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The effect of before school physical activity on child development: A study protocol to evaluate the Build Our Kids Success (BOKS) Program

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ABSTRACT

Introduction: Most childhood physical activity interventions focus on reducing childhood obesity with varying success, indicating that body mass index (BMI) may be a limited marker of health in children. To better understand overall childhood health and wellbeing, this study is investigating BOKS (Build Our Kids Success), an established ongoing before-school physical activity program, to evaluate students' physical health, mental health, cognitive capacity, and academic performance.
Design and methods: The study is a non-randomized controlled trial with 26 elementary and middle schools in 3 Massachusetts communities, including first through eighth grade (aged 5–14) students, their parents, and teachers. Data collection is occurring during the 2015–2016 school year. Physical fitness is being assessed via 400 m run and anthropometrics via height and weight measures (BMI). Psychosocial outcomes are being assessed via student, parent, and teacher survey and include nutrition, daily activities, emotional and relationship scales, bullying and victimization, vitality and energy, student engagement, stress, positive affect, self-efficacy and life satisfaction. Academic performance is reported by grades. Statistical methods include a psychometric evaluation of study measures, Pearson correlations, Student's *t*-tests, ANOVA/ANCOVA and multivariate linear regression including multilevel modeling analyses to account for the hierarchical organization of the data.
Discussion: This study is investigating a before school physical activity program on parameters of physical health, mental health, cognitive capacity, and academic performance by employing a novel triad approach, correlating the input of the child, parent, and teacher. Outcomes will evaluate the effectiveness of a before school physical activity program in elementary and middle schools and potentially provide valuable information for schools looking to institute innovative physical activity programs.

1. Introduction

Sedentary lifestyle and the lack of physical activity have been cited as contributing to childhood physical health problems, specifically obesity [1]. Yet, the majority of childhood physical activity interventions focused on reducing childhood obesity [2–4] have reported varying success in reduction of childhood obesity, indicating that body mass index (BMI) may be a limited marker of health in children. In response, calls have been made to examine the impact of physical activity on children outside the realm of BMI [5,6].

Evidence is accumulating that physical activity may also improve brain health and performance in children, including a wide variety of cognitive, psychosocial, and mental health factors as well as academic performance [7]. Indeed, recent studies indicate that increases in physical activity have a positive effect on aspects of child cognition and cognitive development [8–10] executive control [11], memory [12], and academic achievement [13]. Further research indicates that greater physical activity may decrease symptoms of childhood mental health issues, such as ADHD [14,15] and depression [16], and increase psychosocial wellbeing [17].

Despite this growing breadth of knowledge regarding the positive association between child health and physical activity, only 30–42% of children ages 6–11 achieve the recommended physical activity goal of 60 min per day [18]. Physical education is offered in only 4% of elementary schools in America [19] and only 50% of students attend physical education classes weekly [20]. Innovative school based physical activity programs have been cited as a promising approach to improve total daily physical activity levels of youth [21–23]. Specifically, physical activity programs implemented before school have also shown promising

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results including on-task behavior and the management of ADHD behaviors [14,24].

Throughout the past five years, a volunteer led before school physical activity program called BOKS (Build Our Kids Success) has been implemented in over 2000 elementary and middle schools in the United States and internationally. BOKS was chosen for this study because it is a program designed to address behavioral, mental and cognitive outcomes for students, rather than physical parameters such as BMI [25]. Students participate in the program for 12 weeks, two or three mornings per week for about 1 h per session. BOKS sessions start with a fun warm-up game, transition into running, relay races or obstacle courses, and include a skill of the week. In a recent report in a single school, BOKS effectively decreased percent body fat and fat weight, and increased aerobic performance in participants when compared to control students [25]. However, no study has examined behavioral health risk and protective factors or academic performance outcomes associated with this program.

The purpose of this paper is to outline the design of a non-randomized control trial to determine the multivariable effects of a before-school physical activity program (BOKS) on elementary and middle school students during two 12-week periods over one school year. The major objective of the study is to compare behavioral health risk and protective factors (e.g. nutrition, emotional and relationship scales, vitality and energy, student engagement, stress, positive affect, self-efficacy and life satisfaction) as well as academic performance between BOKS participants and control students. Secondary aims include examining correlations of behavioral health risk and protective factors between student, parent and teacher reports as well as investigating the effect of timing and dose of physical activity on major outcomes.

2. Materials and methods

2.1. Study design

This study is utilizing a non-randomized controlled design aimed at evaluating BOKS, an established and ongoing before-school physical activity program, in twenty-six newly participating elementary and middle schools in Plymouth, Weymouth and Quincy Massachusetts. Rather than use a randomized design, this study seeks to establish and maintain equitable partnerships using a Community-Based Participatory Research (CBPR) approach [26]. The CBPR approach encourages active engagement of all stakeholders in the process, including researchers, community leadership, school district leadership, teachers, parents and students. Outcomes include students' physical health, mental health, cognitive capacity, and academic performance. The study utilized a two-phase design over the fall and winter/spring semesters of the 2015–16 school year. Students from Plymouth and Weymouth were enrolled in fall and are being followed through two 12-week sessions (fall and winter/spring). Students from Quincy were enrolled in winter/spring and were followed for one 12-week session. The study was approved by the Institutional Review Board (IRB) of Spaulding Rehabilitation Hospital, Charlestown, MA and the administrative leadership (e.g. Superintendent, school board) for each school district.

2.2. Study population, recruitment and eligibility

This study was conducted in the towns of Plymouth, Weymouth and Quincy due to their expressed interest in integrating the BOKS program within their school communities. Eligible participants included students in grades 1–8 (aged 5–14 years) who were new participants in the BOKS program and control students in the same school who did not participate in BOKS. This age group was chosen as it falls within the critical period where brain growth and cognition are still under rapid development [27].

Recruitment took place in September 2015 and January 2016 within each school district as a collaborative effort by BOKS leadership and trainers along with the study research team. Students interested in participating in BOKS were recruited as well as all non-BOKS participants in the same school (as controls). Students were not prevented from participating in the BOKS program if they declined participation in the study.

Prior to the start of each trial, parents who registered their children in the BOKS program were given the opportunity to voluntarily enroll

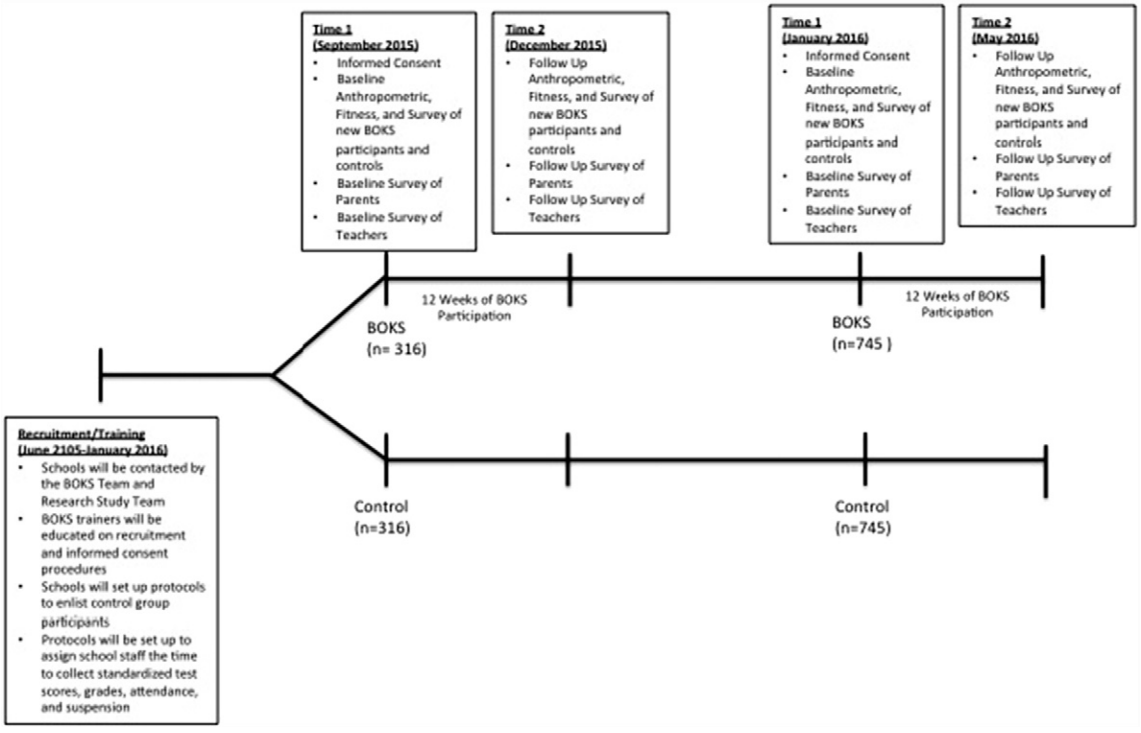

Fig. 1. Recruitment, training and data collection timeline for the 2015–2016 school year. Children included in the September 2015 baseline data collection are included in both the December 2015 and June 2016 follow-up data collection.

their child in the study. Parents were notified of the study through a flyer attached to the packet that included the BOKS registration and parental consent forms. To establish a control group, school administrators asked students to bring a study information page and parental consent form home to their parents. Students with a signed parental consent form who did not participate in BOKS comprised the control group. Prior to data collection, all students signed a child assent form. Additionally, all participant and control students' parents and teachers were asked to take part in the study by completing online surveys. Study participants, including students, parents, and teachers, were compensated for their time with small items from Reebok (i.e., keychains, bracelets, discount coupons).

2.3. Intervention

Students participate in BOKS, a before school physical activity program for 12 weeks, 2 or 3 times per week, depending on the school district. BOKS sessions last approximately 60 min and start with a fun warm-up game, transition into running, relay races or obstacle courses, and include a skill of the week (e.g. plank, running, jumping). Aspects of the core curriculum are consistent across all age groups. Volunteers, including parents and/or school staff such as nurses or physical education teachers, were recruited by schools and the BOKS program and run all BOKS sessions. All volunteers were trained by the BOKS organization in program content and teaching methods led each of the sessions. The BOKS curriculum has been developed by the BOKS educational leadership team and was not altered for the study. Assessments for fidelity to the BOKS curriculum, including deviations from the lesson plan and student attendance, are being tracked in order to ensure consistency between schools.

2.4. Assessments

All participant baseline measures are being collected during the first week of the BOKS session for both BOKS participants and controls (Fig. 1, Time 1). Follow-up data collection will be completed during the final week of the BOKS program (Fig. 1, Time 2). Data collection will take place over two semesters of the BOKS program during the school year of 2015–2016. Trial 1 was conducted during the fall semester of 2015, while Trial 2 is being conducted during the winter/spring semester of 2016. The measurement sessions are scheduled before school for BOKS participants and during first period for control students. Student anthropometric, physical fitness performance tests, and questionnaires are performed on the same day.

Parent and teacher surveys for both participant and control students are emailed to both parents and teachers during the first week of BOKS and are requested to be returned within one week. Follow up surveys will be emailed in the final week of the BOKS program and will be requested to be returned within one week. Three reminder emails will be sent to all parents and teachers throughout the week in order to achieve maximum participation.

2.4.1. Student demographic and anthropometric data

Demographic data will be collected from student and parent questionnaire including age, grade level, and gender. Weight and height will be measured using a Seca scale and a stadiometer (Chino, CA) without shoes and in light clothing. From these measurements BMI (wt/ht^2) and BMIz will be calculated.

2.4.2. Physical fitness performance tests

Aerobic fitness is measured utilizing a 400 m timed run. Students are asked to run a marked 400 m course as quickly as possible and times are recorded to the nearest tenth (0.1) of a second. The same course is to be used pre- and post-intervention.

2.4.3. Student questionnaire

Students aged 8 years or older are asked to complete online questionnaires at school in either a school based computer lab or via tablets/laptops on a rolling cart system. Study staff monitors student survey administration. Each item is read aloud to students as they followed along. The self-administered questionnaires are composed of scales that have been validated for use by children in previous research or created specifically for this protocol (Table 1).

2.4.4. Parent and teacher questionnaire

Parents and teachers will receive an email with the link to their respective survey. The self-administered parent questionnaires are

Table 1
Child survey outline and references.

Instrument and reference	Description
Nutrition questions [31] This scale contains select questions from the Food Behavior Checklist developed by the University of California Cooperative Extension	The questions (e.g. "How many sports drinks or sodas do you drink each day?") are answered on either a 5-point or 6-point scale from "none" to "6 or more".
Daily Activities questions [32] PROMIS pediatric physical activity 4-item short form	The child responds on a 5-point scale how often during the past 7 days he/she has engaged in certain physical activities.
Pediatric Emotion and Relationship scales from the NIH PROMIS program [33] • PROMIS® Pediatric Anger - scale 5a • PROMIS Pediatric Anxiety - short form 8b PROMIS • PROMIS pediatric depressive Symptoms • PROMIS pediatric fatigue symptoms • PROMIS pediatric peer relationships - short form 8a (www.nihpromis.org)	The child responds on a 5-point scale how often during the past 7 days he/she has experienced emotions related to anger, anxiety, sadness, fatigue, and interactions with peers.
Healthy Pathways Child Report Scales: bullying victimization [34]	The child responds on a 5-point scale how often during the past 4 weeks he/she has experienced bullying.
Healthy Pathways Child Report Scales: vitality/energy [34]	The child responds on a 5-point scale to questions about his/her health and energy level.
Healthy Pathways Child Report Scales: student engagement [34]	The child how interested and involved he/she is in work at school.
Pediatric Psychological Stress Reactions – (SF-4) from the PROMIS NIH program [35]	The child responds on a 5-point scale how much stress he/she has experienced during the past 7 days.
Pediatric Positive Affect (SF-4) from the NIH PROMIS program [36]	The child responds on a 5-point scale how accurately each of 9 statements related to positive emotion (e.g. "I felt enthusiastic") describes how they have felt during the past 7 days.
NIH Toolbox Self-Efficacy for Children [33]	The child responds to how accurately each of 10 statements (e.g., "I can manage to solve difficult problems if I try hard enough") generally describes him/her on a 5-point scale.
Academic Performance – Child [34]	The child responds on a 5-point scale to questions about the child's academic performance.
Resilience Scale for Kids™ (RS-10) child report [37]	Children report how much each of 10 statements describes themselves on a 4-point scale (e.g., "I know how to calm down when I am upset." The scale is written at the 2nd grade reading level and measures resilience across five essential elements: purpose, perseverance, equanimity, self-reliance, and authenticity.
Pediatric Life Satisfaction (SF-4) from the NIH PROMIS program [37]	Child responds on a 5-point scale how accurately each of 4 statements related to life satisfaction (e.g. "My life is going well") describes their feelings about their life.

Table 2
Parent survey BOKS.

Instrument	Reference
Eating Behaviors and Nutrition questions [31] This scale contains select questions from the Food Behavior Checklist developed by the University of California Cooperative Extension	These questions address that information, such as questions on fruits and vegetable consumption. All questions are answered on a 7-point scale.
M5–PS–35 [38] Validated measure of child personality based on the five-factor model.	Parents respond how much each of 35 questions describes their child using a 5-point scale. The measure assesses personality factors of Neuroticism, Extraversion, Openness, Agreeableness, and Conscientiousness.
Physical Activity Scale [39]	Parents report how much time their child spent in physical activity during the past 4 weeks using a 5-point scale
Activities Scale Devised for this survey and includes child activities of interest	Parents report how much time their child spends weekly on a variety of behaviors using a 4-point scale
Validated Emotion and Relationship Scales from the PROMIS NIH program [40] • PROMIS Parent Proxy Short Form v1.0 - Anger 5 • PROMIS Parent Proxy SF v1.1 – Anxiety 8b • PROMIS Parent Proxy Bank v1.1 – Depressive Symptoms • PROMIS Parent Proxy Item Bank v1.0 – Fatigue 10 • PROMIS Parent Proxy Item Bank v1.0 – Peer Relationships 7	Parents respond on a 5-point scale how often during the past 7 days their child has demonstrated emotions related to anger, anxiety, depression, fatigue, and interactions with peers. [2 additional sleep quality questions]
Attention subscale of Vanderbilt ADHD Diagnostic Parent Rating Scale [41] Assesses the child's ability to attend to the environment.	Parents report how true each behavior is of their child on a 4-point scale.
Strengths & Difficulties Questionnaire for age 4–17 (SDQ) [42] The SDQ is a validated measure of child behavior and psychological health that includes problematic behaviors and experiences (e.g., "constantly fidgeting or squirming," "gets along better with adults than with other children."	The measure contains subscales of emotional, hyperactivity/inattention, conduct and peer problems as well as prosocial behavior. Parents report how true each item is of their child on a 3-point scale.
Psychological Stress Reactions Scale SF4- Parents from the PROMIS NIH program [40]	Parents respond to how often within the past month their child has experienced stressful situations (e.g., "how often was your child upset because of something that happened unexpectedly?)" on a 5-point scale.
Healthy Pathways Vitality/Energy Scale parent report [39]	The parent responds on a 5-point scale to questions about his/her child's health and energy level.
NIH TB Self Efficacy Parent Report CAT [33]	Parents respond to how accurately each of 10 statements (e.g., "Your child can handle whatever comes his/her way") generally describes their child on a 5-point scale.
NIH TB Positive Affect Parent Report CAT [33]	Parents respond on a 5-point scale how accurately each of 13 statements related to positive emotion (e.g. "My child was energetic") describes their child during the past 7 days.
Healthy Pathways Academic Performance Scale – Parent [32]	The parent responds on a 5-point scale to questions about his/her child's academic performance.
Resilience Scale for Kids™ (RS-10) Parent Report [43] This scale is a parent version of the RS-10, a valid and reliable measure for child resilience. The parent scale was developed specifically for this research has not yet been validated.	Parents report how much each of 10 statements describes their child on a 4-point scale (e.g., "My child knows how to calm down when she/he is upset." The scale measures resilience across five essential elements: purpose, perseverance, equanimity, self-reliance, and authenticity.
NIH TB General Life Satisfaction Parent Report Short/Fixed Form for children [33]	Parents respond on a 5-point scale how accurately each of 5 statements related to life satisfaction (e.g. "My child's life is going well") describes their child.

composed of scales that have been validated in previous research on children (Table 2). Teachers are asked to complete a brief survey which addresses the teacher's perception of each student's behavior, performance, strengths, difficulties, and academic engagement. The surveys are composed of scales that have been validated for use by teachers in previous research (Table 3).

2.4.5. School record review

Computerized records containing standardized test scores, grades, attendance, and suspension rates will be retrieved for students. Permission to access this information was included in the informed consent form.

2.5. Statistical analysis

2.5.1. Psychometric evaluation of study measures

Analysis of data will be conducted to evaluate the psychometric properties of student, parent, and teacher report scales. In general, the psychometric analyses will comply with best-practice methods outlined by the NIH Patient Reported Outcome Measurement Information System (PROMIS) program (www.nihpromis.com). Confirmatory factor analysis (CFA with weighted least squares, mean- and variance adjusted chi-square statistics) will be performed using one-factor and bi-factor models to evaluate scale unidimensionality. If a significant misfit is discovered, we will conduct exploratory factor analyses to aid consideration of how scale unidimensionality could be retained or improved through item reduction. Item response theory (IRT) models will be fit to the data using Samejima's two-parameter polytomous graded response model. The psychometric properties of the items will be examined by estimating the item parameters, and plotting the item characteristic curves and item information curves. As indicated by IRT parameters, items that fail to fit the model, have poor discrimination, or are redundant with other items may be removed from the scales. Test and selected item information function curves will be plotted to show the precision with which the retained items measure various levels of student outcomes. Finally, differential item functioning (DIF) analyses will be conducted for each scale to evaluate item bias for salient subgroups including student age, gender, and race. Items demonstrating DIF will be recommended for possible exclusion from the scales.

2.5.2. Evaluation of program impact

Data will be analyzed using IBM SPSS version 21. Data scoring and cleaning will take place after each survey administration. Correlations will be utilized to assess associations between linear variables, Students' t-tests and repeated measures ANOVA will assess within-subject and ANOVA/ANCOVA will assess between-group variability. Linear regression will be also utilized to model associations between continuous variables and select factors (Table 4) and covariates, such as baseline activity/fitness level, grade, gender, ethnicity, school, and school district, both within and between groups. Multilevel modeling analyses will be used to account for the hierarchical organization of the data.

2.5.3. Power analysis

Longitudinal studies that evaluate the impact of a three-year physical activity program on academic performance found effect sizes ranging from Cohen's d = 0.16 to 0.28 [28,29]. With an equal number of participants in the intervention and control groups, a total sample size of 1028 participants (514 per group) is required to detect small effects ($d = 0.16$) at 90% power. A total of 706 participants (353 per group)

Table 3
Teacher survey.

Instrument	Reference
Vanderbilt ADHD Diagnostic Teacher Rating Scale [44] • Inattention subscale • Hyperactivity/impulsivity subscale	Teachers answer questions on a 4-point Likert scale assessing the child's attention (e.g., "Has difficulty sustaining attention to tasks or activities") and hyperactivity levels (e.g., "Has difficulty playing or engaging in leisure activities quietly")
Informant-Rated Strengths & Difficulties Questionnaire (SDQ) [42] • Conduct problems subscale	Teachers rate student's conduct on a 3-point scale, (e.g., "Often has temper tantrums or hot temper")
Research Assessment Package for Schools (RAPS) [45] • Student engagement subscale • Student organization subscale • Student fatigue subscale	Teachers rate student's behavior on a 4-point scale, (e.g., "In my class, this student seemed tuned in")
Questions on Student Behavior and Performance • These items reflect questions and information that is pertinent to study objectives.	These ask teachers to rate a specific child's current behavior and performance relative to other children at the same grade level (e.g., "The items are rated on a 5-point scale. All questions are patterned after questions derived from validated instruments related to child mental health, physical health, and performance.

is required to detect small effects at 80% power. Assuming that 80% of participants who complete the pretest will also complete the posttest (20% attrition), the planned initial enrollment of 1490 students (632 in the fall semester and 858 in the winter/spring semesters) will provide sufficient power to detect hypothesized between-group differences and allow for attrition.

2.6. Discussion

The proposed study is the first to the authors' knowledge that will investigate a before school physical activity program on parameters of physical health, mental health, cognitive capacity, and academic performance outcomes in a community wide population of elementary and middle school students. Previous research has indicated that before school physical activity increases overall physical activity [30] and anthropometric outcomes including lean and fat mass, although not BMI [25]. Additionally, smaller scaled physical activity programs implemented before school have also shown promising results including on-task behavior and the management of ADHD behaviors [14,24].

In addition to evaluating student outcomes, this study will also utilize a novel triad approach, correlating the input of the child, parent, and teacher on all outcomes. This study will help elucidate both physical and behavioral outcomes associated with participation in a physical activity program, but perhaps more importantly, will also shed light on the effect of community, parental, and teacher attitudes toward child health.

The strength of this study lies in objective measurement strategies (i.e. 400 m run, academic outcomes) combined with more subjective techniques utilizing a comprehensive battery of validated survey tools. Applying a within-school controlled study design allows for direct comparison within each individual school as well as control for between-school variation. Some limitations of the study include utilizing a Community Based Participatory Research (CBPR) model [26], which requires creating and engaging a relationship with willing communities, rather than being randomized. Since BOKS is being offered as a volunteer participatory program within each school, there is risk for bias among participants of the physical activity program itself. However, utilizing

Table 4
Continuous variables and select factors for analysis.

Variable category	Specific variable	Child report	Parent report	Teacher report	Performance/physical test	School report
Biological						
	Physical fitness				x	
	BMI/BMIz				x	
	Physical activity	x	x	x		
	Nutrition	x	x			
	Energy/vitality	x	x			
	Fatigue/sleep	x	x	x		
Psychological						
	Self-efficacy/resilience	x	x			
	Psychological stress reactions	x	x			
Cognitive						
	Sustained attention		x	x		
	Focused attention		x	x		
Emotional						
	Anger	x	x	x		
	Anxiety	x	x			
	Depressive symptoms	x	x			
	Positive affect	x	x			
	Life satisfaction	x	x			
Behavioral						
	Impulsivity		x	x		
	Organization		x	x		
	Compliance/conduct		x	x		
	Leisure activities	x	x			
Social						
	Pro social activity	x	x	x		
	Peer relationship	x	x	x		
	Bully victimization	x				
Academic						
	Student engagement	x		x		
	Grades					x
	Standardized tests					x
	Sick days					x

within-school controls as a comparison will help to rule out the possibility that the observed changes are due to participation bias. Lastly, it is possible that the results may not be generalizable to other communities. However three towns with typical resources of varying urban and suburban makeup are being included in the analysis in order to mitigate this limitation.

Because research suggests that physical activity contributes to optimal brain health [8–12,17], this proposal to investigate before-school bouts of physical activity of children is novel and necessary to understand the overall effect of physical activity, as well as, implications of timing (e.g., before school) and dose (e.g., number of sessions per week) on physical health, mental health, cognitive capacity, and academic performance. Moreover, this investigation will give insight into the perceptions of the parents and teachers on health outcomes. The proposed study will provide valuable information for school districts looking to institute innovative physical activity programs in their communities.

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