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Effect of a School-Based Physical Activity Intervention on Number and Letter Recognition in Preschoolers

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ABSTRACT

International Journal of Exercise Science 11(5): 168-178, 2018. The aims of this study were to determine if physical activity (PA) and sedentary behaviors were correlated to components of school readiness skills (i.e., symbol recognition – numbers and letters) in preschoolers and to evaluate the efficacy of a 12-week, academically connected PA intervention on letter and number recognition in preschoolers. Two preschool centers were randomized to a 12-week preschool-based PA intervention (INT) that incorporated short-bout PA lessons embedded into the Massachusetts Early Learning Standards or a health-tracking control group (CON). INT preschoolers completed two 10-minute (as part of morning circle time) and three 5-minute bouts (afternoon after naptime) of PA each week. One hundred fourteen students (INT, n = 60; CON, n = 54) participated in the study, but assessment was completed in 52 children INT, n = 26; CON, n = 26). Whole day PA was measured over one week (including one weekend day) by accelerometry at baseline. School readiness skills were assessed by recognition of symbols (i.e. letters and numbers) at baseline and at 12-weeks. Spearman rank correlations were used to assess a relationship between PA and symbol recognition. Multiple linear regression models were used to assess the effect of the intervention on symbol recognition. There were no significant correlations between PA and symbol recognition and no significant effect of the intervention on pre- to post-scores. Further research may be valuable to examine the benefits of a preschool PA intervention by utilizing longer intervention periods, additional bouts of academically-tailored PA, and more comprehensive measures of school readiness skills.

KEY WORDS: Early childhood, academic performance, active classrooms

INTRODUCTION

The Society of Health and Physical Educators (SHAPE) recommends that preschool-age children should engage in at least one hour of structured physical activity (PA) and one hour of unstructured PA every day (1). More recent guidelines from the Institute of Medicine recommend that young children in childcare should receive opportunities for light, moderate, and vigorous intensity PA for least 15 minute every waking hour (30). Although health and wellness components are included in most preschool curriculums, only 32% of preschoolers obtain the SHAPE recommended amount of daily PA (22). Furthermore, preschoolers spend the majority of their full day in sedentary activity, with researchers reporting an average of 32.8 (37) to 56.3 (2) minutes per hour measured by accelerometers. About 61% of American

preschoolers (age 2.9 - 5 years) attended center-based childcare arrangements in 2012, making preschool centers an ideal setting for PA interventions (3). However, preschool teachers often face a variety of time constraints and teaching demands (e.g., fitting in curriculum, state mandated learning standards, and center-specific requirements into the daily schedule). Therefore, interventions to increase PA in preschoolers that have been integrated into the preschools' mandated learning standards appear more acceptable and feasible to preschool staff as opposed to interventions that solely consisted of activity breaks (25, 36, 39, 41).

The mission of many preschool programs includes enhancing students' readiness (or preparedness) for kindergarten in a variety of learning domains (6). The health and wellness domain is usually incorporated into preschool programs and focuses on health behaviors such as PA (6). For example, in the state of Massachusetts (the location of this study) the health curriculum framework for pre-kindergarten through grade 8 includes learning standards that emphasize motor skill development and opportunities to participate in a variety of physical activities to increase knowledge and promote physiological changes (15). Early childhood program standards provide examples of how to promote these behaviors (11). In addition, increasing PA in an effort to enhance learning in preschoolers may be ideal, particularly since this age group experiences a high rate of cognitive development and neurophysiological change (19). Recent studies that have reported the impact of PA interventions in school-aged children (i.e., children ≥5 years) have reported beneficial effects on some academic performance related outcomes such as executive function skills, school-related behaviors, and academic achievement (21, 23, 24, 27, 28). Although the examination of the relationship between PA and academic performance related outcomes in preschoolers has been primarily limited to observational research (4, 7, 33), there is some preliminary support from experimental study designs that PA can positively affect cognitive outcomes in preschoolers. Palmer et al. (34) compared a 30-minute bout of PA to a 30-minute sedentary period in 16 preschoolers (mean age = 49.4 months) and reported that the PA condition significantly increased sustained attention. A cross-over study by Webster et al. (41) demonstrated further support for PA when preschoolers (n=188) demonstrated significantly improved on-task behavior from two school days with 10-minute activity breaks, compared to two school days without activity breaks (i.e., a typical instruction condition). Further experimental studies are needed to determine what academic-related outcomes can be impacted by PA in the preschool population.

The purpose of this study was to examine the relationship between PA and school readiness skills (a domain of academic performance) in preschool-age children (ages 2.9 to 6) by utilizing an experimental design. The first aim of this study was to determine if PA and sedentary time were correlated to components of school readiness skills (i.e., symbol recognition – numbers and letters) in preschoolers. The second aim was to evaluate the efficacy of a 12-week, academically connected PA intervention on letter and number recognition in preschoolers.

METHODS

Participants

This pilot study was conducted from January 2016 to July 2016 in two preschool centers in the greater Springfield, MA area. The centers were randomized to either the preschool-based PA intervention group (INT, classrooms = 4, n = 60) or the health tracking program control group (CON, classrooms = 3, n = 54). The PA intervention was offered to all children enrolled in the preschool that was randomized to the PA treatment group. However, children were individually recruited to participate in the study (specifically the assessments) (INT, n = 26; CON, n = 26). Children were to be excluded from participating in the assessment portion of the study if they were unable to participate in routine outdoor playtime, required oxygen supplementation for exertion, had a developmental or physical disability preventing participation in the intervention, or any other limitations that prevented them from increasing PA. However, no children in either preschool were excluded from analyses for any of these criteria. The study was approved by the University of Massachusetts Amherst Institutional Review Board and parents provided written informed consent and permission for their child to participate in the study assessment protocol.

Protocol

The PA intervention consisted of active learning lessons and PA breaks that were integrated into the preschool center's academic curriculum. Research assistants implemented the PA intervention by leading the lessons plans for 12 weeks with assistance from the classroom teachers. Brief (i.e., approximately 5 to 10 minute) PA lessons were connected to the Massachusetts Early Learning Standards and were implemented in the morning preschool schedule for two to three days per week. Every other week, in place of one of the 5 to 10-minute PA bouts, a 30-minute motor skill lesson was offered. In addition, a 5-minute PA video lesson was implemented in the afternoon (after naptime) on three days per week. The weekly intervention schedule is presented in Table 1 and a sample lesson plan of each type of activity bout is presented in Table 2. Many of the morning PA lessons incorporated symbol recognition such as the "Counting Pirates" lesson described in Table 2. The control preschool center was asked to follow their regular curriculum during the intervention period and was offered the intervention at the conclusion of data collection.

Table 1. Weekly schedule of PA intervention lessons.

Time	Monday	Tuesday	Wednesday	Thursday
Morning	PA Lesson (5 to 10 minutes)	N/A	PA Lesson (5 to 10 minutes)	PA Lesson (5 to 10 minutes) or Motor Skill Lesson (30 minutes)
Afternoon	N/A	PA Video (5 minutes)	PA Video (5 minutes)	PA Video (5 minutes)

Table 2. Sample lesson plans for PA intervention.

Morning: PA Lesson	Morning: Motor Skill Lesson	Afternoon: PA Video
"Counting Pirates" MA Curriculum Framework Links: Mathematics - Counting and Cardinality • MA.1. Listen to and say the names of numbers in meaningful contexts. • MA.2. Recognize and name written numerals 0–10. Materials • Number flashcards (1-10) DAY 1 – Treasure Hunt Directions: The students will line up behind the teacher and follow directions as they are lead through a "treasure hunt". The teacher may hold up number cards as they start each action and ask the students what number he/she is holding. 1. Off the ship (1 broad jump) 2. Log roll under the fort wall (2 rolls) 3. Belly crawl under the fishing nets (3 low crawls) 4. Hop across the hot sand (4 hops) 5. Jump high to grab a coconut (5 jumps) 6. Swim across the stream (6 swim strokes on belly) 7. Duck under the jungle branches (7 squatting walks) 8. March with high knees through the mud (8 marches) 9. Run 9 paces around the quicksand (jog in place 9x) 10. Jump for joy - found the treasure (10 jumps)	"Introduction to Galloping" MA Learning Standards: Growth & Development (1.1, 1.2), Physical Activity & Fitness (2.2) Preschool Learning Guidelines: Physical Development (2, 4) Materials • 2 paper plates per student • Hula hoops • Beanbags Prior to Initial Activity Present and demonstrate galloping. Initial Activity Students should stand at the circle and find their self-space. They should turn to the right and will be traveling counterclockwise around circle. Each student should make his or her lead leg far from the back leg. They should then be told to bring their feet together. The teacher should say 'Far' and 'Near' several times in the row so each child gets to practice the sliding motion. Sample Extension Activity: Ice Skating Have paper plates placed around the outside of the gymnasium and have students place a plate under each foot. Have the students ice skate around the room while maintaining self-space. They should focus on sliding with one foot in front of them and then bringing the trail foot next to the lead foot.	Warm-Up (30 seconds) Song: "I Like to Move It (More's Instrumental)" Movements: • Knee bounce • March in place • Reach both arms up and down • Alternate reaching arms up • 4 little jumps • March in place Funky Farmer (4 minutes, 30 seconds) Song: "Achy Breaky Heart (Instrumental)" Movement 1: Milk the Cow • Shovel hay to the side • Milk the cow • Jump • Repeat in the other direction • Repeat 2 more times Movement 2: Stack the Hay • 8 heel digs • Stack the hay (bend down and throw it up) • 4 lasso jumps • Jump out and in • Repeat 2 more times Movement 3: Chicken Dance • March with high knees • Jump & clap • Repeat 3 more times • Flap small wings to the right • Flap big wings to the left • Repeat 3 more times

Measurements were assessed at both preschools within two weeks prior to the start of the PA intervention (baseline) and at week 12 of the intervention (post-assessment). Parents were

asked to complete demographic information about their children via Qualtrics (online survey system; Qualtrics, 2016, Provo, UT). Weight was measured twice to the nearest 0.1 kg (digital scale) and standing height was measured twice to the nearest millimeter (stadiometer), averaged for analyses, and used to calculate body mass index (BMI; kg/m^2) and BMI percentile (5). PA was objectively measured using Actigraph accelerometers (Manufacturing Technologies Inc. Health Services, Ft. Walton Beach, FL). Trost et al. (40) recommend that accelerometers be placed either on a participant's hip or lower back. In a monitor placement comparison study in 7 year old children (n=16), Nilsson et al. (32) did not observe significant differences in total counts per minute for accelerometers placed on the hip or back and reported a good correlation between the two sites (r = 0.81). Therefore, accelerometers were placed on an adjustable elastic belt and worn around the participant's waist, with the monitor positioned on their lower back to be unobtrusive (40). Families were asked to encourage their preschooler to wear the accelerometer during all waking hours for seven consecutive days (including one weekend day) and to remove it only when the accelerometer would get completely wet. Parents/guardians and classroom teachers were instructed on accelerometer placement and asked to ensure accurate repositioning of the accelerometer whenever removed. The accelerometers were programmed to collect data at 15-second intervals for each monitoring day. The ActiLife software program (version 6.9.1) was used to process all Actigraph data. The Choi algorithm was used to determine wear time (9). A minimum of three days of at least 8 hours per day were required to be included in the analysis (9). For percent time of total day, PA data was analyzed from average waking hours (i.e., 7 AM to 10 PM) and for minutes per hour of preschool day, data was analyzed from the normal preschool day schedule (i.e., 8 AM to 4:30 PM). The Pate et al. (35) cut-points (15-second epoch) were used to determine classifications of activity intensity (i.e., percent time spent in sedentary, light, moderate, vigorous PA). Once a week, research staff documented if the lessons were implemented as planned for one morning lesson (i.e., lessons were implemented according to the schedule and followed the original lesson plan) and one afternoon PA lesson (i.e., the 5-minute video was implemented at the expected time) as a measure of fidelity.

Recognition of symbols, an area within academic performance skills in many preschool readiness tests, was assessed at baseline and post-intervention (week 12 of the intervention) (6). Symbol recognition was measured in the morning, prior to the PA lessons. Preschool participants completed two assessments: letter recognition and number recognition. Two research assistants conducted the assessment. For each assessment, a deck of letter (i.e., all 26 letters) and a deck of number (i.e., numbers 1 through 15) cards were used in a random order. One research assistant presented each card to the preschooler and asked them to identify the symbols without any additional prompts or verbal cueing. The other researcher recorded the correct responses (out of the view of the student). Correct responses were summed for letters and numbers scores, and used to calculate a total symbol score.

Statistical Analysis

Between groups baseline differences were assessed with 2 sample *t*-tests for continuous variables and chi square tests for categorical variables. Spearman rank correlations were used to assess the association between percent time spent in different sedentary and activity

intensity categories and letter and number recognition. Multiple linear regression models were used to assess the effect of the intervention on letter recognition, number recognition, and total symbol scores. Two models were run for each dependent variable (letter score, number score, and total score). Model I adjusted for baseline score only and model II adjusted for baseline score and age. All analyses were performed in Stata (version 14, College Station, TX) and statistical significance levels were determined using an alpha-level less than 0.05.

RESULTS

A total of 52 (INT, n=26; CON, n=26) preschool students enrolled in the assessment portion of this study, but post-intervention analyses included participants with complete data (INT, n=19; CON, = 22). The average wear time for the accelerometers during the baseline data collection week was 5.9 ± 1.6 days. Descriptive characteristics for each treatment group are presented in Table 3. There were no significant differences in demographic variables at baseline between treatment groups, but there was a significant difference between groups for preschool sedentary and moderate-to-vigorous PA in minutes per hour. One participant moved out of the area prior to post-assessment. Other participants were missing data either due to school absences during baseline or post-assessment days or unwillingness to participate in the symbol recognition assessment. There were no significant correlations between any of the baseline PA and academic performance skills. Two multiple linear regression models with post-scores as the dependent variable and randomization to the intervention group as the independent variable were used to examine the effect of the intervention on number and letter recognition scores. The first model adjusted for baseline score only and the second model adjusted for baseline score and age. Randomization to the intervention group was not significantly associated with improvements in pre- to post-scores for letters, numbers, or a combined total of symbols in either regression model (Table 4). Specifically, the beta coefficients demonstrated that randomization to the intervention group was associated with average scores that were non-significantly lower than the control group by 3.15, 0.76, and 3.72 for letter, number, and total scores respectively. Of the observed sessions that were documented for fidelity purposes (i.e., once per week), 78% of the morning PA lessons and 100% of the afternoon lessons were implemented as planned.

DISCUSSION

We did not observe a significant relationship between symbol recognition skills and percent time spent in PA or sedentary activities at baseline. Furthermore, this 12-week school-based PA intervention did not elicit significant improvements (from baseline to post-intervention) in such skills in preschoolers. The lack of correlation between PA and academic-related outcomes or the impact of the intervention on these variables could be attributed to an insufficient PA dose or the length of the PA intervention. Intervention trials in preschoolers and elementary school children that have resulted in beneficial effects on academic performance or cognitive outcomes often followed the participants over a whole school year (i.e., 8 to 9 months) (17, 21, 25), while our intervention was only offered for 12 weeks as it was part of a pilot study. Although 22% of the observed morning PA lessons were not implemented completely as

planned because adaptations were made to keep the preschoolers engaged, all of these lessons were implemented at the intended time. A different intervention prescription may be needed to observe changes in academic-related outcomes. Improvements in executive functions (which may be pivotal to improvements in school readiness skills) are probably mediated by aerobic fitness (8, 16). Improvements in aerobic fitness may require more frequent and/or longer PA bouts. For example, a 9-month intervention by Puder et al. (38) reported significant improvements in aerobic fitness of preschoolers with a multidimensional health intervention that targeted PA in multiple settings throughout the day (i.e., classroom break, recess, and after preschool PA opportunities), rather than just the one to two short daily bouts we incorporated. In a slightly older sample of 7 to 11 year old children, Davis et al. (12) found that a longer duration dose of aerobic PA (40 minutes versus 20 minutes or a control condition) resulted in greater improvements in one area of executive function (planning).

Table 3. Distribution of baseline characteristics according to treatment group.

	Treatment Group		
Variables	Intervention (n=26)	Control (n=26)	p-Value
Demographics			
Age (years)	4.1 (0.1)	4.3 (0.1)	0.60
BMI percentile	53.8 (4.9)	46.6 (28.6)	0.36
Gender (male)	14 (53.8%)	12 (46.2%)	0.58
Symbol Recognition			
Letters score	11.6 (1.8)	15.2 (1.9)	0.18
Numbers score	7.2 (0.9)	7.3 (1.0)	0.93
Total score	18.8 (2.5)	22.5 (2.7)	0.33
Physical Activity			
Percent time in MVPA	7.9 (0.7)	8.9 (0.9)	0.41
Percent time in SB	84.5 (1.1)	82.8 (1.5)	0.41
SD sedentary (minutes/hour)	50.1 (3.5)	47.5 (3.2)	**0.02**
SD MVPA (minutes/hour)	4.6 (2.2)	6.4 (2.2)	**0.02**

MVPA = moderate-to-vigorous physical activity; SD = preschool day (8:00 AM to 4:30 PM); p-values derived from chi-square tests for categorical variables and from two-sample *t*-tests for continuous variables.

Table 4. Multivariate linear regression model results for each outcome (post-score) with intervention group as the predictor variable.

Outcome	Post-Score (Mean ± SD)		Model I*		Model II**	
	PADS	CON	β coef. (95% CI)	p-value	β coef. (95% CI)	p-value
Letter score	15.4 ± 9.3	20.2 ± 7.3	-3.15 (-5.53, 0.22)	0.06	-2.94 (-6.34, 0.46)	0.08
Number score	8.2 ± 4.4	8.6 ± 4.7	-0.76 (-2.74, 1.21)	0.44	-0.54 (-2.59, 1.51)	0.60
Total score	23.6 ± 12.6	28.9 ± 11.6	-3.72 (-8.27, 0.83)	0.11	-3.46 (-8.14, 1.21)	0.14

PADS = Intervention group; CON = Control group; SD = Standard deviation *Adjusted for baseline score. **Adjusted for baseline score and age.

Short bouts of PA were specifically selected in this study because 1) the intervention was designed to be easily implemented into a preschool's curriculum and 2) preschool literature has demonstrated some preliminary support that shorter bouts may be more effective than 30 to 60-minute PA sessions that are typically used in this population. In studies of gross motor play time in preschools, children tend to be most active in the first 10 minutes of a 30-minute

period (14, 29). Furthermore, in SHAPE's Active Start PA guidelines for preschoolers, short structured PA sessions (i.e., 20 minutes or less) are recommended to keep young children engaged and to promote moderate-to-vigorous PA intensity levels (1). More preschool intervention studies examining the effect of short bouts of PA on aerobic fitness (a potential mediator on school readiness skills) are needed. Furthermore, Trost et al. (39) demonstrated that repeated short bouts of PA were effective in improving classroom moderate-to-vigorous PA. Therefore, it is possible that incorporating multiple short bouts of PA per school day in the future may impact our outcomes differently.

Although the literature reporting on relationships between PA behaviors and academic-related outcomes in preschool age children is limited, a few studies have reported on the relationship between PA and school readiness skills in kindergarten and young elementary school-age children. Niederer et al. (31) reported no relationship between PA and attention, another school readiness-related outcome, in a sample of 245 Swiss five year olds. Oja et al. evaluated the relationship between PA and motor ability (i.e., physical education fitness measures) and school readiness in 294 kindergartners in Estonia (33). Motor ability was positively related to school readiness skills, which was assessed with the Controlled Drawing Observation Test. However, unlike the objective assessment used in our study, Oja et al. utilized parent reported measures to assess PA, which can sometimes over-estimate PA levels in children (33). Reports on elementary school-age children have provided some support of a relationship between objectively measured PA and academic-related outcomes (i.e., reading scores and overall grades) (10, 18).

Few studies have reported on the impact of PA interventions on academic-related outcomes in preschoolers. For example, in a quasi-experimental design comprised of 54 African American preschoolers in two Head Start centers, Kirk et al. (25, 26) examined the effects of PA integrated into the lesson on early literacy skills (i.e. alliteration, picture naming, and rhyming). Although the PA setting was similar to our study, the Head Start study implemented the PA lessons 5 days per week over 8 months and reported significant improvements in early literacy skills in the intervention group compared to the control group. It is difficult to compare the findings of the present study to those reported by Kirk et al., due to differences in the outcome variables measured and the length and dose of the interventions.

Aside from the intervention length, other limitations of our study should be noted. The symbol recognition assessment used here was not used in previous research studies and we only assessed one specific component of school readiness (i.e., symbol recognition of letters and numbers). However, the method we used is common in education practice (6), and was specific to the academic skills that were included in many of our intervention PA sessions. In addition, this method was more time efficient than more comprehensive school readiness assessments (which was important because all assessments were completed during the classroom time).

Although many of our PA lessons incorporated recognition of numbers and letters, some lessons focused on other school readiness skills as well, such as measurements and opposites.

Future studies may want to use a more comprehensive method to measure school readiness. Finally, as this was a pilot study designed to primarily assess the feasibility, acceptability, and efficacy of this PA intervention on obesity-related health behaviors, a power calculation was not completed for school readiness outcomes. Strengths of this study include the use of a randomized controlled trial design and an objective assessment of PA.

In conclusion, a 12-week PA intervention of three 5 to 10-minute physically active academic lessons and three brief PA bouts per week was not sufficient to increase symbol recognition in preschoolers, compared to a traditional curriculum. Although the intervention used in this study was part of a pilot study and was designed to change PA, it is possible that the dosage was not enough to change symbol recognition school readiness-related skills, as this was not the primary outcome variable. Adaptations to the program could be integrated to target school readiness skills by increasing the frequency of the PA academic lessons and PA breaks and increasing the length of the intervention. It is possible that this type of PA may improve other measures of cognition such as executive functioning tasks, which should be considered in future studies. Although our study did not provide support for our hypothesized relationships between PA and symbol recognition in preschoolers, further research may be warranted given the scarcity of research in this age population and the growing support for such relationships in school-age children (8, 13, 20).

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