "hyperactive?" Or are they just more fidgety? Are those really the same thing?

Mechanisms of Action

I. Response Inhibition Research

Research into the symptomatology and manifestation of ADHD has revealed an inhibitory deficit in children with the disorder, leading many researchers to suggest that it is the inability to inhibit a given action that underlies the pathology (Durston, 2003; Wodka, et al., 2007). Several studies have found that patients with ADHD have difficulty inhibiting their responses during the "No-Go" trials of standard Go/No-Go tasks, as evidenced by the commission of high numbers of false alarm errors during these trials (Barkley, 1999; Durston, et al., 2007). One study (Schachar, et al., 2007), posited that there are two major components of response inhibition: restraint (the ability to withhold a strong response tendency) and cancellation (the ability to cancel an ongoing action). They had 9 to 10 year-olds with ADHD and matched controls complete restraint and cancellation trials, which were embedded in a simple "go" response task. The restraint trials involved the presentation of an auditory "no-go" stimulus concurrently with a visual "go" stimulus, while the cancellation trials involved the presentation of an auditory "no-go" stimulus directly following the presentation of a visual "go" stimulus. Measures of accuracy and reaction time were collected, as well as the standard deviation of correct "go" task reaction time (a measure of variability) and the probability of successful inhibition. Results showed that, on the restraint task, children with ADHD had poorer accuracy, longer mean reaction time, and greater mean reaction time variability than matched controls. On the cancellation task, children with

ADHD showed lower mean accuracy and shorter mean delay (denoting more unsuccessful inhibition) than controls. Because of the literature's strong support for response inhibition deficits in ADHD, a response inhibition task was used in the present study.

II. Functional/Anatomical Research

In order to examine the neural correlates of ADHD, several studies have used MRI and fMRI techniques to identify which brain regions might be implicated in the disorder. Results of fMRI research suggest several regions of interest, including the ventral prefrontal cortex, basal ganglia structures, and areas of the cerebellum (Suskauer, et al., 2008).

Because response inhibition is thought to be a primary deficit in ADHD (Wodka, et al., 2007) much of the functional imaging research surrounding ADHD has focused on identifying brain regions involved in response inhibition. In studies using a go/no-go paradigm, researchers have found that several brain regions (such as the bilateral precentral gyrus, thalamus, and right anterior cerebellum) show greater activation in controls compared to ADHD patients for trials involving response inhibition (Anderson, Polcari & Lowen, 2002; Booth, Burman & Meyer, 2005; Casey, Castellanos & Giedd, 1997; Ernst, Liebenauer & King, 1994; Rubia, Overmeyer & Taylor, 1999; Suskauer, et al., 2008). This decreased activation suggests that the poor performance on go/no-go tasks that children with ADHD exhibit may be linked to deficits that exist at the physiological level.

Several studies have found anatomical differences in the brains of patients with ADHD relative to control groups (e.g., Ellison-Wright, Ellison-Wright & Bullmore, 2008; Plessen, et al., 2006; Shaw, et al., 2009). In a recent review paper, Krain and Castellanos (2006) highlight findings from several studies, and identify many anatomical discrepancies.

In particular, they identify decreased global brain volume, and decreased frontal cortex volume as hallmarks of ADHD. They discuss how structures within the basal ganglia are often significantly smaller in ADHD children than age-matched controls. Their conclusions are in line with other research suggesting that the developmental trajectory of the cerebellum in children with ADHD is often abnormal compared to neurotypicals (Makie, et al., 2007). Reductions in the gray and white matter of the prefrontal cortex have also been reported in several studies (Kates, et al., 2002; Overmeyer, et al., 2001), although there is still some debate as to whether such differences are bilateral or not. When taken together these results provide some insight into the neurological features of ADHD. This literature, coupled with the previously reviewed research on BDNF, provides a substantial theoretical framework for the present study.

III. The Benefits of Youth

The present study sought to investigate the relationship between physical activity and ADHD, closer to its onset. One benefit of working with young children is that, by targeting children who are at high risk for, but have not yet been diagnosed with ADHD, we can examine the potential for physical activity to alter the path of development.

Previous research using animal models has consistently documented that the brain is most plastic and most able to adapt and recover from injury early in development (Nelson & Bloom, 1997), and that increased physical activity boosts brain plasticity, leading to greater neurogenesis, synaptogenesis, angiogenesis, and myelination (e.g., Churchill et al, 2002; Cotman & Berchtold, 2002; Dishman, et al., 2006). Additional animal research has shown that physical activity can alter both the structure and function of brain areas via increases in the number of new neurons and synapses that are formed and that survive, as well as increases in the consistency of myelination between brain areas (Churchill, et al., 2002; Dishman, et al., 2006). BDNF is one of the mechanisms underlying these changes, which reflect increases in brain plasticity and generally translate into improved cognitive and behavioral performance for the more active animals (Cotman & Berchtold, 2002). Because BDNF signaling and exercise-induced expression of BDNF decrease with age, however, physical activity's ability to increase neural plasticity also decreases with age (Adlard, Perreau, & Cotman, 2005; Mattson, Maudsley, & Martin, 2004), which suggests that a physical activity intervention might be more beneficial to a young population. Although the previous findings are suggestive, it is clear that further research is needed to explore the potential benefits of physical activity in preschoolers at risk for ADHD.

The previously reviewed behavioral and neurological literature, coupled with recent ADHD research, suggests that physical activity may prove to be a viable and effective tool in alleviating the symptoms of ADHD. The present study proposed the use of three dependent measures to examine the effects of a physical activity intervention on preschool-aged children at increased risk for developing ADHD. By increasing these children's daily physical activity, monitoring chronic levels of activity, and assessing ADHD symptoms and inhibitory control, the following hypotheses were evaluated: 1) that, at baseline, BASC-2 scores would be negatively correlated with movement count and time spent in moderate-to-vigorous physical activity (MVPA); 2) that increased physical activity in the intervention group would result in a decrease in ADHD symptoms over the course of the 6-month study; 3) that participants in the locomotor-based structured PA (LBPA) group would show a decrease in the number of errors committed during the response inhibition task, as well as a decrease in hyperactivity scores on the BASC-2 scale; and 4) that increased physical activity would result in a decrease in hyperactivity, as evidenced by a change in overall movement counts over time and a change in time spent in MVPA.

CHAPTER 2

METHOD

Overview

Data collection for the present study occurred as part of a larger exercise intervention study called Project PLAY that was being conducted by Dr. Sofiya Alhassan, Assistant Professor in the Department of Kinesiology at the University of Massachusetts in Amherst.

General Study Design

Project PLAY was a group-randomized controlled six-month pilot study designed to examine the feasibility and efficacy of using a classroom teacher taught locomotor-based physical activity (PA) program to increase total daily PA and percent time spent in MVPA in preschool-age children. This larger study used an age-appropriate physical education program designed by Dr. Stephen Coulon, Professor of Physical and Health Education at Springfield College, to increase physical activity levels and durations in this population. Classrooms were randomized into two groups: a locomotor-based structured PA (LBPA) group, and an unstructured free play PA (UFPA) group.

Assessments for the ADHD study took place in concert with Project PLAY, and included three measures: scores on the Behavior Assessment System for Children, 2nd Edition (BASC-2; Reynolds & Kamphaus, 2004), behavioral performance on a response inhibition (RI) task called the Cheese Game, and physical activity levels as assessed by the Actigraph® accelerometer (Manufacturing Technologies Inc. Health Services, Ft. Walton Beach, FL). At baseline, midpoint, and post-intervention, classroom teachers completed the teacher version of the BASC-2, and participants completed the RI task (the Cheese Game). In addition, each wore an Actigraph ® accelerometer (Fairweather, et al., 1999) for seven days during each of the three assessment periods.

Participants

Study participants were preschool-aged children participating in the Square One early education program (Springfield, MA). Because Springfield's Square One centers mainly service working-class minorities, it was expected that the majority of study participants would be African American, Hispanic, and Latino children of low socioeconomic status (SES). Previous research examining the correlates of ADHD has found that a negative relationship exists between ADHD symptom presentation and SES. That is, children of low SES are more likely to exhibit symptoms of ADHD than their middle and upper class counterparts (Biederman, Faraone, & Monuteaux, 2002; Counts, et al., 2005; Lasky-Su et al., 2007; Pineda, et al., 1999). Although much of the literature examining the risk factors for ADHD does not provide a clear explanation for the negative relationship, one study sited quantitative and qualitative differences in at-home stimulation as well as an impoverished social environment as factors that may contribute to the increased prevalence of ADHD symptoms in low SES populations (Pineda, et al., 1999). Another study suggested that genetic polymorphisms might play a role in the ADHD/SES interaction (Lasky-Su, et al., 2007). While the roots of this vulnerability are still unclear, given that ADHD symptoms are more prevalent in low SES populations, it is reasonable to classify the target participant group for the present study as "at increased risk."

Target enrollment for the current study was 80 participants, including males and females. Children ages 3-5 years were eligible for participation in the study. Children were not eligible for assessment if they had a condition limiting their participation in the intervention (are unable to participate in routine outdoor playtime at school, require oxygen supplementation for exertion, have a developmental or physical disability preventing participation in the intervention, cannot increase PA levels for any reason) or if they had a condition limiting participation in the assessment (child is unable to wear the activity monitor, if the child was unable to complete the computer game, parent/guardian was not able to read surveys in English. Although all participants from the Project PLAY study were eligible for inclusion in the ADHD study, only those children who were able to complete all parts of the ADHD assessment were included in the analyses.

Recruitment

76 children who attend one of the two eligible Square One agency early education centers were recruited for participation in this study. Within each classroom, children were individually recruited to participate in the study via flyers sent home with the children. Interested parents/guardians were asked to contact the research team for eligibility screening. In addition, an information table was set-up at each school site, and trained Project Play researchers were available for personal consultation during afternoon pick-up time. This consultation provided parents/guardians opportunities to ask questions about the study, receive assistance completing study paperwork (e.g., informed consent and demographic forms), and return completed forms.

Intervention

Classroom teachers in the LBPA condition were trained to implement the locomotor-based exercise program, and then administered it to the children during their 30-minute morning playtimes. Teachers in the UFPA group were instructed to allow their students to play freely during the scheduled playtime. All teachers completed a locomotor skills and movement concepts assessment before and after training/instruction sessions. Training for LBPA teachers was separate from the UFPA teachers, and consisted of learning the proper execution of locomotor skills and the LBPA curriculum. The curriculum was presented to teachers as a whole, and then individual lessons/activities were demonstrated. Teachers practiced implementing the lessons to their fellow teachers in a controlled environment. The training session was lead by a trained physical education specialist. The instruction session for the UFPA teachers stressed the importance of allowing their students to play freely during the allocated intervention playtime.

Data Collection

Data collection for the present study took place in concert with the data collection for the larger intervention study. Measures of behavior were taken three times over the course of the six months: at baseline—session 1 (during the first month), mid way through the intervention—session 2 (during month three), and at the end of the intervention—session 3 (during month six).

I. ADHD Symptomatology Measures

1. BASC-2

The teacher rating scales of the BASC-2 (Reynolds & Kamphaus, 2004) were used to assess several behaviors in participants. The BASC-2 is a multimodal 100-item questionnaire designed to evaluate children's behavior, and measure aggression, anxiety, hyperactivity, conduct issues, and social functioning. Scores on the hyperactivity, aggression, and attention subscales were used to evaluate ADHD symptomatology in participants. The BASC-2 has been found to be a reliable and valid measure of these behaviors in children (Reynolds & Kamphaus, 2004). The version being utilized is approved for use in 2-5 year olds. Scores on the BASC-2 are calculated as *T* scores, with a mean of 50. Scores greater than 69 are generally considered to indicate clinical pathology.

2. Accelerometry

All children participating in the larger intervention study wore the Actigraph ® accelerometer (Fairweather, et al., 1999)—a uniaxial monitor designed to measure vertical accelerations—for seven consecutive days during months 1, 3 and 6. The monitor was attached to an elastic belt, and fastened to the child's waist, with the device positioned at the lower back. The device stored movement data at 15-second intervals for the entire 7-day period. Time spent at sedentary, light and MVPA were calculated using age-appropriate counts per minute thresholds. Thresholds for 3, 4, and 5 year olds were set for sedentary activity at 1204, 1452, and 1592, respectively, for light activity at 1205-2456, 1453-3244, and 1593-3560, respectively for moderate activity, and at 4921, 4937, and 5017, respectively, and 4921, 4937, and 5017, respectively for vigorous activity (Sirard, et al., 2005). In addition, average counts per minute was calculated (a movement count that measures average activity level). In order to evaluate changes in activity over time, time spent at MVPA levels (calculated as minutes spent in moderate-to-vigorous physical activity) as well as average counts per minute were analyzed.

3. Response Inhibition Task

All children participating in the larger intervention study completed the RI Cheese Game. This go/no-go task was designed to measure inhibitory control, and administers 192 trials in two blocks over a 7-minute period. Each trial was separated by 1500-2000 milliseconds, and the ratio of go to no-go trials is 3:1. To ensure that participants were not able to discern any kind of pattern in stimulus presentation, a staggered structure was used to sequence go and no-go trials. Presentations of the no-go stimulus were separated by 1 to 6 presentations of the go stimulus, with occasional repeated presentation of the no-go stimulus. (This structure is designed to increase the difficulty of withholding a response—children with ADHD have more trouble inhibiting a response if they have been responding repeatedly for several previous trials). Before the start of the task, go trials (a screen displaying a large piece of yellow cheese in the entry of a mouse hole) and no-go trials (a screen displaying a grey cat in the entry of a mouse hole) were explained to participants, and they were instructed to respond to go trials by pressing the right mouse button, and to inhibit their response during no-go trials by not pressing any button. Responses were measured in terms of the number of hits (trials where the participant correctly responds to a go trial), and correct rejections (trials where the participant correctly inhibits during a no-go trial), and accuracy scores as well as mean reaction times were calculated.

CHAPTER 3

RESULTS

Analytic Strategy

Analyses sought to address two main questions: 1) Can a physical activity intervention reduce the presentation of ADHD symptoms in preschoolers over time? 2) Can a physical activity intervention alter movement counts/time spent in MVPA in preschoolers at increased risk for ADHD? Three measures were used to assess changes in participants' behavior over the 6-month intervention period: cheese task scores from the response inhibition task, BASC-2 scores, and movement counts from accelerometer data.

To examine the rate and magnitude of change in these dependent variables over time, Hierarchical Linear Modeling (HLM; Raudenbush & Bryk, 2002) was used. This type of analysis estimates individual growth curves, and uses them to assess changes in behavior over time, and to develop a trajectory-based model of change. In order to assess which variables significantly impacted ADHD symptomatology over time, several 2-level longitudinal HLM models were fit. Level-1 and Level-2 variables used to construct the best models were as follows:

Table 1. Study Variables

Level-1 Variables
BASC-2 Attention Score (ATT)
BASC-2 Aggression Score (AGG)
BASC-2 Hyperactivity Score (HYPER)
Movement Count (MOVE)
Time Spent in MVPA (MVPA)
Cheese Task Hit Accuracy (CheeseAcc)
Cheese Task Correct Rejection Accuracy (CatAcc)
Cheese Task Reaction Time (CheeseRT)
Time (TIME)
Level-2 Variables
Intervention Group (INT)
Age (AGE)
Initial BASC-2 Attention Score (T1_ATT)
Initial BASC-2 Aggression Score (T1_AGG)
Initial BASC-2 Hyperactivity Score (T1_HYPER)

For all models, full maximum likelihood estimation was used. The time variable was centered at baseline (Time 1= 0, Time 2= 1, Time 3= 2), and the group variable was coded such that intercepts indicated trajectories for the control group (Control=0, Intervention=1). Initial BASC-2 score variables and age were centered around their means. For each outcome variable, stepwise HLM models were fit. For all planned models, subsequent models were only fit if the current model was found to be a significant improvement over previous models (as assessed by chi-square model comparison tests).

For each BASC-2 outcome variable, two planned models were fit. First, an unconditional model (Model A) was fit, and average trajectories were assessed. Next, a conditional model (Model B) was fit, including “GROUP” at level-2. For PA outcome variables (average movement counts and minutes spent in MVPA), the same approach used for BASC-2 variables was taken, but a third model was also planned (Model C), which examined the intervention’s effect on PA while taking into account initial ADHD symptomatology. Time 1 BASC-2 scores (T1_ATT, T1_AGG, T1 HYPER) were included individually at level-2. For a list of all models fit by outcome variable, see table 4.

For response inhibition outcome variables, a similar stepwise approach was taken. Model A was the same as for the BASC-2 outcome variables. Model B, however, included age as a predictor at level-2. This was done to control for differences in performance on the task based on age (task accuracy and reaction time generally improve as a function of age). If Model B was found to be a significant improvement from the previous model, than a third model was fit, Model C, which added “GROUP” at level-2.

Missing Data and Attrition

Of the 76 participants recruited for the study, 9 dropped out before completing baseline assessment. Dropout participant data, while included (if available) in demographic data, were excluded from study measure characteristics. One participant's data in its entirety was excluded from analyses due to incomplete participation and lack of comprehension of the response inhibition task. In addition, 10 participants had incomplete data due to dropout at later sessions and absences (5 participants dropped out between baseline and midpoint assessment, 3 participants dropped out between midpoint and post assessment, and 2 participants have incomplete baseline data due to absences). These data were included in analyses, so long as the participant had enough data to satisfy statistical parameters.

Data Reduction and Exclusion Criteria

I. Response Inhibition Task

When analyzing cheese task data, a 30% cheese trial accuracy cut-off was used (see Appendix C for participant inclusion information). The rationale behind this cut-off was that, because cheese trials make up the majority of trials in the task (144 of 192 trials), participants responding to less than 30% of cheese trials may not have been attending to the task enough to accurately assess response inhibition, or simply may not have understood how to complete the task. Because there has been little research utilizing go/no-go tasks in preschoolers, general attention to the task as well as response inhibition was thought to be important to assessing attention in this population. As a result, accuracy for cheese trials (go trials), accuracy for cat trials (no-go trials) and reaction time were examined.

II. Accelerometer Data

In order to obtain an accurate assessment of PA levels in this population, an 8-hour minimum was required for accelerometer data. Participants without at least 8 hours of recording time within a 24-hour period were excluded from analyses, discretely for each time point (see Appendix C).

III. BASC-2 Data

ADHD symptomatology was assessed using the *Hyperactivity*, *Attention Problems*, and *Aggression* subscales of the overall BASC-2 instrument at each of the three time points. These scores were calculated using specific items from the BASC-2 (see Appendix A), which are designed to measure each construct.

Baseline Group Characteristics & Group Differences

To assess the success of random assignment by classroom, baseline group characteristics were examined, and were analyzed using independent samples t-tests (see Tables 2 and 3). The groups were found to be equal in all respects but two: baseline hyperactivity scores on the BASC-2 were higher in the intervention group than the control group (see table 3 for specific values). In addition, the intervention group had significantly more female participants than the control group (see table 2 for specific values). Next, demographic information was examined to assess earlier hypotheses about the ethnic make-up and SES of study participants. 36.2% of study participants were identified by parents/guardians as being African-American or Black; 50.7% were of Latino or Hispanic descent; 7.2% identified as Caucasian, and 1.4% identified as some other race. Furthermore, 71% of study participants had an annual household income of less than $40,000.00. These figures confirm the hypothesized make up of the sample, and affirm their "at increased risk for ADHD" status.

Table 2. Baseline Demographic Characteristics

Variable	Intervention Group (n=40)	Control Group (n=29)	*P*	All (n=69)
Gender, n (%)	40 (100%)	29 (100%)	.037	
Boys	16 (40%)	19 (65.5%)		35 (50.7%)
Girls	24 (60%)	10 (34.5%)		34 (49.3%)
Race/Ethnicity, n (%)	40 (100%)	26 (89.7%)	.720	
African-American	11 (27.5%)	14 (48.4%)		25 (36.2%)
Caucasian	4 (10%)	1 (3.4%)		5 (7.2%)
Latino/Hispanic	24 (60%)	11 (37.9%)		35 (50.7%)
Other	1 (2.5%)	0 (0%)		1 (1.4%)
Parent/guardian marital status, n (%)	40 (100%)	26 (89.7%)	.690	
Single-never married	23 (57.5%)	14 (48.3%)		37 (53.6%)
Married	15 (37.5%)	10 (34.5%)		25 (36.2%)
Divorced/Separated or Widowed	2 (5.0%)	2 (6.9%)		4 (5.8%)
Maximum household education level, n (%)	38 (95%)	25 (86.2%)	.468	
High school graduate or less	23 (57.5%)	11 (38.0%)		34 (49.3%)
Some college/technical school	7 (17.5%)	9 (31.0%)		16 (23.2%)
College graduate	8 (20.0%)	5 (17.2%)		13 (18.8%)
Annual total household income, n (%)	40 (100%)	26 (89.7%)	.873	
Less than $20,000	14 (35.0%)	13 (44.9%)		27 (39.1%)
$20,000 - $39,000	16 (40%)	6 (20.7%)		22 (31.9%)
$40,000 - $59,000	8 (20.0%)	2 (6.9%)		10 (14.5%)
> $60,000	2 (5.0%)	5 (17.2%)		7 (10.1%)

Table 3. Baseline Measures

Variable	Intervention Group (n=40)	Control Group (n=29)	*P*	All (n=69)
Age (yrs)	4.34 ± .66	4.19± .70	.390	4.28 ± .68
Weight (kg)	18.70 ± 4.28	17.96 ± 4.06	.470	18.38 ± 4.17
Height (cm)	105.58 ± 8.70	103.22 ± 5.52	.200	104.57 ± 7.55
Body mass index (kg/m^2)	16.70 ± 2.33	16.72 ± 2.64	.970	16.71 ± 2.44
Average accelerometer counts/min	993.60 ± .140.07	1049.86 ± 193.76	.254	1017.54 ± 165.49
Average time spent in MVPA	45.38 ± 28.59	52.08 ± 23.10	.395	48.23 ± 26.34
BASC-2 Hyperactivity Score	57.95 ± 12.22	52.17 ± 9.07	.050	55.06 ± 10.65
BASC-2 Aggression Score	57.67 ± 13.32	55.12 ± 12.58	.449	56.40 ± 12.95
BASC-2 Attention Score	54.08 ± 7.28	52.24 ± 8.98	.372	53.16 ± 8.13
Cheese Task Accuracy Score	.53 ± .07	.51 ± .06	.186	.52 ± .07
Cheese Task RT (milliseconds)	332.17 ± 74.20	315.52 ± 65.99	.357	323.85 ± 70.10

Response Inhibition & ADHD Symptomatology

Because go/no-go tasks such as the cheese game are rarely utilized in preschool populations, it was necessary to examine the relationship between performance on the task and ADHD symptomatology. It was hypothesized that accuracy on the cheese task would be negatively correlated with ADHD symptomatology. Simple correlations were run, and results showed a significant negative correlation between *Attention Problems* scores and cheese trial accuracy ($r(31)= -.31$, $p= .04$) (see Appendix B). No other significant correlations were found.

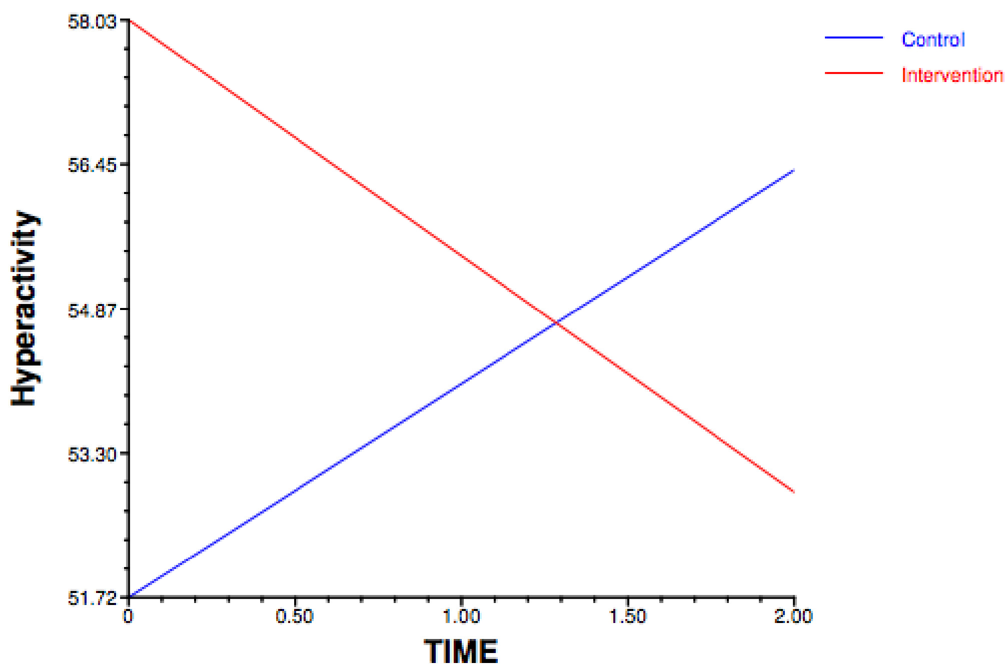
Intervention Effects

I. ADHD Symptomatology

1. Hyperactivity

Model B was found to have the best fit (χ^2 =11.90, df = 2, p= .003). (See tables 5, 6, 7 for all model comparisons). Fixed effects showed that the average hyperactivity score for the control group at baseline was 51.72 (se= 2.09, p <.001), 6.31 points lower than the intervention group (se= 2.79, p=.027). The predicted rate of change for the control group was 2.33 points per three months (se= 1.08, p=.034), while the predicted rate of change for the intervention group was 4.91 points less (a rate of change of -2.58 points) per three months (se=1.43, p=.001). The tau variance components for the intercept and slope were 84.06 and 7.57, respectively. Both random effects were significant, indicating that there was still significant unexplained variance around the residuals. Overall, hyperactivity decreased in the intervention group over the course of the 6-month study, while the control group's BASC-2 hyperactivity scores increased over time.

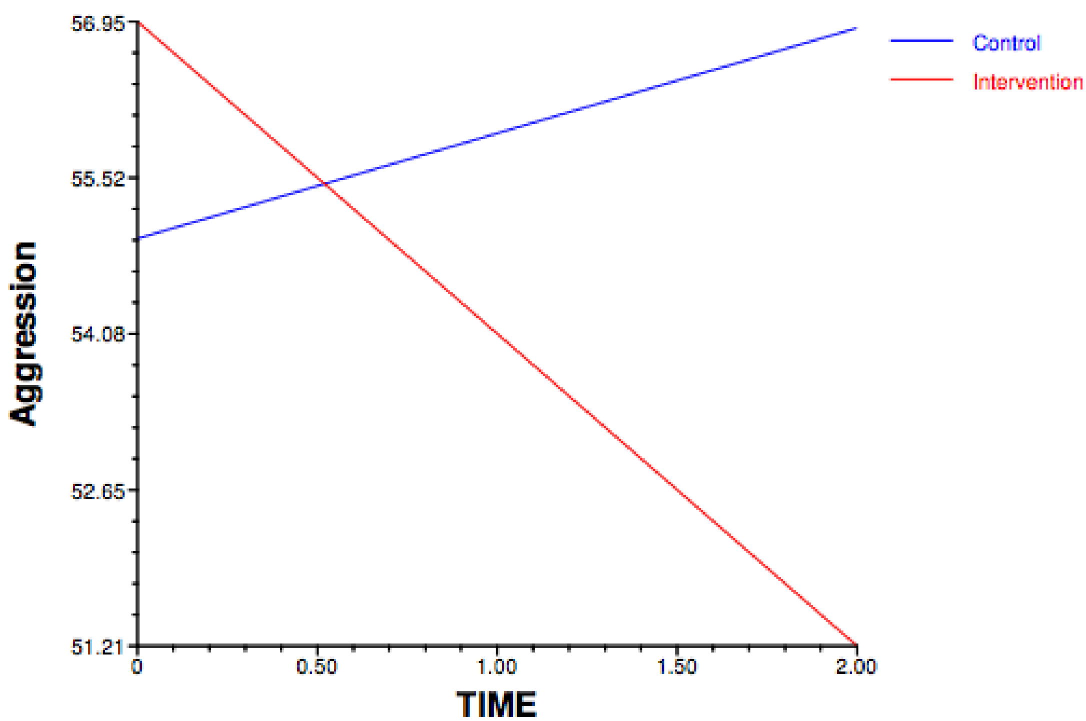
Graph 1. Final Hyperactivity Model



2. Aggression

For the final aggression model, Model B, fixed effects showed that the average aggression score for the control group at baseline was 54.95 (se= 2.41, $p < .001$), 2.00 points lower than the intervention group. These values, however, were not significantly different (se= 3.23, $p=.54$). The predicted rate of change for the control group was .97 points per time point, but this value was not significantly different from zero (se= 1.08, $p=.378$). The predicted rate of change for the intervention group was 3.84 points less (a rate of change of -2.87 points) per time point, and this value did differ significantly from that of the control group value (se=1.44, $p=.011$). Tau variance components for the intercept and slope were 122.02 and 5.98, respectively. Both random effects were significant. This result suggests that aggression scores decreased in the intervention group over time, while remaining constant in the control group.

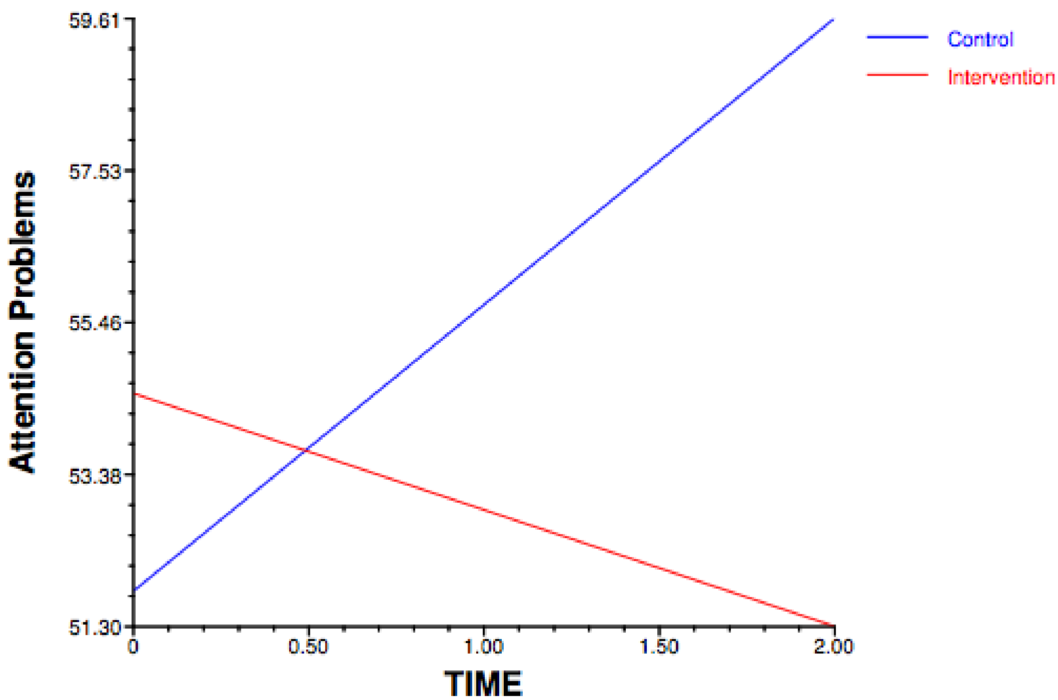
Graph 2. Final Aggression Model



3. Attention

The final attention model, Model B, with "GROUP" added as a predictor at level-2, showed that the average attention score at Time 1 for the control group was 51.79 (se= 1.57, $p < .001$). The average attention score for the intervention group was 2.69 points higher, but this value was not significantly different from the control group value (se=2.11, $p=.21$). The predicted average rate of change for the control group was 3.91 points per time point (se= .81, $p<.001$), and the average rate of change for the intervention group was 5.50 points lower (a -1.59 point decrease per time point). So, on average, attention scores increased over time in the control group, and decreased over time in the intervention group. The tau variance components for the intercept and slope were 45.27 and 2.48, respectively, but only the variance in the slope was significant.

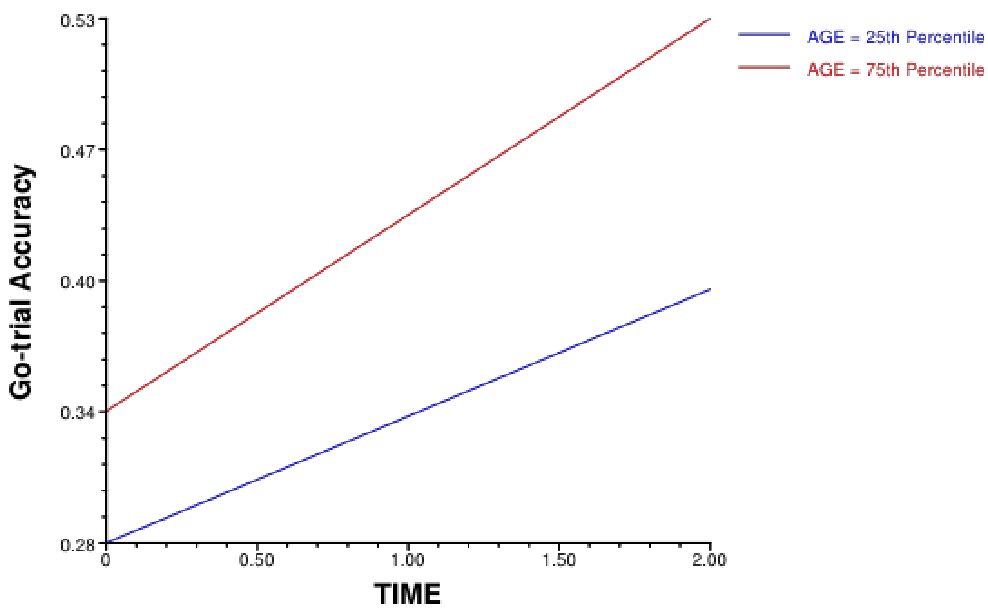
Graph 3. Final Attention Model



4. Response Inhibition

Go-trial accuracy for the cheese task was assessed using HLM, and results showed that adding "GROUP" as a predictor at level-2 did significantly improve model fit. The best fitting model was Model B, which included age as a predictor at level-2. Tau variance components were .014 and .003 for the intercept and slope, respectively, and both effects were significant at the .01 alpha level, indicating significant unexplained variance. Fixed effects showed that the average accuracy score for children of average age at baseline was .31 (se= .021, $p < .001$), and that older children scored .06 points higher than younger children, though this value was not significantly different from the mean (se= .039, $p=.148$). The predicted rate of growth for go-trial accuracy was .078 points per three months for children of average age (se= .013, $p<.001$) and the predicted growth rate for older children was not significantly different from the mean (coefficient= .107, se=.021, $p=.157$).

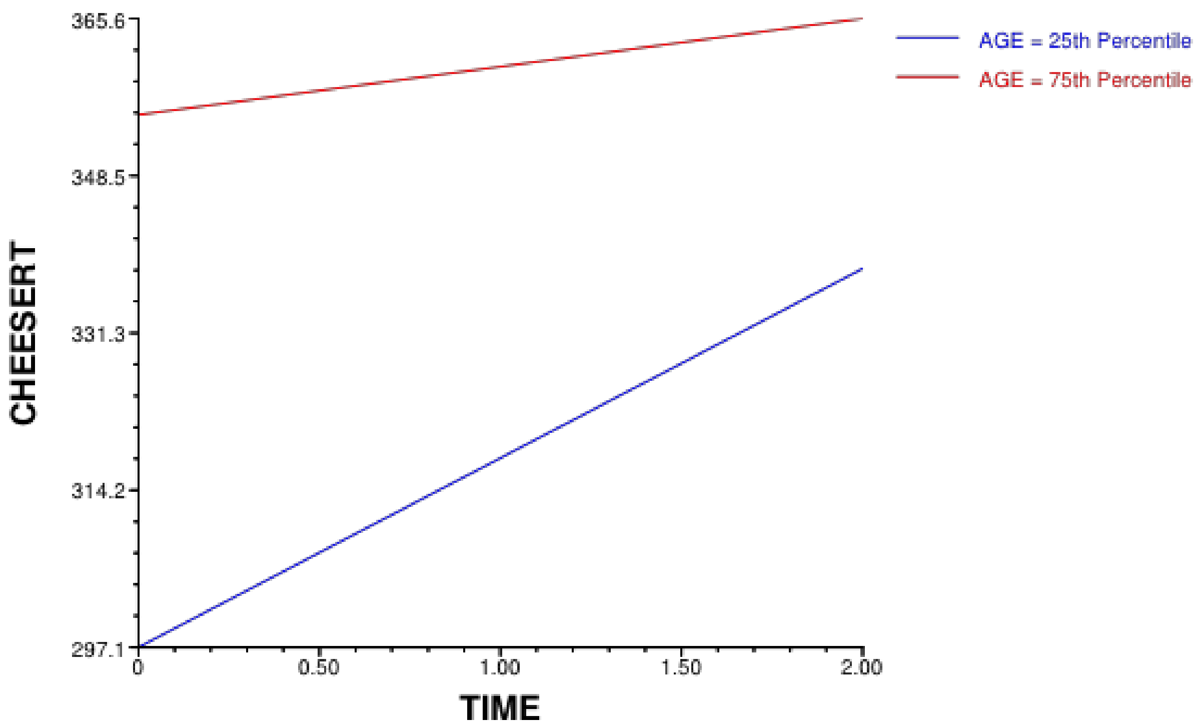
Graph 4. Final Cheese Trial Accuracy Model



Accuracy for the cat trials of the cheese task (no-go trials) was examined using the outlined planned models. However, none of the models fit proved to be a significant improvement over the unconditional model (Model A).

The final conditional model of cheese task reaction time was found to be significant at the intercept and slope. Intercept fixed effects showed that the average reaction time for children of average age was 325.22 milliseconds (se=7.86, $p<.001$), and that older children were 56.02 milliseconds slower than younger children at baseline (se=11.29, $p<.001$). The predicted rate of growth for children of average age was 13.17 milliseconds per three months (se=3.54, $p=.001$), with older children decreasing in response time by 1.69 milliseconds per three months (se=4.60, $p=.002$).

Graph 5. Final Cheese Task Reaction Time Model



II. Physical Activity

1. MVPA & Movement Counts

Several models were fit for physical activity data collected, but none proved to be a significant improvement over the unconditional models. No group differences were found, nor any differences which could be attributed to BASC-2 scores.

The unconditional MVPA model showed that, on average, participants spent 55.04 minutes per day engaged in MVPA at baseline (se=6.83, $p<.001$). The predicted rate of growth was 2.13 minutes per three months, but this value was not significantly different from zero (se=2.55, $p=.408$). The tau variance component for the intercept was 19.84, and was significant ($p=.038$). The variance component for the slope was 1.51, but was non-significant ($p>.50$). The unconditional model for movement count showed no significant effects whatsoever. These results indicated that there wasn't significant variance around the residuals to estimate growth trajectories

Table 4. HLM Models

	Model		
Outcome Variable	A	B	C
Hyperactivity	Level-1 Model: Y = P0 + P1*(TIME) + E	Level-1 Model: Y = P0 + P1*(TIME) + E	
	Level-2 Model: P0 = B00 + R0 P1 = B10 + R1	Level-2 Model P0 = B00 + B01*(GROUP) + R0 P1 = B10 + B11*(GROUP) + R1	
Aggression	Level-1 Model: Y = P0 + P1*(TIME) + E	Level-1 Model: Y = P0 + P1*(TIME) + E	
	Level-2 Model: P0 = B00 + R0 P1 = B10 + R1	Level-2 Model P0 = B00 + B01*(GROUP) + R0 P1 = B10 + B11*(GROUP) + R1	
Attention	Level-1 Model: Y = P0 + P1*(TIME) + E	Level-1 Model: Y = P0 + P1*(TIME) + E	
	Level-2 Model: P0 = B00 + R0 P1 = B10 + R1	Level-2 Model P0 = B00 + B01*(GROUP) + R0 P1 = B10 + B11*(GROUP) + R1	
Cheese RT	Level-1 Model: Y = P0 + P1*(TIME) + E	Level-1 Model: Y = P0 + P1*(TIME) + E	Level-1 Model: Y = P0 + P1*(TIME) + E
	Level-2 Model: P0 = B00 + R0 P1 = B10 + R1	Level-2 Model P0 = B00 + B01*(T1_AGE) + R0 P1 = B10 + B11*(T1_AGE) + R1	Level-2 Model P0 = B00 + B01*(T1_AGE) + B02*(GROUP) + R0 P1 = B10 + B11*(T1_AGE) + B12*(GROUP) + R1
CheeseAcc	Level-1 Model: Y = P0 + P1*(TIME) + E	Level-1 Model: Y = P0 + P1*(TIME) + E	Level-1 Model: Y = P0 + P1*(TIME) + E
	Level-2 Model: P0 = B00 + R0 P1 = B10 + R1	Level-2 Model P0 = B00 + B01*(T1_AGE) + R0 P1 = B10 + B11*(T1_AGE) + R1	Level-2 Model P0 = B00 + B01*(T1_AGE) + B02*(GROUP) + R0 P1 = B10 + B11*(T1_AGE) + B12*(GROUP) + R1
CatAcc	Level-1 Model: Y = P0 + P1*(TIME) + E	Level-1 Model: Y = P0 + P1*(TIME) + E	Level-1 Model: Y = P0 + P1*(TIME) + E
	Level-2 Model: P0 = B00 + R0 P1 = B10 + R1	Level-2 Model P0 = B00 + B01*(T1_AGE) + R0 P1 = B10 + B11*(T1_AGE) + R1	Level-2 Model P0 = B00 + B01*(T1_AGE) + B02*(GROUP) + R0 P1 = B10 + B11*(T1_AGE) + B12*(GROUP) + R1
Movement Count	Level-1 Model: Y = P0 + P1*(TIME) + E	Level-1 Model: Y = P0 + P1*(TIME) + E	Level-1 Model: Y = P0 + P1*(TIME) + E
	Level-2 Model: P0 = B00 + R0 P1 = B10 + R1	Level-2 Model P0 = B00 + B01*(GROUP) + R0 P1 = B10 + B11*(GROUP) + R1	Level-2 Model P0 = B00 + B01*(GROUP) + B02*(T1_HYPER) + B03*(HYPINT) + R0 P1 = B10 + B11*(GROUP) + B12*(T1_HYPER) + B13*(HYPINT) + R1
MVPA	Level-1 Model: Y = P0 + P1*(TIME) + E	Level-1 Model: Y = P0 + P1*(TIME) + E	Level-1 Model: Y = P0 + P1*(TIME) + E
	Level-2 Model: P0 = B00 + R0 P1 = B10 + R1	Level-2 Model P0 = B00 + B01*(GROUP) + R0 P1 = B10 + B11*(GROUP) + R1	Level-2 Model P0 = B00 + B01*(GROUP) + B02*(T1_HYPER) + B03*(HYPINT) + R0 P1 = B10 + B11*(GROUP) + B12*(T1_HYPER) + B13*(HYPINT) + R1 P1 = B10 + B11*(GROUP) + B12*(T1_HYPER) + B13*(HYPINT) + R1

Table 5. ADHD Symptomatology Model Fit Statistics

Hyperactivity

	Model	
	A	B
Fixed Effects	Coefficient (SE)	Coefficient (SE)
Intercept	55.29(1.44)††	51.72 (2.09) ††
Group		6.31 (2.79) †
Slope	-.47(.78)	2.33 (1.08) †
Group		-4.91 (1.43) ††
Variance Components	Model A	Model B
Intercept	92.56††	84.06††
Slope	13.26††	7.57†
Goodness of Fit		
Deviance (df)	1151.84 (6)	1139.94 (8)**

Aggression

	Model	
	A	B
Fixed Effects	Coefficient (SE)	Coefficient (SE)
Intercept	56.09 (1.62) ††	54.96 (2.41) ††
Group		2.00 (3.23)
Slope	-1.19 (.77)	.97 (1.09)
Group		-3.84 (1.45) †
Variance Components	Model A	Model B
Intercept	124.48††	122.02††
Slope	10.80††	5.98†
Goodness of Fit		
Deviance (df)	1183.75 (6)	1177.24 (8)*

Attention

	Model	
	A	B
Fixed Effects	Coefficient (SE)	Coefficient (SE)
Intercept	53.31(1.06) ††	51.79 (1.57) ††
Group		2.70 (2.11)
Slope	.79 (.66)	3.91 (.81) ††
Group		-5.50 (1.08) ††
Variance Components	Model A	Model B
Intercept	46.61††	122.02††
Slope	9.84††	5.98†
Goodness of Fit		
Deviance (df)	1091.16 (6)	1069.98 (8)**

†$p < .05$ ††$p < .001$ *Indicates that model fit is significantly better than previous model at .05 level; **$p < .001$

Table 6. Cheese Task Model Fit Statistics

(†$p < .05$ ††$p < .001$ *indicates that model fit is significantly better than previous model at .05 level; **$p < .001$)

Go-trial Accuracy			
	Model		
	A	B	C
Fixed Effects	Coefficient	Coefficient (SE)	Coefficient (SE)
Intercept	.31(.02)††	.31 (.02) ††	.23 (.09) †
Age		.06(.03)	.03 (.04)
Group			.004 (.06)
Slope	.08(.01) ††	.08(.01) ††	.072 (.04)
Age		.03(.02)	.003 (.03)
Group			.03 (.02)
Variance	Model A	Model B	Model C
Intercept	.02††	.01††	.13††
Slope	.003†	.06†	.05†
Goodness of Deviance (df)	-134.88 (6)	-143.54 (8)*	-143.62 (10)

No-go-trial Accuracy			
	Model		
	A	B	C
Fixed Effects	Coefficient	Coefficient (SE)	Coefficient (SE)
Intercept	.71(.02)††	.71 (.02) ††	
Age		.03 (.03)	
Slope	-.008(.01)	-.008 (.01)	
Age		-.01 (.01)	
Variance	Model A	Model B	Model C
Intercept	.14††	.02††	
Slope	.01	.0001	
Goodness of Deviance (df)	-164.67 (6)	-165.55(8)	

Reaction Time			
	Model		
	A	B	C
Fixed Effects	Coefficient	Coefficient (SE)	Coefficient (SE)
Intercept	310.89(12.64)††	325.22 (7.86)††	319.64 (10.84)††
Age		56.02 (11.29)††	55.80 (11.33)††
Group			10.20 (15.78)
Slope	13.49(4.10)†	13.17 (4.54)†	10.11 (4.89)†
Age		-14.86 (4.60)†	-15.32 (4.48)†
Group			5.37 (7.00)
Variance	Model A	Model B	Model C
Intercept	5873.29††	2522.91††	55.31††
Slope	14.61	122.26	11.91
Goodness of Deviance (df)	1670.80 (6)	1652.38 (8)**	1649.46 (10)

Table 7. Physical Activity Model Fit Statistics

MVPA

	Model	
	A	B
Fixed Effects	Coefficient (SE)	Coefficient (SE)
Intercept	55.04 (9.85) ††	50.50 (14.64) †
Group		8.13 (19.74)
Slope	2.13 (8.61)	1.04 (12.74)
Group		2.03 (17.25)
Variance Components	Model A	Model B
Intercept	19.84†	15.74†
Slope	1.51	1.44
Goodness of Fit		
Deviance (df)	1115.40 (6)	1114.88 (8)

Movement Count

	Model	
	A	B
Fixed Effects	Coefficient (SE)	Coefficient (SE)
Intercept	2724.20(1883.01)	1037.93(2773.27)
Group		3011.73 (3739.47)
Slope	648.69 (1645.00)	24.46 (2412.36)
Group		1149.38 (3268.06)
Variance Components	Model A	Model B
Intercept	1429275.28	853393.83
Slope	58699.11	75305.13
Goodness of Fit		
Deviance (df)	2155.66 (6)	2153.29 (8)

†$p < .05$ ††$p < .001$ *Indicates that model fit is significantly better than previous model at .05 level; **$p < .001$

CHAPTER 4

DISCUSSION

ADHD Symptomatology

As hypothesized, the intervention group showed significant reductions in ADHD symptomatology as compared to the control group over the 6-month period. Significant models of hyperactivity, aggression, and attention problems in this sample provide support for the efficacy of physical activity as an alleviative tool in treating ADHD, and bolster previous findings from the physical activity literature (e.g., Azrin, Vinas & Ehle, 2007; Morand, 2004; Wendt, 2000). Random effects from the final models of ADHD symptomatology were, however, significant, which indicates that a significant portion of the variance in BASC-2 scores remains unexplained by the predictors included in the models.

Response Inhibition

Although it was hypothesized that the 6-month PA intervention would significantly impact performance on the cheese task, results from the present study did not support this theory. Age was the only factor that was found to significantly predict performance on the go/no-go task. One explanation for this null finding is that the go/no-go task may not have been an adequate instrument with which to measure response inhibition in this population. Though several child studies have documented the relationship between response inhibition and ADHD (e.g., Barkley, 1999; Durston, et al., 2007; Schachar, et al., 2007), there has been very little research utilizing classic go/no-go tasks in preschool populations (see Lindqvist & Thorell, 2009 or Mahone, Pillion & Hiemenz, 2001 for examples of go/no-go task use in preschoolers). Because response inhibition generally improves as a function of age (Mahone, Pillion & Hiemenz, 2001), it is possible that the selected task was not developmentally appropriate for use in 3-5 year olds. The correlational analyses that were performed in order to examine the relationship between BASC-2 scores and performance on the cheese task support this conclusion. If the task was adequately measuring response inhibition, a stronger correlation between ADHD symptomatology and task performance would be expected. More research is needed to determine the efficacy of go/no-go tasks of this nature in measuring response inhibition in preschool-age populations.

MVPA & Movement Counts

The hypotheses surrounding the physical activity data from the present study are complex. One goal in examining these data was to further elucidate how hyperactivity manifests in preschoolers. While there is some evidence to suggest that the hyperactivity element of ADHD refers to increased gross motor movement (Wood, Asherson, Rijsdijk & Kuntsi, 2009), other studies imply that it is not gross motor movement but more subtle, fidgety movements that constitute hyperactivity in ADHD (Teicher, Ito, Glod & Barber, 1996; Tsujii, Okada, Kaku, Kuriki, Hanada & Shirakawa, 2009). To this end, the present study sought to examine whether or not a 6-month PA intervention would alter movement counts and time spent in MVPA in a preschool-age population at risk for ADHD. In line with the fine motor movement theories of hyperactivity in ADHD, it was hypothesized that the intervention and control groups would show no significant differences in movement count or time spent in MVPA. Results of the present study did not show any significant differences between the physical activity patterns of the intervention and control groups. A factor that may have influenced this result was the size of the usable data sample. Because an 8-hour cutoff point was set for the accelerometer data, only data from 47 participants at baseline, 36 participants at midpoint, and 26 participants at post were included in analyses. Because of this restriction, power was significantly reduced, making it more difficult to detect real group differences. In addition, there was a lot of variability in wear-time (the number of hours each subject wore the accelerometer, above and beyond the 8-hour cut-point), average counts per minute, and time spent in MVPA. These factors, coupled with the small sample size, made it difficult to assess physical activity characteristics.

Limitations and Future Directions

One of the most prominent limitations of the present study was sample size. Though the target enrollment for the study was nearly met, the final data set was considerably smaller than anticipated. Given the substantial attrition that took place, and the exclusion criteria applied (which further narrowed the size of the usable data set), power to detect real group differences was considerably diminished.

Another constraint affecting the results of the present study was the sample used. Although the sample was identified as an "at-risk" population, it would more appropriately be classified as a community sample. Thus, the results of the present study cannot necessarily be generalized to pathological ADHD populations. An added limitation of this particular sample was the inability to randomly assign individuals to groups. Because the children were already nested within classrooms, there was no way to execute a truly random assignment process, and this increased the likelihood that the groups would be unequal in some way (e.g., the fact that the intervention group had significantly higher BASC-2 hyperactivity scores than the control group at baseline).

Measurement difficulties also became an important limitation in the present study—with regard to response inhibition, movement, and BASC-2 data. The task used to measure response inhibition proved to be challenging for this age group, and may have hindered the study's ability to accurately examine response inhibition in preschoolers. In addition, the accelerometer used to measure activity, while adequate for measuring gross motor movements as low as the sedentary level, was not sufficient to fully examine the hypothesis that fine motor movement and not gross physical movements may be the more prominent deficit in ADHD. Lastly, in measuring ADHD symptomatology, utilizing teacher reports of child behavior proved to be a threat to the internal validity of the study in that it was not possible for teachers to be blinded. That is, it was necessary for teachers in the intervention group to be aware of their participation in the intervention, and thus their report of child behavior over the course of the study may have been influenced by expectation bias.

Future research along the present vein will not only seek to increase sample size and implement a more genuine random assignment process, but also delve deeper into the question of whether and how physical activity may be beneficial in the treatment of ADHD in preschoolers. Rather than using a community sample, an atypical sample will allow prospective studies to generalize results to the affected population, and provide greater insights into the pathology of ADHD. More specifically, examining symptomatology in this age group will offer more developmental information, which will inform intervention measures. Utilizing more sophisticated accelerometry to monitor fine as well as gross motor movement and more age appropriate measures of response inhibition will allow future research to better explore the hyperactivity aspect of ADHD. Qualifying potential motoric issues and more closely examining the trajectory of response inhibition deficits may help researcher glean more about the etiology of ADHD.

Conclusion

The present study sought to add to the literature about the benefits physical activity. This study is one of the first lines of research to examine the efficacy of a physical activity intervention in a population at increased risk for ADHD in the preschool age range. Results suggest that physical activity does indeed benefit this at-risk group, and, with more research, physical activity may prove to be a viable alternative or supplement to other more invasive therapies. More research is needed to examine the long-term implications of utilizing physical activity to improve symptoms in ADHD patients, but preliminary findings are promising.

APPENDIX A

BASC-2 SUBSCALE ITEMS

Subscale	Items
Hyperactivity	
	11. Has trouble staying seated
	15. Acts out of control.
	18. Screams.
	36. Has poor self-control
	40. Bothers other children when they are working.
	43. Throws tantrums.
	61. Interrupts others when they are speaking.
	68. Cannot wait to take turn.
	93. Is overly active.
Aggression	
	4. Teases other.
	9. Disrupts the play of other children.
	23. Bullies others.
	29. Argues when denied own way
	34. Hits other children.
	48. Threatens to hurt others.
	54. Breaks other children's things.
	59. Seeks revenge on others.
	73. Defies teachers or caregivers.
	79. Loses temper too easily.
	84. Annoys others on purpose.
Attention Problems	
	3. Has a shore attention span.
	28. Listens carefully.
	53. Listens attentively.
	75. Listens to directions.
	78. Is easily distracted.
	100. Pays attention.

APPENDIX B

TIME 1 BASC-2/CHEESE TASK CORRELATIONS

Variable	Cheese Trial Acc	Cat Trial Acc	Cheese Task RT
Time 1 AGG r (sig.)	-.01 (*p*=.47)	-.29 (*p*=.44)	.09 (*p*=.32)
Time 1 HYP r (sig.)	-.24 (*p*=.09)	.012 (*p*=.48)	.04 (*p*=.41)
Time 1 ATT r (sig.)	-.31 (*p*=.04)	-.21 (*p*=.12)	-.25 (*p*=.08)

APPENDIX C

PARTICIPANT INCLUSION

Participant Inclusion (N)									
Variable	Baseline			Midpoint			Post		
	Intervention	Control	All	Intervention	Control	All	Intervention	Control	All
BASC-2 (HYPER, ATT, AGG)	39	24	63	33	22	55	33	23	56
Accelerometer Data (MOVE, MVPA)	20	27	47	21	15	36	15	11	26
Cheese Task (RI, ACC)	22	13	35	22	15	37	23	19	42

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