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A Randomized Trial Examining the Effects of Aerobic Physical Activity on Attention-Deficit/Hyperactivity Disorder Symptoms in Young Children

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Abstract

The goal of this study was to compare the effects of before school physical activity (PA) and sedentary classroom-based (SC) interventions on the symptoms, behavior, moodiness and peer functioning of young children (M_{age} = 6.83) at risk for attention-deficit/hyperactivity disorder (ADHD-risk; n = 94) and typically developing children (TD; n = 108). Children were randomly assigned to either PA or SC and participated in the assigned intervention 31 minutes per day, each school day, over the course of 12 weeks. Parent and teacher ratings of ADHD symptoms (inattention, hyperactivity/impulsivity), oppositional behavior, moodiness, behavior toward peers, and reputation with peers, were used as dependent variables. Primary analyses indicate that the PA intervention was more effective than the SC intervention at reducing inattention and moodiness in the home context. Less conservative follow-up analyses within ADHD status and intervention

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groups suggest that a PA intervention may reduce impairment associated with ADHD-risk in both home and school domains; interpretive caution is warranted, however, given the liberal approach to these analyses. Unexpectedly, these findings also indicate the potential utility of a before school SC intervention as a tool for managing ADHD symptoms. Inclusion of a no treatment control group in future studies will enable further understanding of PA as an alternative management strategy for ADHD symptoms.

Keywords

Physical activity; ADHD; behavior; peer; mood; young children; aerobic

parent and teacher reports of HI, inattention (IA), and total problems on the ADHD-IV Rating Scale.

Secondary screening to establish eligibility€ At Step 2, parents completed additional study measures about their children (N = 338) at an in-person screening; a subset of these measures were used to establish final eligibility. In addition, parents affirmed informed consent at the in-person screening pertaining specifically to the intervention portion of the study. Participants were ultimately identified as at-risk for ADHD based on several criteria. First, at least five HI symptoms were endorsed by parent report on the ADHD module of the National Institute of Mental Health Diagnostic Interview Schedule for Children, Version IV (DISC-IV; Shaffer, Fisher, Lucas, Dulcan, & Schwab-Stone, 2000). The DISC-IV is an interviewer-administered computerized structured diagnostic interview to assess child psychiatric diagnoses; only the ADHD module was administered. For children who met the 90th percentile cutoff at initial screening, but failed to meet the five HI symptoms on the DISC-IV, up to two additional unique symptoms by teacher report from the ADHD-IV Rating Scale could be utilized to reach the required five HI symptoms for inclusion in the ADHD-risk group. This strategy was similar to one used to obtain a symptom count of six in the Multimodal Treatment Study of Children with ADHD (MTA Coop. Group et al., 1999). A second requirement for inclusion in the ADHD-risk group was impairment in two or more domains as reported by parent and/or teacher on the Impairment Rating Scale (Fabiano et al., 2006) or by parent report on the DISC-IV impairment questions. Inclusion criteria for TD participants required four or fewer endorsed HI and IA symptoms on the DISC-IV; further, to avoid recruiting a •supernormal, sample, TD children were not excluded on the basis of impairment in one or more domains.

Additional eligibility requirements for both ADHD-risk and TD participants included the following: a non-verbal, verbal, or total IQ score that was not less than 1.5 SD below the mean (i.e., standard score ˆ 78) on the Kaufman Brief Intelligence Test, Second Edition (KBIT-2; Kaufman, & Kaufman, 2004

if an overrepresentation resulted on any of these factors in either intervention condition, a subgroup was re-randomized to achieve balance. Body mass index (BMI) was also examined post-randomization to ensure that average BMI was approximately equivalent across intervention groups; if not, a limited number of adjustments were made to achieve pre-treatment equity (e.g., highest BMI participant in one group was switched with lowest BMI participant in the other group). Descriptive statistics for factors used in the randomization process are presented in Table 1 by intervention group. Chi-square and ANOVA analyses indicated no intervention group differences based on factors considered during randomization.

Both intervention programs were administered daily over 12 weeks when school was in session. Intervention programs were administered during winter and spring months to ensure that participants were acclimated to the school context before the intervention began. The PA intervention involved continuous activity at a rate that required children to breathe hard, a benchmark used in the PA literature to describe energy expenditure in the moderate-to-vigorous range (see Marshall & Welk, 2008). PA was structured within age-appropriate activities and games that maintained participants… interest. The SC program was designed to keep participants sedentary, but engaged in classroom-based art projects for the duration of the before-school program. Each daily intervention program was 31 minutes in duration. The program day was organized in the following manner: (1) a 2-minute large group activity; (2) three, 9-minute small group stations (in the PA program, the last minute of each station was used for transitioning to the next station); and (3) another 2-minute large-group activity. Each program followed a structured manual with suggested activities spelled out for each day of the program. For example, in PA, a typical day might consist of a game of •tag, for the initial large group activity, followed by •Sharks and Minnows,, •Spiders and Flies,, and an obstacle course for the three small group stations, finishing with •Follow the Leader, for the final large group activity. Similarly, in SC, the initial large group activity might be an art show, followed by construction of a pop-up frog broken into three small group stations such as (1) trace and cut out the frog (2) decorate the frog (3) assemble the frog, finishing with a large group clean-up activity. The manuals were developed specifically for this study; more information regarding the programs and manuals may be obtained from the first or second authors. ADHD-risk and TD participants were not separated for the interventions.

In both the PA and SC settings, research staff members were trained to use praise and effective instructions freely. Emphasis was placed on having all children attend to the instructor before instructions were given (•Stand on the line, eyes on me, in PA; •hands in your lap, eyes on me, in SC). Participants received a sticker for each of the three activity segments during which they were actively involved. Participants whose participation lapsed at a PA or SC station for more than a cumulative two minutes did not receive a sticker for that station; thus, number of stickers accumulated throughout the program was a proxy for the dose of intervention received. Importantly, participation in the PA or SC activity (regardless of appropriateness of child behavior) was the criterion for receiving a sticker. Each participant who earned a specified number of stickers by the end of each week received either a small (value approximately $0.25; earned if participant received at least 75%, but less than 100% of stickers) or large (value approximately $1.00; earned if participant received 100% of stickers) prize. No other behavior management strategies were used.

Numerous strategies were utilized to increase the likelihood that procedures were consistent across study sites. Specifically, program supervisors from both sites participated in joint site comprehensive training sessions prior to the start of the intervention. In addition, supervisors monitored program fidelity throughout the interventions and participated in weekly calls between the sites to review study protocols.

Measures

Participation rates—Intervention participation rates were calculated by dividing the number of participation stickers received during the course of the intervention by the number of possible stickers that could be earned across the intervention.

Manipulation check—To examine if participants in the PA condition increased their fitness level more than participants in the SC condition, the Progressive Aerobic Cardiovascular Endurance Run (PACER; Leger, Mercier, Gadoury, & Lambert, 1988) was used to measure aerobic capacity pre- and post-intervention. Participants completed a series of continuous 15-meter shuttle run segments that become progressively more difficult because of the decreasing time allowed to complete a segment. If a participant did not complete the run in the designated time frame, the segment was considered a miss. The count of the 15-meter segments that each participant completed in the designated time frame before the second (consecutive or nonconsecutive) miss was the measure of aerobic capacity.

Medication use—Although participants were medication naïve at study entry, participants were permitted to seek and start medication during the intervention. At mid- and post-intervention, parents were asked if participants began medication to treat symptoms of ADHD during the intervention. This information was examined in supplemental analyses.

Symptom severity—Parent and teacher reports of ADHD and oppositional symptom severity were collected at both pre-intervention (Time 1; T_1) and post-intervention (Time 2; T_2). ADHD symptom severity was assessed using the home and school versions of the ADHD-IV Rating Scale (DuPaul, 1991), previously described in the preliminary screening section, and yielding measures of HI symptom severity (nine items; parent report: T_1 α = .93; T_2 α = .92; teacher report: T_1 α = .96; T_2 α = .95) and IA symptom severity (nine items; parent report: T_1 α = .94; T_2 α = .92; teacher report: T_1 α = .96; T_2 α = .95). Oppositional symptom severity was measured using a revised version of the Oppositional/Defiant subscale of the Pittsburgh Modified Conners Parent and Teacher Rating Scale (PMC; Pelham, 2002). One item from the original five-item subscale was removed for the current study (i.e., "temper outburst" behavior explosive and unpredictable,") to prevent singularity (i.e., redundant items on distinct assessments) with a moodiness subscale derived from the PMC (described below). Reliability estimates for this version of the subscale were acceptable (parent report: T_1 α = .83; T_2 α = .76; teacher report: T_1 α = .89; T_2 α = .81). For all PMC subscales, respondents used a four-point scale (0 = *not at all*, 3 = *very much*) to rate participants. Thus, higher values on the PMC indicate more extreme problems.

Moodiness—Three items from Pelham's (2002) PMC (i.e., "temper outburst" behavior explosive and unpredictable,"; "cries often and easily,"; and "mood changes quickly and

drastically,) were used to assess participant moodiness in the current study. Chronbach†s alphas (parent report: T_1 Y= .80; T_2 Y= .82; teacher report: T_1 Y= .84; T_2 Y= .86) suggest good internal consistency of scores.

Peer functioning€ Items from Pelham†s (2002) PMC also were used to develop two peer subscales for the current study. The first subscale included six items assessing problematic peer behavior (i.e., •disturbs other children,; •fights, hits, punches, etc.,; •frequently interrupts other children†s activities,; •bossy: always telling other children what to do,; •teases or calls other children names,; and •refuses to participate in group activities,) and was internally consistent (parent report: T_1 Y= .83; T_2 Y= .78; teacher report: T_1 Y= .82; T_2 Y = .82). In light of findings indicating that positive behavior in the peer context does not necessarily correspond with improved peer reputations for children with ADHD (Hoza, Pelham, Gnagy, & Greiner, 2003), a separate three-item peer reputation subscale was developed from Pelham†s (2002) PMC (i.e., •is disliked by other children,; •is actively rejected by other children,; and •is simply ignored by other children,; parent report: T_1 Y= .82; T_2 Y= .89; teacher report: T_1 Y= .82; T_2 Y= .91). Higher values on the respective subscales correspond with poorer peer functioning.

Data Analysis

A series of 2 (within-subject factor: time) ‰ 2 (between subjects factor: ADHD-risk vs. TD status) ‰ 2 (between subjects factor: PA vs. SC intervention group) mixed model ANOVAs was conducted to examine if symptom severity, moodiness, or peer functioning changed (1) over the course of the intervention (main effect of time); (2) over the course of the intervention as a function of ADHD-risk status (interaction of time and status); (3) over the course of the intervention as a function of intervention group (interaction of time and intervention group); and (4) over the course of the intervention as a function of both status and intervention group (three-way interaction of time, status, and intervention group). Given the lack of previous work comparing the efficacy of a PA intervention with other interventions, or with a randomized control group, we were unable to estimate expected between-subjects effects prior to beginning the study (i.e., whether adaptive change over the course of the intervention was stronger for the PA condition as compared to the sedentary condition). Thus, initial power analyses were based on within-subjects effects and, consistent with this approach, planned follow-up dependent-samples *t*-tests were used to examine pre-post intervention change within groupings based on status and intervention group. Effect sizes (i.e., Cohen†s *d*) were calculated by dividing the pre-post change over the course of the intervention by the pooled standard deviation of the pre-test scores for the focal status group (i.e., ADHD-risk or TD). Thus, for example, effect sizes for the ADHD-risk group in the PA intervention were calculated by dividing the pre-post change for that specific group by the pooled standard deviation of the pre-test score for the entire ADHD-risk status group.

No data were missing for parent reports at pre-intervention and data from one participant were missing on the PMC measure for teacher reports at pre-intervention. Data missing on post-intervention measures ranged from 4% € 9% across ratings and reporters. Thus, intent-to-treat procedures were used in analyses to address missing data at Time 2. Specifically, for

missing data at post-intervention, pre-intervention scores from the same item were used for the post-intervention value.

Pre-Post Analyses

Change in symptom severity€ Overall, parents reported that children†s ADHD and oppositional symptom severity decreased over the course of the intervention, HI symptoms: $F(1, 198) = 69.21$, $p < .001$, $\eta^2_{partial} = .26$; IA symptoms $F(1, 198) = 64.31$, $p < .001$, $\eta^2_{partial} = .25$; oppositional symptoms $F(1, 198) = 25.91$, $p < .001$, $\eta^2_{partial} = .12$. These

Symptoms

In regards to ADHD and oppositional symptoms, our results provided partial support for our first hypothesis. Specifically, we found greater reductions in parent-reported IA symptoms on a DSM-IV symptom-based rating scale for children in the PA intervention, relative to those in the SC program, regardless of status group (i.e., ADHD-risk or TD). Differential improvement on ADHD symptoms by intervention group, however, was not reported by teachers. Interestingly, as shown in Table 4, despite the lack of a significant Time ‰ Intervention interaction for teacher reports of ADHD symptoms, effect sizes for improvements in ADHD symptoms reported by teachers were similar to those reported by parents for ADHD-risk children receiving the PA intervention (Cohen's *d* effect sizes were .69 for parents and .54 for teachers on HI, and .65 for parents and .61 for teachers on IA). Hence, the non-significant Time ‰ Intervention interaction by teacher report appears to be

hence the change for the ADHD-risk group is likely to be of greater clinical significance.

the results of future studies, schools should feel comfortable to integrate PA into the school day. It is unlikely to have any negative effects and may produce positive effects comparable to those seen in the present study. Importantly, although we focused this study on children

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Table 1

Descriptive Statistics for Factors Considered During Randomization

	PA Group (N = 104)	SC Group (N = 98)
Status (%)		
ADHD-risk	47.1	45.9
TD	52.9	54.1
Sex (%)		
Boys	55.8	51.0
Girls	44.2	49.0
Grade (%)		
Kindergarten	26.9	28.6
1st Grade	37.5	40.8
2nd Grade	35.6	30.6
BMI [*M* (*SD*)]	37.5	

Table 3

Means and Standard Deviations for Study Variables within Status and Intervention Group

At-risk for ADHD PA Group (N = 49)

Table 4

Effect Sizes for Pre- to Post-Intervention Change within Status and Intervention Group

Measure	At-risk for ADHD PA Group	At-risk for ADHD SC Group	Typically Developing PA Group	Typically Developing SC Group
Parent Reports				
HI Symptoms	.69	.57	.65	.31
IA Symptoms	.65	.46	.68	.13
Opp. Symptoms	.31	.53	.19	.11
Moodiness	.40	.23	.21	Œ.26
Peer Behavior	.54	.34	.24	.26
Peer Reputation	.30	.19	.26	Œ.15
Teacher Reports				
HI Symptoms	.54	.60	.10	.29
IA Symptoms	.61	.62	.08	.24
Opp. Symptoms	.18	.09	.01	.03
Moodiness	.07	.17	.02	.00
Peer Behavior	.32	.22	.21	.15
Peer Reputation	.16	.01	.15	.01

Notes.Effect sizes representing significant ($p < .05$) adaptive pre-post intervention change are in boldface. Effect sizes (i.e., Cohen†s d) were calculated by dividing the pre-post change over the course of the intervention by the pooled standard deviation of the pre-test scores for the focal status group (i.e., ADHD-risk or TD). PA = physical activity; SC = sedentary classroom-based; HI = hyperactivity/impulsivity; IA = inattention; Opp. = oppositional.