



Before the School Bell Rings

How a Before-School Physical Activity Program Improves Executive Functions

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Across the country, school administrators and educators struggle to find time for children to engage in physical activity while still giving them enough time in academic instruction. The steep rise in childhood obesity in the U.S. (National Center for Health Statistics, 2011; Ogden, Carroll, Kit, & Flegal, 2014) suggests that the concern is urgent.

However, the need to meet accountability standards puts pressure in the direction of more “seat time” rather than physical activity time.

Research suggests that the tension between physical activity and academic achievement rests on a false dichotomy. Physical activity can and does support children’s learning: Providing children with opportunities for moderate-to-vigorous physical activity can help them improve their academic performance.

In keeping with this research, a before-school physical activity program called BOKS (Build Our Kids’ Success) launched during the 2009–2010 school year with a pilot

program at one elementary school in the Natick Public School district in Natick, Massachusetts. The following year the program expanded to include all five Natick elementary schools during the 2010–2011 school year. BOKS is now offered in 1,600 schools worldwide. In Natick, BOKS is offered free of charge through funding from the Reebok Foundation and MetroWest Health Foundation.

BOKS operates for approximately 40 minutes before school begins. Children participate for two to three mornings per week. Programming includes an average of 20 minutes of moderate-to-vigorous activity through interactive games, exercises, running, and physical skill building. Previous data suggest that BOKS children accumulate an average of 1,800 steps daily during program time (Hall, Fay, & Harris, 2014).

To investigate how a before-school physical activity program like BOKS can support the positive development

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of young children and support school learning, we conducted a three-year study of school-related outcomes for BOKS students in Natick Public Schools. In particular, we examined whether program participation was associated with “executive functions” such as working memory and the ability to shift between tasks. We found that children in the BOKS program did experience greater increases in some executive functions than did a comparison group of non-participating children.

Research on Physical Activity and Learning

Sattelmair and Ratey (2009) suggest that the link between learning and physical activity may be strong: Students who engaged in a high level of strenuous physical activity exhibited higher test scores than those who did not. The researchers suggest that “physical activity or fitness are not causes per se of enhanced academic performance,” but that enhancing learning, concentration, memory, and mood helps children to be better learners (Sattelmair & Ratey, 2009, p. 365).

A meta-analysis by Sibley and Etnier (2003) of 44 studies found a significant positive relationship between physical activity and cognitive functioning in children. Cognitive assessments included tests of perceptual skills, intelligence quotient (IQ), verbal and math achievement, memory developmental level, and others. Types of physical activity included resistance or circuit training, physical education programs, aerobic exercise, and perceptual-motor training.

Research by Sallis and colleagues (1999) provides strong evidence that devoting substantially increased school time to physical activity has no detrimental effects on students’ academic achievement. Berg (2010) found that, when time in physical education is increased, academic performance is at least maintained, despite the reduction in classroom time.

Some evidence links physical activity to a particular type of learning, specifically executive functions. Executive functions are the brain’s management skills. They include, for example, impulse inhibition, the ability to plan and organize tasks, and the ability to transition from one task to another. Executive functions have been linked to many aspects of learning including language comprehension, reading, and writing (Gathercole, Alloway, Willis, & Adams, 2006; Swanson & Jerman, 2007). Executive functions are more strongly associated with school readiness than are IQ or entry-level reading

or math skills (Blair & Razza, 2007; McClelland, Morrison, & Homes, 2000).

A study by Kubesch and colleagues (2009) found that executive functions can be improved by physical activity. Working with 81 students in grade 7, they examined the effects of a single 30-minute physical education program featuring aerobic endurance exercise on working memory, cognitive flexibility, and inhibition of distraction and unproductive behaviors. In contrast with students who took a five-minute aerobic movement break, students who engaged in 30 minutes of aerobic exercise were better able to stay on task in the face of distraction.

Several studies have found relationships between academic achievement and the executive function known as working memory. Working memory, which includes both short-term memory and attention, is vital to such basic learning activities as doing mathematical calculations or listening to a story. Some cross-age studies report an association between children’s working memory skills and early math skills (Bull, Espy,

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& Wiebe, 2008; Bull, Johnston, & Roy, 1999; Gathercole & Pickering, 2000; Gathercole, Pickering, Knight, & Stegman, 2004). St. Clair-Thompson and Gathercole (2006) showed that working memory was closely linked with attainment in English and mathematics in 11- and 12-year-old children. Alloway and Alloway (2009) concluded that children’s working memory skills at age 5 were the best predictor of literacy and numeracy six years later.

In a meta-analysis of research on the association between schoolchildren’s physical activity and academic outcomes, Taras (2005) found that short-term physical activity was associated with short-term improvements in some areas such as concentration. The effect of more vigorous physical activity over time on longer-term academic improvements is not well enough substantiated (Taras, 2005).

Our study shed light on how participation in physical activity over time may be linked to improved executive functions.

Methods

We studied BOKS from September 2011 through June 2014 in five Natick elementary schools. At the beginning and end of each of the three school years, we collected

surveys from teachers and parents of children who did and did not participate in BOKS. Teacher and parent surveys were collected electronically using Survey Monkey, an online survey tool.

Some teachers and parents elected to complete paper surveys. These surveys were sent to parents in children's backpacks and to teachers through the school administration office. Completed parent surveys, in sealed envelopes, were returned in children's backpacks and picked up by researchers at the school offices, along with teacher surveys that had been returned in sealed envelopes.

Teachers and parents completed surveys in November and April of each of the three years of the study. Each teacher completed six to nine surveys. Because some classrooms had 15 or more participants, we randomly capped the number of surveys each teacher had to complete at eight. A few teachers completed nine surveys because BOKS students enrolled in the study after the surveys were distributed.

As an incentive, parents who returned both annual surveys were included in drawings for tickets to local baseball and hockey games. We called and emailed parents to solicit missing surveys. In most families, the same parent completed the surveys every year. The survey return rate for teachers during the three study years was more than 96 percent. Parent return rates ranged from 66 percent during the first year to 51 percent during the third year.

Study Participants

Study participants were recruited in September 2011 through flyers sent home with all children in grades K–2. The families of children enrolled in BOKS also got a reminder email from their BOKS trainer. All families who gave written informed consent were admitted to the study.

Of the 570 students enrolled in the study in Year 1, 136 had registered to participate in BOKS. Most enrolled in BOKS for both the fall and spring sessions. The remaining 434 students comprised the comparison group. In Year 2, the 2012–2013 school year, most students—104 BOKS students and 254 comparison students—remained in the study. After reviewing findings from Year 1, we focused on recruiting a new kindergarten group for Year 2 rather than continuing to follow second graders from Year 1 into Year 2. We were interested in repeating the measurements with a sample of children who had not been exposed to BOKS before. We also wanted to keep the number of participants below 600 to reduce the burden of survey completion on teachers. We recruited 141 new kindergarten students in fall 2012.

No new participants were recruited after the fall of Year 2. For Year 3, the study had 467 participants in grades 1–3. Of these, 167 were enrolled in BOKS. Girls slightly

outnumbered boys in both BOKS and comparison groups across all three years, except in Year 2, when 47 percent of the comparison group was girls. Because 92 percent of the school population was white, race was not included in the analysis.

Tools

In the first year of the study, we used three survey tools to collect data from parents and teachers. The survey on which our findings are based is the Behavior Rating Inventory of Executive Function (BRIEF; Gioia, Isquith, Guy, & Kenworthy, 2000), which was completed by both teachers and parents. In addition, during the first year, parents completed the Social Skills Rating System (SSRS; Gresham & Elliott, 1990) and teachers completed the Survey of Academic and Youth Outcomes (SAYO; Miller & Surr, 2003). However, findings from Year 1 showed no evidence that participation affected SSRS or SAYO scales, so we did not conduct these surveys in Years 2 and 3. We collected BRIEF data from both parents and teachers for all three years. The four BRIEF subscales are inhibit, plan/organize, shift, and working memory.

Analysis

Year 1 analysis showed no significant effects of BOKS participation on SAYO or SRSS subscales or on the inhibit or plan/organize subscales of BRIEF. We therefore dropped these measurements in Years 2 and 3 to focus on the BRIEF'S scales for working memory and shift. We used a combination of analyses, including linear regression, analysis of variance (ANOVA), and independent sample *t*-tests to examine the impact of BOKS participation on teachers' and parents' ratings for these two scales.

Treating participation as an independent variable, we analyzed its effect on average differences in scores for working memory and shift skills between pre- and post-participation assessments. Because we found no significant differences in parents' and teachers' ratings of these skills between BOKS and non-BOKS children at baseline for any of the three study years, we did not control for baseline rating in the analyses. For both working memory and shift, we conducted separate analyses for each study year, for each grade, and for teachers' ratings and parents' ratings.

How Exercise Affected Students' Executive Functions

We found significant results or promising patterns in effects of BOKS participation on two BRIEF subscales:

- **Working memory** is the ability to remember and manage information—the brain's "sticky note" (Alloway, 2011).

- **Shift** is the ability to transition from one situation, activity, or aspect of a problem to another (Gioia et al., 2000).

In the area of working memory, we found statistically significant¹ correlations between BOKS participation and improvements in working memory for some analysis subgroups. In Year 1, teachers rated kindergarteners ($N = 134$) who participated in BOKS for a full year as significantly improved ($M = 1.29$) in working memory; they did not perceive significant improvement in the non-BOKS kindergarteners ($M = -0.22$). Although teachers did not rate this group of BOKS children, now in first grade, as showing significant improvement in working memory at the end of the year, parents did see significant improvement (BOKS $M = 0.90$, non-BOKS $M = 0.29$). In Year 3, first-graders who were full-year BOKS participants showed significant improvement ($M = 0.69$) in parents' ratings of their working memory skills, while their non-participating peers ($M = -0.54$) did not. For other years and subgroups, pre- to post-participation change in working memory was not significant.

Year 1 data showed no significant differences in either teachers' or parents' ratings of BRIEF shift skills between pre- and post-test. However, in Year 2, teachers rated second-graders who participated in at least one semester of BOKS as showing significant improvement in shift skills ($M = 0.25$) at the end of the year. They rated non-BOKS second-graders as having declined ($M = -0.95$) between pre- and post-assessment. Parents also rated BOKS second-graders as showing less of a decline in this domain than their non-BOKS peers, though these effects were not significant. In Year 3, parents rated first-graders who participated in at least one semester of BOKS as showing significant improvement in shift skills ($M = 0.94$), while their non-BOKS peers declined ($M = -0.20$). Changes in shift skills for other years and subgroups were not significant.

Activity and Academics

Researchers and educators continue to raise concern about how schools can balance physical activity with academic instruction. The findings from our three-year study of BOKS strengthen the argument that physical activity can position children to be more ready and alert for learning experiences. The specific executive functions correlated

with BOKS activity in this study, working memory and shift, enable children to hold information, complete tasks, carry out instructions, and transition from one task to another. These clearly are important skills for success in elementary school.

Participating in physical activity before school has double benefits: Not only do children get essential moderate-to-vigorous exercise, but they also build skills linked to academic achievement (Hall, Fay, & Harris, 2013; Hall et al., 2014). Consistent with the findings of Sattlemair and Ratey (2009), our research on BOKS suggests that participation is associated with enhanced readiness to learn. Though effects were not evident in every grade and every study year, a pattern emerged over the three years suggesting that participation in a before-school physical activity program can help to improve children's working memory and shift skills as measured by the BRIEF assessment.

This study had limitations that restrict generalization. First, children and families who chose to participate in BOKS may have differed from those who did not elect to participate in important ways that influenced outcomes. Another limitation is that this study used survey data rather than more objective measurements of executive function such as cognitive tests of the children. More research is needed to explore which models of before-school physical activity programming are most likely to be associated with improved learning skills.

Other research on BOKS has pointed to the program's valuable contribution to children's daily accumulated physical activity time and perceived change in physical activity habits. Parent and school administrator feedback has been overwhelmingly strong (Hall et al., 2013). Numerous mechanisms have been proposed to explain the relationship between physical activity and cognition: physiological changes such as blood flow, change in brain neurotransmitters, structural changes in the nervous system, and others (Sibley & Etnier, 2003). Further research could help elucidate which program components are most essential to such physiological changes. Programs could then be designed with these changes in mind. What has become increasingly clear through our study and previous research is that consistent participation in before-school physical activity programming not only fosters children's wellness but also makes an important contribution to their school success.

The findings from our three-year study of BOKS strengthen the argument that physical activity can position children to be more ready and alert for learning experiences.

¹ Significance was determined at the $p < .05$ level.

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