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Physical Activity, Health-Related Fitness, and Classroom Behavior in Children: A Discriminant Function Analysis

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ABSTRACT

Purpose: The purpose of this study was to examine the predictive relationship among physical activity, health-related fitness, and on-task classroom behavior in children using a discriminant function analysis. **Method**: Participants were a convenience sample of children (N = 533; M_{age} = 8.8 ± 1.9 years) recruited from 77 1st- through 5th-grade classrooms at 3 low-income schools in a capital city in the Southwest United States. Percent of the school day spent in sedentary behavior (%SED), moderate-to-vigorous physical activity (%MVPA), and health-related fitness scores (body mass index [BMI] and Progressive Aerobic Cardiovascular Endurance Run [PACER] laps) were assessed during school hours. Classrooms were observed for on-task behavior during the academic year with the use of 5-s momentary time sampling methodology. A discriminant function analysis was performed using a binary on-task behavior outcome, stratified by an 80% on-task behavior cut point. **Results**: The results yielded 1 function (r^2 = .26, F = 13.1) explaining approximately one quarter of the total variance. The standardized function coefficients were −.29, .29, −.48, and .48 for %SED, %MVPA, BMI, and PACER laps, respectively. The sensitivity and specificity of the derived function for classifying a child into an on-task or off-task classroom were .79 and .73, respectively. Children who belonged to classrooms that achieved 80% on-task behavior displayed shorter times in sedentary behaviors (d = 1.01), lower BMI (d = 0.13), and higher PACER scores (d = 0.22) compared with children who belonged to off-task classrooms. **Conclusion**: School-day physical activity behaviors and health-related fitness scores can moderately discriminate children who belong to classrooms from low-income schools that are categorized as being sufficiently on task.

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MVPA; on-task behavior; physical education; sedentary

The health benefits of physical activity and health-related fitness are well established (Poitras et al., 2016). Physical activity also has a positive effect on children's cognitive functioning (Donnelly et al., 2016; Sibley & Etnier, 2003). Further, physical activity programming has been linked to improved frontoparietal white-matter integrity in children (Krafft et al., 2014) and overall brain function (Hillman et al., 2014). The associations between physical activity and academic achievement have been mixed (Donnelly et al., 2016) with studies showing positive relationships (Booth et al., 2014), some relationships with some academic subjects (Lambourne et al., 2013), no relationship (LeBlanc et al., 2012), and a negative relationship (Tremblay, Inman, & Willms, 2000). Classroom physical activity (Mahar et al., 2006) as well as multicomponent school physical activity programs (Burns, Brusseau, Fu, Myrer, & Hannon, 2016) have been linked to improvements in on-task behavior. This improvement in on-task behavior has been associated with executive function that is a prerequisite for successful learning (Hofmann, Schmeichel, & Baddeley, 2012).

Cardiovascular fitness has also been linked to improvements in academic performance regardless of sociodemographic variables (Castelli, Hillman, Buck, & Erwin, 2007; Van Dusen, Kelder, Kohl, Ranjit, & Perry, 2011). Fitness has also been associated with cognition, specifically executive function and resistance to distraction in children (Davis & Cooper, 2011). Similarly, overweight in children has been associated with decreased cognitive function (Li, Dai, Jackson, & Zhang, 2008), and exercise programming targeting obesity has been linked to improvements in academic performance (Hollar et al., 2010). .

Off-task behavior has been highly correlated with loss of instructional time in schools (Lee, Kelly, & Nyre, 1999). Research has also suggested that off-task behavior is related to negative academic achievement (Goodman, 1990). Roberts (2002) suggested that programming

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designed to decrease off-task behavior has been unsuccessful because it has not taken into account the causes of these behaviors. Previous research has suggested that elementary school students spend up to 50% of their time off task (Lee et al., 1999). Furthermore, studies exploring children's off-task behavior have been limited to small numbers of classrooms with a recent study using 30 total classrooms (Godwin et al., 2016).

Previous studies have shown improvements in classroom behavior with specific physical activity programming; however, it is unknown how classroom behavior independently correlates with specific physical activity and health-related fitness variables within a large sample of elementary school-aged children. The relative relationship among sedentary time, physical activity, body composition, and cardiorespiratory endurance with classroom behavior, when considered together, is currently unknown within a multivariate framework. Knowing the specific relative contribution of physical activity and health-related fitness variables to classroom behavior could improve understanding the importance of these movement-based constructs in modifying academic behavior. Therefore, the purpose of this study was to examine the predictive relationship among physical activity, health-related fitness, and on-task classroom behavior in children using a multivariate discriminant function analysis.

Method

Participants

Participants in the final sample were a convenience sample of 533 school-aged children recruited from three low-income elementary schools receiving government financial assistance from the Mountain West region of the United States. Children were recruited from first- through fifth-grade classrooms. The mean age of the sample was 8.8 ± 1.9 years, and 277 girls and 256 boys participated. The sample was obtained across 77 academic classrooms. Written assent was obtained from the students and consent was obtained from the parents prior to data collection. The university institutional review board approved the protocols employed in this study.

Physical activity assessment

Physical activity and sedentary behaviors were assessed using ActiGraph wGT3X-BT triaxial accelerometers (Pensacola, FL). The devices were worn for 5 school days (Monday–Friday) between the hours of 8 am and 3 pm with no included nonwear time. Accelerometers were worn on the right hip at the level of the iliac crest aligned with the kneecap. Classroom teachers, physical educators, and members of the research team ensured that the devices were worn during the entirety of the school day. A valid day for accelerometers was determined to be at least 6 hr out of total wear-time (7-hr school day). Data were collected in 5-s epochs at 100 Hertz but were reintegrated into 60-s epochs within the ActiLife 6.0 software program. Cut points established by Evenson, Catellier, Gill, Ondrak, and McMurray (2008) were used to stratify count data into sedentary and moderate-to-vigorous physical activity (MVPA) intensity categories. Although the Evenson cut points were based off of 15-s epochs, the ActiLife software multiplied these cut points by 4 to align with 60-s epochs. Data used for the analyses included percent of student wear time in sedentary behaviors (%SED) and in MVPA (%MVPA). The Choi, Liu, Matthews, and Buchowski (2011) algorithm was used to classify accelerometer wear and nonwear time intervals.

Health-related fitness assessment

Body mass index (BMI) was used to assess body composition. Body mass index is a proxy assessment for body composition that is easy to administer and calculate. However, a major limitation is that BMI does not take into account the relative distribution of fat mass and fat-free mass in its calculation. Therefore, BMI scores should be interpreted with caution. Body mass index was calculated by taking a student's weight in kilograms and dividing it by the square of his or her height in meters. Height was measured to the nearest 0.01 m using a portable stadiometer (Seca 213, Seca, Hanover, MD), and weight was measured to the nearest 0.1 kg using a portable medical scale (BD-590, Tanita, Tokyo, Japan). Height and weight were collected in a private room during each student's physical education class.

Cardiorespiratory endurance was assessed using the 20-m Progressive Aerobic Cardiovascular Endurance Run (PACER), administered during physical education class. The PACER is a field assessment of cardiorespiratory endurance that is easy to administer to large groups of youth. The PACER is a validated assessment of cardiorespiratory endurance (Mahar, Welk, & Rowe, 2018) but is limited in its construct validity and precision compared with a more direct assessment of peak oxygen consumption (VO_2peak) using indirect calorimetry. The PACER was conducted on a gymnasium floor with background music provided by a compact disc. Each student was instructed to run from one floor marker to another floor marker across a 20-m distance within an allotted time frame. The allotted time given to reach the specified distance incrementally shortened as the test progressed. If the student twice failed to reach the other floor marker, the test was terminated. The final score was recorded in laps.

Classroom observations

On-task behavior is considered verbal or motor behaviors that align with class rules and are appropriate to the learning situation (Grieco, Jowers, & Bartholomew, 2009). On-task behavior facilitates learning and memory retention in the classroom, while off-task behaviors are behaviors that lead to excess disruption in the classroom and do not align with goals set out by the classroom teacher. Examples of off-task behavior include students placing their heads on the desks, reading or writing inappropriate or unassigned material, talking to or looking at other students when not part of a given assignment, and leaving their desks without receiving permission from the teacher or teacher's aide. A Planned Activity Check 5-s momentary time sampling procedure was used to record students' on-task and off-task behavior on an observation sheet. All observations were completed during a 15-min lesson that focused on one topic to avoid the impact of transitions or multiple activities. Observations occurred at the end of a 5-s interval, which started immediately after the observer marked the behavior on the observation sheet from the prior interval. Intervals were coded as being on task or off task. The instrument and methods have been used in previous research (e.g., Goh, Hannon, Webster, Podlog, & Newton, 2016).

Before the start of a respective observation period, the primary and secondary observers established the order of sequence to observe the students, which corresponded to positioning students within each observer's line of sight. Observations were made from a left to right sequence for each observation period. The observers repeated this sequence for the remainder of the observation period. The observers listened to a prerecorded audio file via headphones that signaled the start of the 5-s interval. Upon hearing the 5-s signals, the observers observed and recorded the behavior of the students. The observers repeated this sequence for the entire 15-min observation period. A primary observer recorded all observations in this study, and a secondary observer recorded approximately 50% of the classes with the primary observer to determine interobserver reliability and the potential for observer bias. The aforementioned procedures are in accordance with those recommended by Mahar et al. (2006).

Observation training involved watching a video of a recorded third-grade classroom lesson to practice recording behaviors in 15-min intervals. This training also provided observers with background on the science of systematic observation, ethical issues, and objectivity to minimize any potential bias (Mahar, 2011; McKenzie, 2010). Training was conducted 1 month prior to the start of data collection. Interobserver reliability was calculated by dividing the agreements of on-task and off-task behavior by the total number if observations and multiplying by 100. Interobserver reliability was found to be 90%. For data analysis, students were stratified into those who belonged to classrooms achieving at least 80% on-task classroom behavior and those who did not. The aforementioned procedures are in accordance to those recommended by Mahar (2011).

Statistical analysis

Data were screened for outliers using box plots and were checked for Gaussian distributions using k density plots. Differences between the sexes and between classroom behavior strata on all continuous variables were analyzed using 2×2 factorial analysis of variance tests. Effect sizes were calculated using Cohen's delta (d) where $d < 0.20$ indicates a small effect, $d = 0.50$ indicates a medium effect, and $d \geq 0.80$ indicates a large effect (Cohen, 1988). A discriminant function analysis was then employed to determine the utility of school-day sedentary behaviors, MVPA, and health-related fitness variables in classifying students who did and did not belong to classrooms that were at least 80% on task. The grouping variable was the binary on-task classroom behavior variable (meeting = 1, not meeting = 0), and the variate consisted of the continuous variables of %SED, %MVPA, BMI, and PACER laps. Because the grouping variable only consisted of two levels, one significant function was expected. Reporting of the results included the canonical correlation, the standardized function coefficients, the canonical structure, group centroids, and a classification table. The discriminant function analysis was conducted using STATA's "candisc" command. The assumptions of discriminant function analysis were examined including multivariate normality, linearity, homogeneity of covariance matrices between the two classroom behavior strata, and absence of multicollinearity. Multivariate normality was estimated by the Doornik-Hansen test, linearity was examined using scatterplots, homogeneity of covariance matrices was examined using Box's M test, and multicollinearity was assessed using bivariate Pearson product–moment correlations. Alpha level was set at $p < .05$, and all other analyses were also carried out using the STATA statistical software package (STATA, College Station, TX).

Results

No outliers were identified, and each continuous variable's distribution was approximately Gaussian. The descriptive statistics are presented in Table 1. In this sample, there were no statistically significant differences between sexes on any physical activity or health-related fitness variable. There were statistical differences between classroom strata on %SED ($\Delta = -4.19\%$, $p < .001$, $d = 1.01$), BMI ($\Delta = -0.55$ kg/m^2, $p = .041$, $d = 0.13$), and PACER Laps ($\Delta = +3.62$ laps, $p < .001$, $d = 0.22$). There were no statistically significant differences between classroom behavior strata on %MVPA. Students who belonged to classrooms that were at least 80% on task recorded shorter times in sedentary behaviors, lower BMI, and more PACER laps. Table 2 communicates the aforementioned mean differences between classroom strata on sedentary times, MVPA, and health-related fitness.

The discriminant function analysis yielded one statistically significant function ($r_{canonical} = .51$, eigenvalue = .35, $F = 13.1$, $p < .001$). The standardized function coefficients were −.29, .29, −.48, and .48 for %SED, %MVPA, BMI, and PACER laps, respectively. Additionally, canonical structure coefficients were −0.69, 0.53, −0.49, and 0.45 for %SED, %MVPA, BMI, and PACER laps, respectively.

Table 1. Descriptive statistics (means and standard deviations).

	Total sample ($N = 533$)	Girls ($n = 277$)	Boys ($n = 256$)
%SED	81.2 (7.1)	80.3 (6.7)	82.1 (7.5)
%MVPA	6.3 (4.7)	5.7 (4.6)	6.5 (5.0)
BMI	17.9 (4.4)	18.1 (4.3)	17.5 (4.7)
PACER laps	25.6 (16.4)	22.9 (16.1)	28.2 (16.9)

Note. %SED = percent of school day in sedentary behavior; %MVPA = percent of school day in moderate-to-vigorous physical activity; BMI = body mass index; PACER = Progressive Aerobic Cardiovascular Endurance Run. $p < .05$.

Table 2. Differences between classroom behavior strata on sedentary times, moderate-to-vigorous physical activity, and health-related fitness (means and standard deviations).

	On-task behavior ($n = 76$)	Off-task behavior ($n = 457$)	Mean difference
%SED	79.31 (4.18)	83.50 (7.69)	**−4.19 (4.15)**
%MVPA	6.96 (6.08)	5.91 (4.02)	1.05 (7.01)
BMI (kg/m^2)	17.70 (2.12)	18.25 (5.23)	**−0.55 (4.23)**
PACER laps	28.64 (17.18)	25.02 (15.10)	**3.62 (16.45)**

Note. %SED = percent of school day in sedentary behavior; %MVPA = percent of school day in moderate-to-vigorous physical activity; BMI = body mass index; PACER = Progressive Aerobic Cardiovascular Endurance Run. Bold denotes statistical differences between strata, $p < .05$.

Table 3. Classification table derived from the discriminant function (number and approximate percentile).

	Classified Not meeting	Classified Meeting	Total
True Not meeting	334 73.0%	123 27.0%	457 100%
True Meeting	16 21%	60 79%	76 100%
Total	350 65.7%	183 34.3%	533 100%

Note. True values indicate observed classification; classified values indicate predicted classification via the discriminant function; bottom right cell is grand total.

Group centroids were 0.24 for the off-task group and −1.44 for the on-task group. The predictive ability of the discriminant function is communicated in Table 3. The sensitivity and specificity of the derived function for classifying a child into an on-task or off-task classroom were .79 and .73, respectively.

The assumptions of discriminant function analyses were explored. Results of the multivariate Doornik-Hansen test were statistically significant ($\chi^2 = 609.89$, $p < .001$), suggesting violation of the multivariate normality assumption. Scatterplots revealed linear relationships among all predictor variables. The correlation between %SED and %MVPA was statistically significant and strong in magnitude ($r = -.77$, $r^2 = .59$, $p < .001$), which may contribute to some multicollinearity; however, there was still notable unshared variance between the two predictors. All other bivariate correlations among the other predictor variables were considered weak to moderate in magnitude and were not a potential threat to multicollinearity. Finally, results of Box's M test were statistically significant, suggesting inequality of covariance matrices between classroom behavior strata ($\chi^2 = 40.29$, $p < .001$). Although it has been reported that discriminant function analyses are robust to multivariate normality and homogeneity of covariance matrices violations (Stevens, 1996), caution should be used when interpreting the results of the study's multivariate analysis.

Discussion

The purpose of this study was to determine if classrooms accumulating higher levels of physical activity and with students who were more fit spent more time on task. Findings suggested that classrooms that displayed higher levels of on-task behavior tended to record lower sedentary times, a trend toward higher levels of average school-day MVPA, better PACER scores, and lower overall BMI.

Previous studies have highlighted the value of physical activity and fitness for executive function and academic performance (Aadland et al., 2017; Buck, Hillman, & Castelli, 2008). Increases in on-task behavior have been shown to minimize disruptive behavior in the classroom. This decrease in disruption has led to increased focus and memory retention (Young, 2003). Two previous studies (Goh et al., 2016; Mahar et al., 2006) have shown that classroom physical activity can improve on-task behavior in elementary school classrooms. Similarly, schoolwide programming has also led to improvements in on-task behavior in individual classrooms (Burns et al., 2016). These findings together suggest there are benefits to both acute and chronic exposure to physical activity. Each of these three studies examined changes in physical activity from program implementation.

The current study indicated that naturally occurring increases in physical activity were also associated with improved classroom behavior. More specifically, increases of as little as 500 steps or 4 min of MVPA at the class level may result in improved behavior. Burns et al. (2016) found that changes in behavior may have been linked to increases of 600 steps across the school day. Increasing physical activity at school can be done in a variety of ways. Goh et al. (2014) found that an active academic program (TAKE10) led to increases in school-day step counts (Δ = 672) and MVPA (Δ = 2 min). Similarly, Bershwinger and Brusseau (2013) found that classroom activity breaks led to increases up to 1,000 steps/day. Brusseau and Kulinna (2015) found that the addition of a second recess (e.g., 10-min morning or afternoon recess) added 800 steps/day. Larson, Brusseau, Chase, Heinemann, and Hannon (2014) found that adding some semistructured games and equipment to recess led to increases of 130 steps and an increase of almost 1 min of MVPA. Studies have also highlighted that making changes across multiple school physical activity opportunities can lead to increases in steps counts (Burns, Brusseau, & Hannon, 2015). Similarly, Brusseau, Burns, and Hannon (2016) found that a comprehensive school physical activity program increased at-school MVPA by 5 min. These increases in physical activity may also naturally improve health-related fitness (Brusseau et al., 2016). These changes do not appear to be profound, but if they can make a difference in on-task behavior, they are likely to lead to improved academic performance and decreases in disciplinary issues in school.

A number of strengths of this study are worth noting. The large number of classrooms observed and the diversity of the student population provided unique insights into this population. The current study also examined together sedentary times, MVPA, and health-related fitness variables, which has precluded previous research linking these constructs to classroom behavior. Further, the objective measures of physical activity were important as self-report measures often overestimate physical activity (Sallis & Saelens, 2000) and thus have lower construct validity.

Several limitations to this study must be considered before the results can be generalized. First, the sample consisted of children from five low-income schools in the Southwest region of the United States. It is questionable whether the results generalize to other geographical regions or to pediatric samples with different demographical characteristics. Second, the study design was cross-sectional; therefore, no causal inferences could be made. Third, only school-day physical activity and sedentary behaviors were assessed; the results may have been different if these constructs were assessed for the entire day. Fourth, health-related fitness was assessed using field measures; the construct validity evidence would have been stronger if criterion and/or lab measures were employed (e.g., measured VO_2peak, dual-energy x-ray absorptiometry scan). Fifth, assumptions of the discriminant function analysis were violated, specifically the multivariate normality and homogeneity of covariance matrices assumption. Although it has been reported that discriminant function analyses are robust to these violations, caution should be used when interpreting the results of the study's multivariate analysis. Additionally, classroom behavior was assessed at the classroom level, while physical activity and health-related fitness were assessed at the individual student level. These assessment levels were employed to improve the feasibility of the study but may have contributed to ecological fallacy risk. Finally, known moderators of effect (e.g., school and grade level) were not explored and thus should be a priority in future multivariate analyses linking physical activity and health-related fitness with classroom behavior.

In conclusion, health behaviors including school-day physical activity and sedentary behavior, in addition to physiological traits composed of the health-related fitness domains of body composition and cardiorespiratory endurance, can predict with modest accuracy children belonging to sufficiently on-task academic classrooms. The results from this study may support and spur school-based interventions to improve health behaviors to facilitate learning in the academic classroom. Because of the links between physical activity and health-related fitness and cognitive functioning, additive effects should be explored in future research.

The benefits of school-day physical activity may extend beyond physical health into academic classroom behavior, which is paramount to facilitate an optimal learning environment for low-income children.

What does this study add?

This study was the first to examine the cross-sectional relationship among classroom-level on-task behavior and average school-day sedentary behavior, MVPA, and health-related fitness. This relationship adds another benefit to school programming and interventions targeting physical activity and health-related fitness. Increases in physical activity opportunities at school may lead to improvements in on-task behaviors in the classroom, which can increase the likelihood of learning taking place. These findings can serve policymakers, practitioners, and researchers who advocate for physical activity in school settings.

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