An Intervention to Increase Physical Activity in Children

A Randomized Controlled Trial With 4-Year-Olds in Preschools

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Introduction: A majority of preschool-aged children spend a significant portion of every weekday in a preschool or child care setting, where they typically participate in limited physical activity. This study determined if an ecologic physical activity intervention in preschools increases children's moderate- to vigorous-intensity physical activity (MVPA).

Design: RCT, with preschool as the unit of randomization and analysis. Child physical activity was measured by accelerometry. Mixed model analysis of covariance with preschool as a random variable was used to test the effects of the intervention on physical activity in the total group and in sex-specific subgroups. Data were collected in 2008–2010 and analyzed in 2012–2014.

Setting/participants: Children in 4-year-olds' classrooms in 16 preschools, pair matched and assigned to intervention or control groups.

Intervention: The intervention focused on increasing children's physical activity by changing instructional practices. Researchers trained preschool teachers to engage children in physical activity during (1) structured, teacher-led physical activity opportunities in the classroom; (2) structured and unstructured physical activity opportunities at recess; and (3) physical activity integrated into pre-academic lessons. Research staff encouraged teachers to adapt the intervention to their classrooms.

Main outcome measures: Minutes/hour of MVPA during the preschool day.

Results: In an analytic sample of 379 children (188 intervention, 191 control), those in the intervention schools engaged in significantly more MVPA than children in control schools (7.4 and 6.6 minutes/hour, respectively). This difference remained significant after adjusting for parent education and length of the school day (half versus full day). In the sex-specific analyses, the difference was significant for girls (6.8 vs 6.1 minutes/hour of MVPA, respectively) but not for boys (7.9 vs 7.2 minutes/hour, respectively).

Conclusions: A flexible ecologic physical activity intervention that trains teachers to provide children with opportunities to be active throughout the school day increased MVPA in preschool children.

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Introduction

Obesity rates in American children and adolescents have increased dramatically since the 1960s, and this alarming trend is evident even in preschool-aged children.[1] Although the causes of the increased prevalence of childhood obesity have not been identified definitively, a secular decline in physical activity is widely seen as one of the contributors.[2] Authorities in several countries, including the U.S.,[3–7] have developed physical activity guidelines for young children, and studies[8–11] have shown that many children aged 3–5 years in the U.S. and elsewhere fail to meet those guidelines.

More than half of preschool-aged U.S. children attend a structured preschool or child care center,[12] and previous studies[10,13,14] have shown that preschool students spend most of their school day engaged in sedentary behaviors. A recent report from IOM called for preschools to implement policies and practices aimed at preventing childhood obesity, including providing opportunities for physical activity for at least 15 minutes/hour of school attendance.[3] Some studies[15–17] have shown that young children's physical activity can be increased when preschools adopt instructional and organizational practices that promote physical activity, but additional research is needed to determine which practices or combinations of practices are most effective.

Though several studies have tested interventions to increase children's physical activity in the preschool setting, observed increases in physical activity have been small and findings have been inconsistent across studies. Several of the interventions were of short duration, from 5 days[18] to 8 weeks,[19] and many were implemented using a structured curriculum. Research staff implemented many of the interventions, although in some studies trained preschool teachers implemented the curriculum.[20–22] In addition, although most studies now measure children's physical activity using accelerometry, the overall number of studies conducted in this population is small.[18–21,23–25] To the authors' knowledge, no previous study has used a randomized design, measured physical activity using accelerometry, and tested a flexible intervention. Accordingly, the purpose of this study was to test the effects of an adaptable ecologic preschool intervention, implemented by preschool teachers, on the physical activity of young children. The primary outcome of interest was minutes/hour of moderate- to vigorous-intensity physical activity (MVPA) during the preschool day, measured by accelerometry.

Methods

Design and Setting

The Study of Health and Activity in Preschool Environments (SHAPES) used a group randomized design with preschool as the unit of randomization and analysis.[26] The study included public preschools and private child care/child development centers (hereafter referred to as preschools) in the Columbia, South Carolina, area that met eligibility requirements, including a focus on developmental and pre-academic skills (e.g., identifying numbers, developing metalinguistic skills, socializing), adherence to state curriculum standards, and program length of $\geq$3 hours/day and $\geq$180 instructional days/year. Sixty-two public and private preschools that met the eligibility criteria were identified, and a stratified random sample of 16 preschools was invited to participate in the study. If a preschool declined to participate, another school from the same stratum was invited. Only two preschools declined to participate, so the response rate was 89%. The 16 preschools that agreed to participate were pair matched by school type (public or private), number of enrolled students, number of classrooms for children aged 4 years, and number of children/classroom. Schools from each pair were randomly assigned by a university staff member not associated with the intervention to either control or intervention condition. Data were collected in two consecutive 4-year-old preschool cohorts (waves) of students (2008–2009 and 2009–2010) from the 16 preschools and analyzed in 2012–2014. Baseline measures were administered in the fall of the school year and follow-up measures in the spring. Reporting of the trial follows the CONSORT statement (Figure 1).

Study Participants

In participating schools, parents of all children enrolled in 4-year-olds' classrooms were invited to participate in the study's measurement protocol. Based on power calculations,[26] the recruitment goal was 15 children/preschool per study wave (N=480). Children were excluded from the study if they had a disability that would invalidate accelerometry as a measure of physical activity or if they were outside the 3- to 5-year age range. Child–parent dyads (N=488) were recruited, 264 in Wave 1 and 224 in Wave 2. The overall response rate approximated 50% in both control (53%) and intervention (48%) preschools. The number of children recruited per wave varied from six to 28 per preschool. Written informed consent was obtained from children's parents or guardians prior to data collection. Participating families and preschools received small incentives for their participation in the study. Families received a $25 gift card at the end of each data collection period, and preschools received $250 each year they participated in the study. The study was approved by the University of South Carolina IRB.

Intervention Description

The SHAPES intervention was guided by a social ecologic model.[27] This model posits that health behavior is influenced by factors operating at multiple levels, including individual, institutional, and social and physical environmental. Implementation of the intervention utilized a flexible and adaptive approach, involving university-based research staff (interventionists) and preschool teachers working together to incorporate key components of the intervention into their individual preschool environments.[26,28] The intervention did not include a scripted curriculum, but focused on encouraging teachers to use the SHAPES elements to modify instructional practices and the class environment in ways that fit their teaching style, classroom, and students. Specifically,

key intervention elements included specific goals for (1) structured, teacher-led physical activity opportunities in the classroom ("Move Inside," e.g., dancing, obstacle courses); (2) structured and unstructured physical activity opportunities at recess ("Move Outside," e.g., races, follow the leader); and (3) physical activity integrated into pre-academic lessons ("Move to Learn," e.g., acting out stories, counting with large motor movements). In addition, modifications were made to the preschool social and physical environments. Social environment elements included teacher verbal encouragement of physical activity, teacher participation in physical activity, and inclusion of activities children enjoy that involve MVPA (e.g., dancing, chase games, ball games). Physical environment changes included providing physical activity supplies (e.g., balls, music, scarves). Emphasis was given to use of space, materials, and existing equipment to engage all children in physical activity.

Interventionists worked in partnership with preschool teachers to modify and adapt the intervention implementation for each teacher's individual classroom and playground to achieve common intervention goals. Teachers had flexibility to determine when and how to implement the elements, while working to achieve the overall intervention goals. The intervention was designed to accommodate a range of common preschool settings (e.g., half- and full-day programs, private and public preschools) with varying resources. Intervention staff provided technical assistance through initial trainings, group workshops, site visits, and newsletters. A complete description of the intervention has been published elsewhere.[26,29] Teachers in control schools continued their regular instructional and organizational practices, and those schools were offered the intervention after final data collection.

Process Evaluation

Investigators used systematic and comprehensive process evaluation procedures to ensure fidelity and completeness of intervention implementation. Multiple methods and data sources were used to assess the extent to which teachers provided physical activity opportunities during the preschool day, children's activity levels during the opportunities, teachers' encouragement of activity during the opportunities, and children's reactions to the physical activity opportunities (i.e., enjoyment). Methods included systematic onsite observation by trained research personnel, periodic surveys to obtain teacher self-report, and periodic intervention staff ratings based on field notes. Detailed descriptions of the process evaluation procedures and results are presented elsewhere.[26]

Measures

Physical activity was measured by ActiGraph GT1M and GT3X accelerometers over 5 days (Monday through Friday) during each data collection period. Children wore the monitors on an elastic belt on their right hip. Parents were instructed to remove the monitor only during water-related activities (e.g., bathing, swimming) and when children went to bed at night. Monitors were initialized prior to data collection and were set to begin collecting data at the start of the school day on Monday. Research staff returned to the school each morning to provide replacement monitors for children who were not wearing their previously assigned monitor. Data were collected and stored in 15-second intervals to capture the sporadic activity patterns that are characteristic of children aged 3–5 years.[30]

Accelerometer data were reduced using activity intensity cut-points developed specifically for children aged 3–5 years to categorize intervals as sedentary (<200 counts/15 seconds); light (200–419 counts/15 seconds); MVPA (≥ 420 counts/15 seconds); and total (≥ 200 counts/15 seconds).[31] Sixty minutes of consecutive zeros were considered non-wear time. For this study, only the time in preschool was used in the analyses. Minutes/hour of observation of sedentary, light, MVPA, and total physical activity were then calculated, using children's wear time during the school day as the divisor. A day of observation was considered compliant if a child provided accelerometry data for $\geq 50\%$ of the school day. Days on which children were absent from preschool or spent $<50\%$ of the school day in the preschool were excluded from the analyses. Children who had ≥ 3 days of accelerometer data were included in the analyses.[32]

Physical activity energy expenditure (PAEE) was calculated by converting accelerometry counts for each 15-second interval to an estimated rate of oxygen consumption using a previously published regression equation.[31] Mean rate of oxygen consumption was calculated for hours of school attendance for each observed day. Mean daily oxygen consumption was transformed to the corresponding rate of total energy expenditure expressed as kilocalories expended per minute, accounting for body weight. Estimated resting rate of energy expenditure was calculated using the procedure of Schofield.[33] Resting energy expenditure was deducted from total energy expenditure to yield an estimate of PAEE.

Race and age of the child and parent education were obtained from surveys completed by the parent. Spanish versions were provided when necessary. The majority of parents who completed the surveys were the children's mothers.

Children's height and weight were measured at baseline by trained staff using standardized procedures, with children in light clothing and shoes removed, using Shorr measuring boards and Seca model 770 scales. BMI was calculated using the standard equation (body weight [kg] / height [m]^2).

Statistical Analysis

Descriptive statistics for the children's demographic and baseline physical activity variables were calculated for sex, wave, and preschool (intervention or control) groups. To address the primary study aim, three mixed-model ANCOVAs were calculated to determine the effects of the intervention on MVPA during the preschool day. The first model compared the intervention and control groups at follow-up after adjustment for the baseline physical activity variable and wave. For the second model, demographic variables (i.e., sex, race, and parent education) were added. The third model also adjusted for whether the school day was half day (3–4 hours) or total day (>6 hours). In all analyses, school was treated as a random variable, with students nested in school and group (intervention or control). Similar models were calculated for sedentary time, light physical activity, total physical activity, and PAEE. Also, sex-specific models were calculated for each variable.

For estimation of the ANCOVA models, light physical activity and MVPA were square-root transformed owing to non-normality, but unadjusted least-square means and SE were reported. Missing values at follow-up for the physical activity variables, height, and weight were replaced using multiple imputation (data

augmentation with Markov-chain Monte Carlo generation of imputed values, SAS PROC MI [SAS, version 9.2]). Twenty replications of the imputed data were generated, followed by identical analysis across each replication, and the combination of results was brought together in SAS (PROC MIANALYZE).

Results

A total of 407 children provided ≥3 days of accelerometer data. After deletions for missing race, baseline BMI, or parent education, data from 379 children were available for analysis. Of that group, approximately 49% attended intervention schools. As shown in Table 1, children in the two school groups were similar in sex, age, and BMI. Parent education was higher in the intervention group (p=0.02), and the distribution of races was different, with the intervention group including higher percentages of white and black children and a lower percentage of children in the other race category (p=0.02). At baseline, children in the intervention and control schools were not significantly different in total physical activity, MVPA, time spent sedentary, and estimated physical activity energy expenditure. However, children in the control schools spent significantly more time in light physical activity (7.2 vs 6.8 minutes/hour, p=0.04). Accelerometer wear time during the preschool day was greater in the control group than the intervention group (5.5 vs 5.1 hours, p=0.01).

Table 2 presents the results of the mixed-model ANCOVA, which compared children in the two groups at follow-up, adjusting for baseline characteristics. When considering the total sample of children (both boys and girls), those in the intervention group spent greater time in MVPA during the preschool day ($p \leq 0.02$). Times spent in sedentary behavior, light physical activity, and total physical activity did not differ between the two groups. Consistent with MVPA, estimated PAEE was greater in the intervention group. Results were mostly similar across the three models for each construct, with between-group differences slightly attenuated after control of demographic variables; length of school day had minimal impact on results.

Sex-specific analyses (Table 3) revealed that the intervention produced an increase in MVPA (0.80 minutes/hour, p=0.04) in girls. In boys, a similar trend was seen for MVPA, but the intergroup difference did not reach statistical significance (p=0.10)

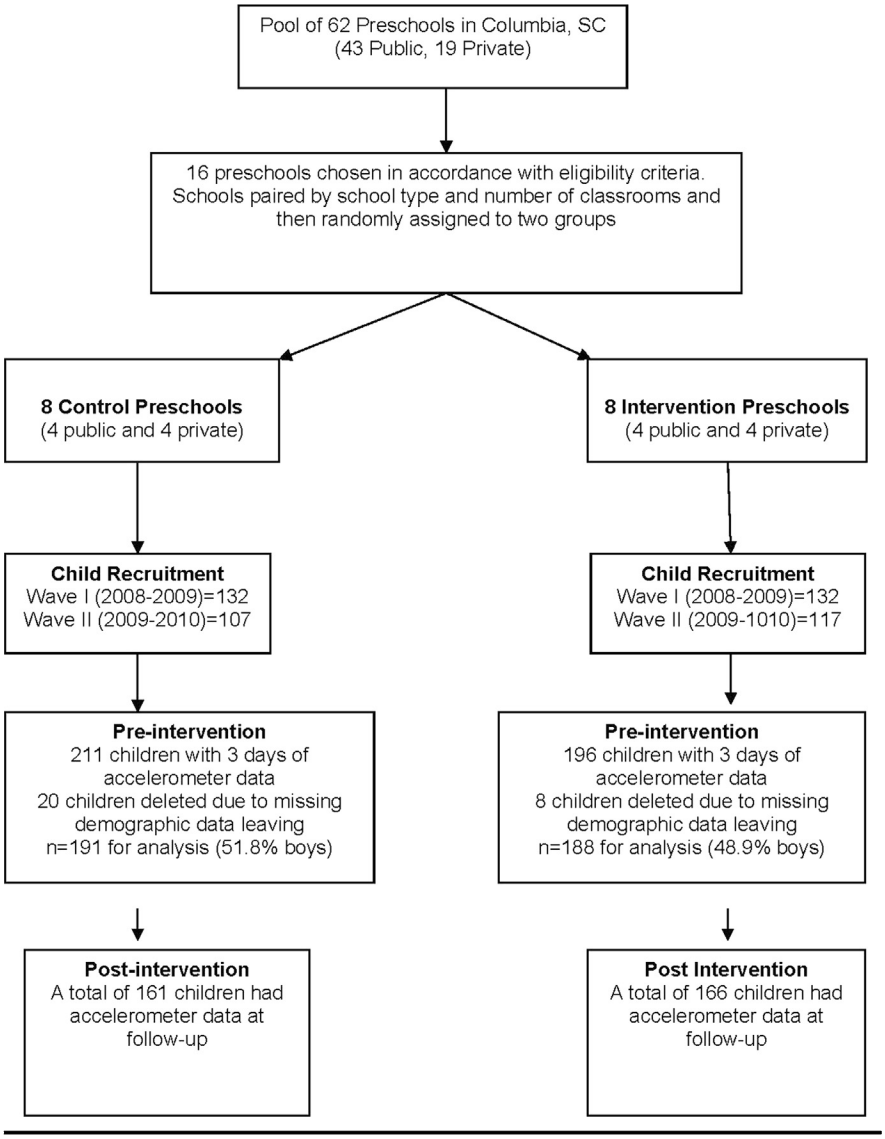

Figure 1. Study flowchart.

Discussion

The major finding of this study was that an ecologic intervention, implemented by preschool teachers in a flexible and adaptive manner, increased MVPA in children aged 4 years during the preschool day. This observation is important because more than half of children aged 3–6 years in the U.S. attend structured preschools or child care

Table 1. Baseline Characteristics of 379 Preschool Children, M (SD) or Percentage

	Total			Boys			Girls		
Characteristic	**Control (n=191)**	**Intervention (n=188)**	***p*-value**	**Control (n=99)**	**Intervention (n=92)**	***p*-value**	**Control (n=92)**	**Intervention (n=96)**	***p*-value**
Sex (% male)	51.8%	48.9%	0.58	—	—		—	—	
Age (years)	4.5 (0.4)	4.5 (0.4)	0.66	4.5 (0.4)	4.5 (0.3)	0.94	4.5 (0.4)	4.6 (0.4)	0.44
Height (cm)	107.0 (5.1)	107.9 (4.9)	0.08	107.2 (5.1)	107.9 (4.9)	0.32	106.7 (5.10	107.8 (4.9)	0.14
Weight (kg)	18.7 (3.4)	19.1 (3.5)	0.30	18.9 (3.5)	19.2 (3.3)	0.58	18.6 (3.3)	19.1 (3.7)	0.36
BMI	16.3 (2.0)	16.3 (1.9)	0.88	16.3 (1.9)	16.3 (1.8)	0.93	16.3 (2.0)	16.3 (2.0)	0.89
Race									
White	39.3%	44.2%	**0.02**	38.4%	51.1%	**0.003**	40.2%	37.5%	0.61
Black	41.9%	46.8%		41.4%	44.6%		42.4%	49.0%	
Other	18.9%	9.0%		20.2%	4.4%		17.4%	13.5%	
Parent education (≥2 years of college/tech school)	54.5%	66.0%	**0.02**	55.6%	70.7%	**0.03**	53.3%	61.5%	0.26
Sedentary (minutes/hour)	45.9 (5.0)	46.3 (4.4)	0.45	45.1 (4.9)	44.8 (4.2)	0.69	46.7 (5.1)	47.6 (4.1)	0.18
Light PA (minutes/hour)	7.2 (1.6)	6.8 (1.9)	**0.04**	7.5 (2.5)	7.2 (1.8)	0.32	6.9 (2.7)	6.3 (1.8)	0.07
MVPA (minutes/hour)	6.9 (2.8)	7.0 (2.7)	0.74	7.4 (2.8)	7.9 (2.6)	0.16	6.3 (2.7)	6.0 (2.5)	0.44
Total PA (minutes/hour)	14.1 (5.0)	13.7 (4.4)	0.43	14.9 (4.8)	15.2 (4.2)	0.72	13.3 (5.0)	12.4 (4.1)	0.18
PAEE (kcal/kg/minute)	0.03 (0.01)	0.04 (.01)	0.18	0.03 (0.01)	0.04 (0.01)	0.12	0.03 (0.01)	.03 (0.01)	0.70
Wear time in preschool (hours/day)	5.5 (1.5)	5.1 (1.6)	**0.01**	5.6 (1.5)	4.9 (1.6)	**0.002**	5.4 (1.6)	5.3 (1.6)	0.60

Note: Boldface indicates statistical significance ($p<0.05$).
MVPA, moderate- to vigorous-intensity physical activity; PA, physical activity; PAEE, physical activity energy expenditure; Total PA, MVPA + light.

centers,[12] and they typically spend at least 4 and as many as 10 hours per day in those settings. Hence, the social and physical environmental characteristics of preschools are likely to exert a critical influence on children's physical activity behavior and overall daily energy expenditure.[3,34] The finding that the SHAPES intervention increased MVPA in preschool children is unique because no previous study has tested a multicomponent intervention in preschools, delivered the intervention by training preschool teachers to modify their practices, encouraged the teachers to adapt the intervention to their setting, and documented the effects of the intervention with accelerometry.

Previous preschool physical activity intervention studies have yielded inconsistent findings. Several studies[35–38] found no effect on MVPA measured by accelerometry, but others[19,20,24,39] have reported increases in objectively measured MVPA during the preschool day. Children in the SHAPES intervention preschools participated in 0.80 minutes/hour more of MVPA than children in the control preschools, an effect that is greater than that reported in most previous studies. Among other studies that modified instructional behavior and the preschool environment over a sustained period of time, Hip-Hop

Table 2. Least-Square Means and 95% CIs From ANCOVA[a] Comparing Intervention and Control Preschools

Dependent variable	Model 1[b]			Model 2[c]			Model 3[d]		
	I	C	*p*-value	I	C	*p*-value	I	C	*p*-value
Sedentary (minutes/hour)	45.6 (44.8, 46.5)	45.9 (45.1, 46.8)	0.64	45.7 (44.9, 46.5)	45.8 (45.0, 46.8)	0.83	45.7 (44.9, 46.5)	45.9 (45.0, 46.7)	0.81
Light PA[e] (minutes/hour)	7.0 (6.4, 7.7)	7.4 (6.7, 8.0)	0.53	7.0 (6.4, 7.6)	7.4 (6.9, 8.0)	0.38	7.0 (6.4, 7.6)	7.5 (6.9, 8.1)	0.34
MVPA[e] (minutes/hour)	7.4 (6.9, 7.8)	6.6 (6.2, 7.1)	**0.01**	7.3 (6.9, 7.7)	6.7 (6.3, 7.1)	**0.02**	7.3 (6.9, 7.8)	6.7 (6.2, 7.1)	**0.01**
Total PA (minutes/hour)	14.4 (13.5, 15.2)	14.1 (13.2, 14.9)	0.61	14.3 (13.5, 15.1)	14.2 (13.4, 14.9)	0.81	14.3 (13.5, 15.1)	14.1 (13.3, 14.9)	0.79
PAEE (kcal/kg/minute)	0.04 (0.03, 0.04)	0.03 (0.03, 0.03)	**0.02**	0.04 (0.03, 0.04)	0.03 (0.03, 0.03)	**0.04**	0.04 (0.03, 0.04)	0.03 (0.03, 0.03)	**0.05**

Note: Boldface indicates statistical significance ($p<0.05$).
[a]Dependent variable at follow-up adjusting for baseline value and with preschool as a random variable.
[b]Model 1 was adjusted for wave only.
[c]Model 2 was adjusted for wave, sex, race, and parent education.
[d]Model 3 was adjusted for wave, sex, race, parent education, and length of school day.
[e]Used square-root transformation for *p*-value.
C, control; I, intervention; MVPA, moderate- to vigorous-intensity physical activity; PA, physical activity; PAEE, physical activity energy expenditure; Total PA, MVPA + light.

to Health Jr., a 14-week structured diet and physical activity intervention implemented by classroom teachers, increased MVPA by 7.5 minutes/day compared with control schools,[24] an effect that is moderately greater than that of the present study. However, the intervention was not sustained when observed after 2 years of implementation.[40] The Start for Life Program, a structured cognitive–behavioral intervention, increased the percentage of children's time spent in MVPA compared with control schools after 8 weeks[20] and 9 months[39] by levels similar to the present study, although physical activity was measured on only 1 day. The present study, by applying a rigorous research design and high-quality objective measurement protocol, expands and strengthens the evidence indicating that young children's physical activity levels in the preschool setting can be increased by modifying instructional practices.

The intervention tested in this study was designed to increase MVPA, and the primary outcome variable was specified as objectively measured MVPA. These study characteristics were stated in the published study protocol[26] and in the clinical trials registry (NCT01885325). Accordingly, the authors have based their major conclusion on the observation that MVPA was increased in children attending the intervention schools. However, in recent years, new physical activity guidelines for preschool-aged children have been developed and these have typically focused on total physical activity, which encompasses light physical activity as well as MVPA.[3–6] In the present study, although MVPA was increased by the intervention, the authors did not observe an effect on total PA. This is not surprising for two reasons. First, the study likely lacked the statistical power to detect the observed increase in total physical activity as significant. Second, as noted, the intervention focused on increasing MVPA, and some of the strategies used to achieve this end were aimed at increasing the intensity of certain activities (e.g., outdoor free play) from sedentary or light intensity to moderate or vigorous intensity. Accordingly, as shown in Table 2, the significant increase in MVPA in the intervention group was associated with nonsignificant decreases in both light physical activity and sedentary behavior. The decrease in light physical activity, though consistent with the intervention goal, may have reduced the impact on total physical activity.

In the present study, the intervention produced an effect that, though statistically significant, was

Table 3. Results (Least Square Means [95% CIs]) of Sex-Specific ANCOVA[a]

	Model 1[b]			Model 2[c]			Model 3[d]		
Dependent variable	**I**	**C**	***p*-value**	**I**	**C**	***p*-value**	**I**	**C**	***p*-value**
Males									
Sedentary (minutes/hour)	44.9 (43.7, 46.0)	45.1 (44.0, 46.3)	0.73	45.0 (44.0, 46.0)	45.0 (44.0, 46.0)	0.83	44.9 (43.9, 46.0)	45.0 (44.0, 46.1)	0.81
Light PA[e] (minutes/hour)	7.0 (6.4, 7.7)	7.4 (6.7, 8.1)	0.52	7.0 (6.4, 7.6)	7.4 (6.9, 8.0)	0.39	7.0 (6.4, 7.6)	7.5 (6.9, 8.1)	0.35
MVPA[e] (minutes/hour)	7.9 (7.3, 8.5)	7.2 (6.6, 7.8)	0.10	7.8 (7.2, 8.3)	7.3 (6.7, 7.8)	0.22	7.8 (7.3, 8.4)	7.2 (6.6, 7.8)	0.14
Total PA (minutes/hour)	15.2 (14.0, 16.3)	14.8 (13.7, 16.0)	0.70	15.0 (14.0, 16.0)	15.0 (14.0, 16.0)	0.86	15.1 (14.0, 16.1)	14.9 (13.9, 16.0)	0.86
PAEE (kcal/minutes)	0.03 (0.03, 0.04)	0.03 (0.03, 0.04)	0.12	0.03 (0.03, 0.04)	0.03 (0.03, 0.04)	0.32	0.04 (0.03, 0.04)	0.03 (0.03, 0.04)	0.22
Females									
Sedentary (minutes/hour)	46.4 (45.5, 47.5)	46.7 (45.8, 47.6)	0.59	46.4 (45.6, 47.2)	46.6 (45.8, 47.5)	0.83	46.4 (45.5, 47.3)	46.6 (45.7, 47.5)	0.81
Light PA[e] (minutes/hour)	7.0 (6.4, 7.7)	7.4 (6.7, 8.1)	0.53	7.0 (6.4, 7.6)	7.4 (6.9, 8.0)	0.40	7.0 (6.4, 7.6)	7.5 (6.9, 8.1)	0.35
MVPA[e] (minutes/hour)	6.8 (6.3, 7.4)	6.1 (5.6, 6.6)	**0.04**	6.8 (6.3, 7.3)	6.2 (5.6, 6.7)	**0.04**	6.8 (6.3, 7.3)	6.2 (5.5, 6.7)	**0.04**
Total PA (minutes/hour)	13.6 (12.8, 14.5)	13.3 (12.4, 14.2)	0.58	13.6 (12.8, 14.4)	13.4 (12.5, 14.2)	0.75	13.6 (12.7, 14.4)	13.4 (12.5, 14.3)	0.75
PAEE (kcal/minutes)	0.04 (0.03, 0.04)	0.03 (0.03, 0.04)	0.09	0.04 (0.03, 0.04)	0.03 (0.03, 0.04)	0.12	0.04 (0.03, 0.04)	0.03 (0.03, 0.04)	0.15

Note: Boldface indicates statistical significance ($p < 0.05$).
[a]Comparing intervention and control preschools at follow-up adjusting for baseline value as a covariate and with school as a random variable.
[b]Model 1 was adjusted for wave only.
[c]Model 2 was adjusted for wave, race, and parent education.
[d]Model 3 was adjusted for wave, race, parent education, and length of school day.
[e]Used square-root transformation for *p*-value.
C, control; I, intervention; MVPA, moderate- to vigorous-intensity physical activity; PA, physical activity; PAEE, physical activity energy expenditure; Total PA, MVPA + light.

modest in absolute magnitude. Children attending intervention preschools engaged in 0.8 minutes/hour of MVPA more than children attending control schools. For children attending school for 6 hours/day, this corresponds to about 5 minutes/day of added MVPA and 35 minutes/week of additional MVPA. Although modest in terms of added time spent in MVPA, this effect may well be physiologically important. It is noteworthy that this study detected a significant intervention effect on PAEE. The intergroup difference in estimated PAEE corresponded to an added 68 kilocalories/day or 342 kilocalories/week for a child weighing 19 kg spending 6 hours/day in the preschool. Because the health effects of physical activity have been linked to the long-term level of energy turnover, the observed effect on estimated PAEE is meaningful. Jansen and LeBlanc[41] conducted a systematic review of the literature on the health effects of physical activity in children, and they considered effects on blood lipids, blood pressure, metabolic syndrome, bone density, and depression. They found that "the dose-response relations observed in observational studies indicate that the more physical activity, the greater the health benefit. Results from experimental studies indicate that even modest amounts of physical activity can have health benefits in high-risk youngsters."

Also, it should be noted that this level of added daily energy expenditure, if consistently manifested across an extended period of exposure, could contribute to maintenance of energy balance and avoidance of excessive weight gain.[42,43] That said, there is still a need to identify intervention strategies that can produce greater increases in physical activity than those observed in this study. Future research should focus on identification of such strategies. There is also a need to better understand the factors that influence implementation of interventions that are based in institutional settings.[44]

Few preschool physical activity intervention studies have examined sex differences in the responses to the interventions. In the present study, when intervention effects were examined separately in boys and girls, the intervention effect was significant only in the girls. Some previous studies[45,46] have found a greater intervention effect on girls' physical activity, but others[21,47–49] have found a greater effect on boys' physical activity. In a meta-analysis of physical activity interventions in children, Metcalf et al.[50] found no significant differences in intervention effects between sexes, but there was a trend toward girls responding more positively to the interventions than boys. Reviews[51,52] of school-based obesity interventions suggest that boys and girls may respond differently to interventions, with girls potentially favoring educational interventions and boys responding better to environmental interventions. A recent review[53] of school-based physical activity interventions with older children concluded, however, that the evidence of sex differences is still limited and needs further study. The greater response of girls in the current study may be a result of girls having lower baseline physical activity levels and, thus, more room to improve. Girls consistently have lower physical activity levels, even at a young age.[13,14,54,55]

The SHAPES intervention used a combination of standardized intervention goals for achieving a physical activity–promoting preschool environment along with flexible teacher implementation. This combination provided common intervention targets for all classrooms while allowing teachers the flexibility to integrate physical activity opportunities throughout the day and to adapt key environmental changes in a manner that suited each classroom's unique features. This approach is feasible for "real-world" settings and is conducive to widespread dissemination beyond this initial SHAPES trial. Accordingly, the authors believe that it has the potential for extensive public health reach and impact in preschool settings.

Over the past decade, numerous authorities have endorsed policies and programs aimed at preventing excessive weight gain in young children.[3,56–58] These recommendations have typically included initiatives aimed at increasing children's physical activity levels, and often these guidelines have been focused on actions that can be taken by preschools or child care programs.[3–6,59] In the U.S., IOM has recommended that children be physically active for at least 15 minutes/hour of time spent in the preschool setting, and IOM has endorsed specific modifications to the preschool environment to support attainment of that goal.[3] These include adoption of physically active teaching/learning activities, provision of indoor and outdoor environments that are conducive to physical activity, and regular provision of outdoor play time.[3] The SHAPES intervention is consistent with these recommendations, and the findings of this study indicate that the practices recommended by IOM can produce significant increases in children's physical activity levels during the preschool day.

Limitations

This investigation has significant strengths and some important limitations. Strengths include a rigorous research design, a lengthy intervention period with two waves of enrollment, and objective measurement of physical activity. Further, it is a strength that the intervention methodology, by operating through classroom teachers, lends itself to broad dissemination. It is a limitation that the study was conducted in preschools

located in a single metropolitan area. Also, parents volunteered to participate in the study, and the authors cannot be certain that the participating children were fully representative of all children enrolled in the preschools. With consideration of those limitations, the authors conclude that a flexible ecologic physical activity intervention that trains teachers to provide children with opportunities to be active throughout the school day can increase MVPA in preschool children.

Conclusions

The findings of this study support the conclusion that a flexible ecological intervention that trains teachers to provide children with opportunities to be physically active throughout the school day can increase MVPA and physical activity energy expenditure in preschool children. Future research should aim to develop physical activity intervention protocols for young children that produce effect sizes that are greater than observed with previously tested interventions.

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