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Benefits of After-School Sports: A Global Analysis of Pediatric Physical Health and Cognitive Function

Michelle Lim,[1] Janis Gaudreau,[1] and Nicole E. Logan[1,2,3]

ABSTRACT

Introduction: The purpose of this study is to explore the effects of after-school sports and physical activity (PA) participation on brain health between samples matched on socioeconomic and demographic factors.

Methods: Data were obtained from the Child Mind Institute Healthy Brain Network's protocol. Participants completed four lab assessment days to collect a battery of data on youth mental health, cognitive health, and physical health. Children aged 6–16 yr were included in the analyses and grouped based on their participation in sports/PA outside of school time. Independent-samples *t*-tests (sports n = 391; non-sports n = 391; age 9.41 ± 2.38 yr) were done on academic achievement, cognitive function, mental health, and physical health (fitness, body composition, PA, muscular strength, and flexibility) outcomes. Groups were matched on age, sex, race, ethnicity, puberty, socioeconomic status, and intelligence quotient (IQ).

Results: Significant between-group brain health differences were observed for executive function skills (sports: 51.38% ± 28.94%, non-sports: 45.24% ± 28.10%; P = 0.03), processing speed (sports: 50.83% ± 27.80%, non-sports: 46.13% ± 27.48%; P = 0.02), attention-deficit/hyperactivity disorder symptoms (sports: 0.21 ± 0.97, non-sports: 0.37 ± 0.97; P = 0.02), attentional problems (sports: 59.71 ± 8.78, non-sports: 61.49 ± 9.28; P = 0.006), social awareness skills (sports: 56.52 ± 10.78, non-sports: 53.69 ± 9.95; P = 0.01), and language comprehension skills (sports: 64.07% ± 27.66%, non-sports: 59.80% ± 28.44%; P = 0.03) in favor of children in the sports group. Children who participated in sports also demonstrated greater physical health indexed by daily energy expenditure (sports: 1950.15 ± 476.09 calories, non-sports: 1800.84 ± 469.22 calories; P = 0.04), PA (sports: 2.81 ± 0.79, non-sports: 2.59 ± 0.74; P = 0.002), *z*-scored fitness (sports: 0.16 ± 1.05, non-sports: –0.08 ± 1.04; P = 0.02), resting heart rate (sports: 79.26 ± 12.16 bpm, non-sports: 81.36 ± 12.94 bpm; P = 0.02), muscular strength in the trunk lift (sports: 9.40 ± 2.77 inches, non-sports: 8.91 ± 2.82 inches; P = 0.01), and flexibility in the sit and reach (sports: 9.33 ± 2.93 inches, non-sports: 8.74 ± 3.15 inches; P = 0.007).

Conclusion: When controlling for important demographic factors (age, sex, race/ethnicity, puberty, IQ, and socioeconomic status), children who participated in after-school sports and PA showed better results on several physical, cognitive, and mental health outcomes compared to their peers.

Keywords: academic performance, children, executive function, mental health, sport participation

INTRODUCTION

The Physical Activity Guidelines for Americans recommend that school-aged children and adolescents (6–17 yr) participate in at least 60 min of moderate-to-vigorous physical activity (MVPA) daily (1). The health benefits of regular physical activity (PA) for children are widespread, positively influencing body composition, cardiovascular fitness, and motor skill development and coordination (1). Importantly, regular PA during childhood also positively influences brain health through improved cognitive development, academic achievement, and mental health (2,3). The positive effects of PA on brain health are a timely consideration in recovery from the coronavirus disease 2019 (COVID-19) pandemic, when children had declines in academic performance in light of remote learning (4). As of 2024, despite some progress, the academic achievement gaps of school-aged children that widened during the 2020 pandemic have not yet stabilized (5). With declining rates of academic achievement and increasing rates of inactivity-related health conditions, such as childhood obesity (6), PA is a prime candidate for improving major aspects of health during childhood.

Despite the overwhelming benefits of PA during childhood, descriptive statistics from the 2019 Youth Risk Behavior Survey demonstrate that only 23.2% of high school students in the United States meet the daily PA guidelines as of 2019, and only 25.9% of high school students attend physical education (PE) classes daily (7). Interestingly, a larger proportion of students reported

Janis Gaudreau ORCID: 0009-0003-8192-8491

[1]Interdisciplinary Neuroscience Program, The University of Rhode Island, Kingston, RI, USA; [2]Department of Kinesiology, The University of Rhode Island, Kingston, RI, USA; and [3]George and Anne Ryan Institute for Neuroscience, The University of Rhode Island, Kingston, RI, USA

Address for correspondence: Nicole E. Logan, Ph.D., University of Rhode Island, 25 West Independence Way, Kingston, RI 02881, USA (E-mail: nicolelogan@uri.edu).

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doing some form of PA outside of school hours by playing on at least one sports team (57.4%) (7). A greater proportion of male students (30.9%) were physically active for ≥60 min·d^{-1} compared to female students (15.4%), and White students had a greater tendency to meet PA guidelines (25.6%) compared to Black (21.1%) or Hispanic (20.9%) students (7). These trends were similar for after-school sports participation, with males (60.2%) out-participating females (54.6%) in after-school sports, and White (62.0%) students out-participating Black (56.1%) and Hispanic (51.6%) students in after-school sports (7). Notably, all youth PA trends have declined linearly since 2011 (7), suggesting a need to enhance avenues for PA promotion, access, and inclusion.

After-school sports participation offers children an additional opportunity to meet PA guidelines. Besides aiding healthy development, after-school sports are also routinely cited to improve leadership skills, prosocial development, confidence, teamwork, resilience, and future successful career outcomes (8,9). However, participation in after-school sports is dependent on a number of family and demographic factors that exclude many children. In particular, children from middle and high socioeconomic backgrounds often report engaging in more sports clubs and organized events for PA time compared to children from lower socioeconomic status (SES) schools, who tend to report receiving their PA time from unstructured activities, such as "free play" with peers (10). Moreover, children from lower SES areas tend to participate in less PA overall due to a lack of access, safety concerns, and financial reasons (11,12). Furthermore, children from lower SES households are more likely to receive their daily PA during school hours compared to their high SES peers (13). Outside of the school environment, parks and playgrounds tend to be free of charge and are particularly important for promoting active play in all areas, regardless of SES (11); however, PA disparities between families from different socioeconomic brackets still exist. In-school PA opportunities (e.g., recess and PE) have shown promise for improving outcomes in the classroom through standardized testing results (14,15), regardless of home status. However, the amount of PE time in schools has been steadily declining since 2007's No Child Left Behind Act (16), with added prioritization of time spent on reading and math instead of non-core subjects such as arts, PE, and recess (17). Notably, there is a large group of literature that supports the notion that children who spend more time in MVPA and who are more aerobically fit have better cognitive and academic achievement outcomes, and therefore, spending more time in PE can benefit the academic outcomes of children (17). Although the evidence surrounding the beneficial effects of generalized PA on academic achievement, cognitive health, and psychosocial outcomes in children is well documented (2,3,17,18), there are few studies that investigate the controlled role of after-school sports participation on academic achievement, cognitive function, and mental health outcomes.

The current study aims to explore the effect of after-school PA and sports programs on academic, cognitive, and psychosocial outcomes in children and adolescents from New York state compared to a matched sample of children who do not engage in after-school PA activities. Children in New York participate in, on average, 120 min·wk^{-1} of PA through recess and PE programs during school hours (19). This averages out to 17.14 min of PA per day over a 7-d period, which does not meet the recommended 60 min·d^{-1} of PA for optimal health benefits for school-aged children. Many children benefit from PA outside of school hours through family leisure time and/or after-school sports and recreation programs. However, not all families have equitable and accessible resources, facilities, and environments to support PA outside of the school system. Novel to our research is the sample of neurotypically developing children matched on sociodemographic factors such as age, sex, race, ethnicity, puberty, household income, and intelligence quotient (IQ) to ameliorate the effect of social, racial, and economic bias and identify the isolated effects of sports participation. We hypothesized that children who receive additional PA in after-school PA programs would demonstrate greater performance on tasks of cognitive function and academic achievement, more positive outcomes on assessments of mental health and mood, and better physical health outcomes compared to their peers.

METHODS

Participants

The data for the current study come from the ongoing Child Mind Institute's (CMI) Healthy Brain Network (HBN) open-access study, with a total sample size of 4790. The HBN seeks to create and share a 10,000-participant biobank of youth aged 5–21 yr from the New York City area that captures the broad range of heterogeneity and impairment that exists in developmental psychopathology (20). Participants were recruited through health and community fairs, print advertising, digital marketing, email efforts, website advertisements, social media, and community lists, all within New York. The Chesapeake College Institutional Review Board approved the study (20). Participants and/or their legal guardians underwent rigorous screening criteria via phone interview with an intake coordinator to determine eligibility. The screening interview collected information about a potential participant's psychiatric and medical history. With few exceptions, diagnoses or symptoms of psychiatric, medical, or neurological illness did not exclude participation in the study. Before conducting the research, written informed consent was obtained from participants 18 yr or older. For participants younger than 18 yr, parental permission was obtained from their legal guardians, and written assent was obtained from the participant.

Inclusion criteria for the original study were male or female individuals aged 5–21 yr and fluency in English. Exclusion criteria included individuals with (i) moderate to severe cognitive impairment (i.e., IQ below 66); (ii) acute encephalopathy caused by brain injury or disease; (iii) known degeneration disorder; (iv) hearing or visual impairment that prevented participation in study-related tasks; (v) diagnosis within the past 6 months of schizophrenia, schizoaffective disorder, or bipolar disorder without treatment; (vi) acute manic or psychotic episode without current, ongoing treatment; (vii) onset within the last 3 months of suicidality or homicidality without current, ongoing treatment; (viii) history of substance dependence requiring chemical replacement therapy; and (ix) acute intoxication at time of any study visit. With few exceptions, psychiatric, medical, or neurological illness did not exclude participation per the goal of CMI. Participants taking stimulant medication were asked to discontinue their medication during the days of participation because stimulants are known to affect cognitive and behavioral testing (20). Any medication taken on the day of participation was recorded.

A subset of participants (n = 1071) was identified as having neurotypical development (i.e., free from language, developmental, and/or mental health conditions) and were included in the current analysis. This subset of participants included 391 children who participated in after-school sporting-related activities and 680 children who did not. From this sample, 391 of the children who did not participate in after-school sporting-related activities (non-sports group) were matched to the 391 children who did participate (sports group), inclusive of the variables of age, sex, race, ethnicity, puberty, household income, and IQ, using the *matchit* function in R (R Foundation for Statistical Computing, Vienna, Austria) (21), for a final sample size of n = 782.

Procedure

During the cross-sectional data collection, participants attended four sessions for approximately 3 h per session (20). The first visit consisted of pediatric assent and parental consent, a series of questionnaires, a clinical preinterview, and cognitive function assessments. During the second visit, children underwent a magnetic resonance imaging (MRI) scan. The third visit consisted of a battery of cognitive assessments from the National Institutes of Health (NIH) Toolbox before completing various fitness measurements. On the final visit, electroencephalography (EEG) data were collected. For the current study, MRI and EEG data were not considered. All testing procedures were administered by trained clinical research assistants (20).

Materials

To access phenotypic data, a data usage agreement was signed by the principal investigator (N.E.L.) and the University of Rhode Island. Phenotypic data were accessed through the Longitudinal Online Research and Imaging System, a web-based data management software for neuroimaging studies. Demographics such as sex, age, and handedness were collected. The tests were administered by, or directly under the supervision of licensed clinicians. All questionnaires underwent a validity check. Alexander et al. (20) have provided a full description of the open resources for pediatric mental health and learning disorders. Where appropriate, we have described additional materials.

Sociodemographic Components

Demographic information about participants included age, sex, protocol completion status, puberty (Peterson Puberty Scale: outcomes range from pre-pubertal to post-pubertal separately for males and females), sleep quality (Sleep Disturbance Scale), SES (Financial Support Questionnaire), and social status of parents' employment and education (Barratt Scale) (22).

Physical Health Assessments

Body Mass Index and Body Composition

Height and weight were obtained and body mass index (BMI; $kg \cdot m^{-2}$) was calculated for each child. BMI percentiles were calculated using the Centers for Disease Control and Prevention percentile calculator for children and teens of the same age and sex. BMI percentiles were used in the current analysis. Bioelectrical impedance was obtained (RJL Systems Quantum III BIA system; Clinton Twp, MI) to calculate body composition metrics of lean mass, fat mass, skeletal muscle mass, bone mineral content, basal metabolic rate, daily energy expenditure, and waist circumference. Resting heart rate (HR; bpm) and blood pressure (systolic, diastolic; mm Hg) were also determined.

Aerobic and Muscular Fitness

Children ≤12 yr old participated in a modified FitnessGram treadmill test of endurance fitness with outcomes obtained in time (minutes, seconds) and the maximum stage reached (23). Children ≥12 yr old completed a graded aerobic fitness test. Both treadmill tests followed the submaximal two-stage National Health and Nutrition Examination Survey (NHANES) protocol (24), which calculates the predicted maximal oxygen uptake ($\dot{V}O_{2max}$) ($mL \cdot kg^{-1} \cdot min^{-1}$) using a formula that includes age (yr), weight (kg), height (m), sex, and PA readiness (PAR; an estimate of habitual PA):

$$\text{Predicted } \dot{V}O_{2max} = 56.363 + (1.921 \times \text{PAR}) - (0.381 \times \text{age}) - (0.754 \times \text{BMI}) + (10.987 \times \text{sex})$$

Next, participants were assigned to one of eight treadmill test protocols that specified treadmill velocity, incline, and duration for a warm-up (2 min) and stages 1 and 2 (3 min each), per the participant's calculated predicted $\dot{V}O_{2max}$ (24). The stages were selected to achieve $\dot{V}O_2$ equal to 45% (warm-up), 55% (stage 1), and 75% (stage 2) of maximal values. The estimated value of $\dot{V}O_2$ at each stage was used along with HR measures to estimate the final $\dot{V}O_{2max}$ for each participant. The velocity and incline selections for the stages were a critical determinant of the NHANES fitness calculation, which assumes (i) a linear relationship between $\dot{V}O_2$ and HR during progressive exercise, (ii) the relationship of HR and $\dot{V}O_2$ is independent of body size when $\dot{V}O_2$ is normalized to body weight, and (iii) maximum HR can be accurately estimated (24). Notably, the NHANES protocol is valid for adolescents but not children; therefore, z-scores were calculated for those who completed the modified FitnessGram treadmill test (i.e., children ≤12 yr; total seconds on the treadmill) and those who completed the submaximal treadmill test (i.e., children ≥12 yr; $mL \cdot kg^{-1} \cdot min^{-1}$) to obtain a single measure of fitness across the sample.

Participants also engaged in push-ups (upper-body muscular strength and endurance; in reps), curl-ups (abdominal muscular strength and endurance; in reps), trunk-lift (trunk extensor strength, flexibility, and endurance; in inches), sit and reach (flexibility; in inches), and grip strength (forearm muscular strength; in kg) assessments of the FitnessGram to measure muscular fitness.

Physical Activity Questionnaire

The Physical Activity Questionnaires (PAQ) for older children (PAQ-C) and for adolescents (PAQ-A) were used to assess children's participation in PA over the last 7 d. The PAQ asks questions about the type and frequency of PA in spare time, in after-school sports, in the evening, or on the weekend; the frequency of activity in PE classes; activities during recess; and activities during lunch. To obtain a summary PAQ score, quantitative items were scored along a scale from 1 to 5, and a mean score was calculated. A score of 1 indicates low PA levels, whereas a score of 5 indicates high PA levels. Data were coded as 1 = very low PA, 2 = low PA, 3 = moderate PA, 4 = high PA, and 5 = very high PA. Qualitative data from individual items were used to characterize involvement in sports and related PA outside of school hours, such as "Physical activity in your spare time: Have you done any of the following activities in the past 7 days (last week)? If yes, how many times?" Possible activities included in the PAQ include skipping, rowing, canoeing, in-line skating, tag, walking for exercise, bicycling, jogging or running, aerobics, swimming, baseball, softball, dance, football, badminton, skateboarding, soccer, street hockey, volleyball, floor hockey, basketball, ice skating, cross-country skiing, and ice hockey/ringette. The PAQ also includes the option to write in any activities not on the list, such as dance, yoga, or martial arts, for example. The PAQ-C was completed by participants aged 8–14 yr, and the PAQ-A (a slightly modified version of the PAQ-C with the "recess" item removed) was completed by participants aged 14–21 yr (25). The PAQ-C has previously shown a test–retest reliability interclass correlation coefficient (ICC) of 0.96, with moderate internal consistency ($\alpha = 0.76$) (26), whereas the PAQ-A has shown an ICC of 0.97, with strong internal consistency ($\alpha = 0.93$) (27). We calculated the ICC between the PAQ-A and PAQ-C for the current study.

Mental Health Assessments

Problematic child behaviors were assessed via the Child Behavior Checklist (CBCL) and the Strengths and Weaknesses Assessment of Normal Behavior (SWAN) (28,29). Attention-deficit/hyperactivity disorder (ADHD) was assessed using the Conners ADHD Rating Scale (30). Childhood disorders relating to anxiety (including general, social, panic, and anxiety), were assessed using the Screen for Child Anxiety-Related Emotional Disorders (SCARED) (31). The Adverse Childhood Experiences Scale (ACES), children's general functioning (Children's Global Assessment Scale; CGAS), General Self-Efficacy Scale (GSES), and Positive Behavior Scale (PBS) of children's social competence, compliance, and autonomy were also assessed to identify key areas of positive and negative mental health components (32–35). For assessments that reflect atypical experiences, behavioral outcomes, or neurodevelopmental processes (e.g., CBCL, SWAN, ADHD, SCARED, ACES), lower scores are considered more optimal. For assessments that reflect positive outcomes (e.g., CGAS, GSES, PBS), higher scores are considered more optimal.

Cognitive Function and Academic Achievement Assessments

A multidimensional set of measures assessing cognitive function (attention, executive function, working memory, processing speed) was obtained from the NIH Toolbox Cognitive Assessment and the Wechsler Intelligence Scale for Children (WISC-V) (36,37). To assess academic performance in reading, math, spelling, listening, and language, the Wechsler Individual Achievement Test (WIAT) was used. Age-corrected standard scores were calculated and converted into percentiles for analysis.

Statistical Analysis

The final sample of participants ($n = 782$) was matched on age, sex, race, ethnicity, puberty, household income, and IQ, and produced two groups: participants who reported participating in at least one after-school sporting-related activity (sports; $n = 391$) and participants who reported participating in zero after-school sporting-related activities (non-sports; $n = 391$).

Independent-samples *t*-test analyses were performed to identify between-group differences in physical and brain health outcomes between the sports and non-sports groups. Significant between-group outcomes of physical health and brain health were considered for interpretation.

Next, Pearson product–moment correlations were conducted as supplementary data analyses between cognitive function outcomes, academic achievement outcomes, mental health outcomes, and all physical health variables. Bonferroni-adjusted P values were computed to account for multiple comparisons of the dependent variables.

A *post hoc* sensitivity analysis using G*Power (version 3.1.9.6; Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany) was calculated to compute the smallest achieved effect size. Given the sample size ($n = 782$), alpha = 0.05, tails = 2, and power = 0.8, the effect size was calculated to equal 0.09 for correlational analyses and 0.20 for independent-samples *t*-tests.

RESULTS

The final sample of participants ($n = 782$) were 9.410 ± 2.381 yr old (range, 6–18 yr), and 290 (37.08%) were female. The sample was matched on age, sex, race, ethnicity, puberty, household income, and IQ, and produced two groups: participants who reported participating in at least one after-school sporting-related activity ($n = 391$, 18.29% female) and participants who reported participating in zero after-school sporting-related activities ($n = 391$, 18.80% female). For those in the sports group, the frequency of activities within the last 7 d was also obtained: 56 children participated in sport-relating activities 1–2 times per week, 126 children participated 3–4 times per week, and 20 children participated ≥7 times per week; the frequency was unreported for 133 children. The mean household income of the sample was $90,000–$99,999 (range, >$10,000 to $150,000 or more), and parents were, on average, college educated (range, less than seventh grade education to graduate degree). Complete demographic frequencies for the overall sample and each group can be found in Table 1. For children in the sports group, a breakdown of after-school PA activities is in Table 2.

There were no significant between-group differences in demographic factors such as age (sports: 9.38 ± 2.25 yr, non-sports: 9.43 ± 2.50 yr; $t(771.13) = 0.32$, $P = 0.74$), puberty (sports: 2.79 ± 2.19, non-sports: 2.70 ± 1.96; $t(770) = 0.60$, $P = 0.55$), sleep disturbances (sports: 16.94 ± 9.33, non-sports: 15.81 ± 8.62; $t(765) = -0.07$, $P = 0.95$), and IQ (sports: 59.78 ± 27.84, non-sports: 58.71 ± 28.63; $t(780) = -0.53$, $P = 0.60$). To appropriately

Table 1

Sample Size and Demographics of Neurotypically Developing Children of the Whole Sample and Between Groups.

	All	Sports	Non-Sports
	n	*n*	*n*
Sample size			
Total	1071	391	680
Matched dataset	782	391	391
Sex			
Male	492	248	244
Female	290	143	147
Ethnicity			
Hispanic	149	73	76
Non-Hispanic	554	276	278
Unknown	79	42	37
Race			
White/Caucasian	439	213	226
Black/African American	96	49	47
Hispanic	56	29	27
Asian	23	11	12
Indian	5	3	2
Native American Indian	0	0	0
American Indian/Alaskan Native	0	0	0
Native Hawaiian/Other Pacific Islander	0	0	0
Two or more races	116	57	59
Other race	5	4	1
Unknown	42	25	17
BMI percentiles			
Underweight	26	16	10
Normal weight	552	275	277
Overweight	109	58	51
Obesity	95	42	53

BMI, body mass index.

Table 2

Breakdown of the Number and Types of Sports and Physical Activities Participated in by the Sports Group.

	n
Number of sports	391
1 sport	66
2 sports	72
>3 sports	253
Type of sports	
Jogging or running	209
Walking for exercise	168
Tag	163
Basketball	123
Skipping	119
Soccer	109
Dance	102
Swimming	83
Martial arts	82
Bicycling	79
Football	73
Aerobics	54
Baseball or softball	50
Volleyball	37
Skateboarding	36
Ice skating	32
In-line skating	25
Floor hockey	15
Ice hockey	13
Street hockey	13
Rowing/canoeing	13
Badminton	12
Cross-country skiing	12
Yoga	7

capture all measures of parental SES, three measures were assessed independently; no significant between-group differences were observed for occupational prestige (sports: 53.52 ± 18.78, non-sports: 53.80 ± 20.93; $t(769) = -1.00$, $P = 0.32$), educational attainment (sports: 7.06 ± 1.75, non-sports: 6.93 ± 2.01; $t(748.06) = -1.50$, $P = 0.13$), and household income (sports: 6.52 ± 3.30, non-sports: 6.54 ± 3.32; $t(765) = 0.59$, $P = 0.56$).

Physical Health

Body Mass Index And Body Composition

The independent-samples *t*-test demonstrated a significant between-group difference in daily energy expenditure (sports: 1950.15 ± 476.09 calories, non-sports: 1800.84 ± 469.22 calories; $t(780) = -2.05$, $P = 0.04$), as seen in Fig. 1. No significant between-group differences were observed for BMI percentiles, fat mass, lean mass, skeletal muscle mass, bone mineral content, basal metabolic rate, or waist circumference.

Aerobic And Muscular Fitness

The independent-samples *t*-test demonstrated a significant between-group difference in resting HR (sports: 79.26 ± 12.16 bpm, non-sports: 81.36 ± 12.94 bpm; $t(774) = 2.33$, $P = 0.02$) and *z*-scored aerobic fitness (sports: 0.16 ± 1.05, non-sports: −0.08 ± 1.04; $t(462) = -2.43$, $P = 0.02$) (Fig. 1). No significant between-group differences were observed for systolic or diastolic blood pressures. From the FitnessGram, significant between-group differences were observed for the trunk-lift (sports: 9.40 ± 2.77 inches, non-sports: 8.91 ± 2.82 inches; $t(780) = -2.44$, $P = 0.01$) and the sit and reach (sports: 9.33 ± 2.93 inches, non-sports: 8.74 ± 3.15 inches; $t(779) = -2.71$, $P = 0.007$) (Fig. 1). No significant between-group differences were observed for the curl-up, push-up, and grip strength tests.

Physical Activity

The independent-samples *t*-test demonstrated a significant between-group difference in self-reported PA from the PAQ (sports: 2.81 ± 0.79, non-sports: 2.59 ± 0.74; $t(510) = -3.18$, $P = 0.002$) (Fig. 1). The ICC between PAQ-A and PAQ-C was 0.996.

Mental Health

The independent-samples *t*-test demonstrated a significant between-group difference for the SWAN ADHD scale (sports: 0.21 ± 0.97, non-sports: 0.37 ± 0.97; $t(773) = 2.35$, $P = 0.02$), the general self-efficacy subscale of social awareness (sports: 56.52 ± 10.78, non-sports: 53.69 ± 9.95; $t(778) = 2.47$, $P = 0.01$), and the CBCL subscale of attention problems (sports: 59.71 ± 8.78, non-sports: 61.49 ± 9.28; $t(779) = 2.75$, $P = 0.006$), as seen in Fig. 2. No significant between-group differences were observed for the remaining CBCL subscales, the global assessment scale, positive and negative affect, positive behavior scale, Conners ADHD subscales, ACES, or SCARED outcomes.

Cognitive Function

The independent-samples *t*-test demonstrated a significant between-group difference for performance (age-corrected standard scores converted into percentiles) on the NIH Toolbox list-sort task (sports: 51.38% ± 28.94%, non-sports: 45.24% ± 28.10%; $t(780) = -3.01$, $P = 0.003$) and the WISC-V processing speed index (sports: 50.83% ± 27.80%, non-sports: 46.13% ± 27.48%; $t(780) = -2.38$, $P = 0.02$) (Fig. 3). No significant between-group differences were observed for the NIH Toolbox flanker, card-sort, and pattern processing tasks or the WISC-V working memory index, fluid reasoning index, and visual–spatial index.

Academic Achievement

The independent-samples *t*-test demonstrated a significant between-group difference for the WIAT listening comprehension receptive vocabulary subscale (sports: 64.07% ± 27.66%, non-sports: 59.80% ± 28.44%; $t(780) = -2.13$, $P = 0.03$) (Fig. 3). No significant between-group differences were observed for the numerical operations, spelling, word reading, reading comprehension, or math problem-solving WIAT subscales.

Associations between Physical Health and Brain Health

To further investigate the effects of sports on brain health outcomes, Bonferroni-adjusted correlation matrices were analyzed for the sports group (Supplemental Content 1, table, http://links.lww.com/EM9/A26) and non-sports group (Supplemental Content 2, table, http://links.lww.com/EM9/A27); interpretations of results have been provided as Supplemental Content 3, http://links.lww.com/EM9/A28.

DISCUSSION

PA promotion is integral to the health and development of children, yet 23.2% of children fail to meet PA guidelines (7). After-school sports and participation in related activities (games like tag, skipping, walking, running, yoga, etc.) provide children with added opportunities to participate in PA and meet the recommended guidelines of 60 $min \cdot d^{-1}$ for optimal health (1). Given the widespread research detailing the beneficial effects of PA on

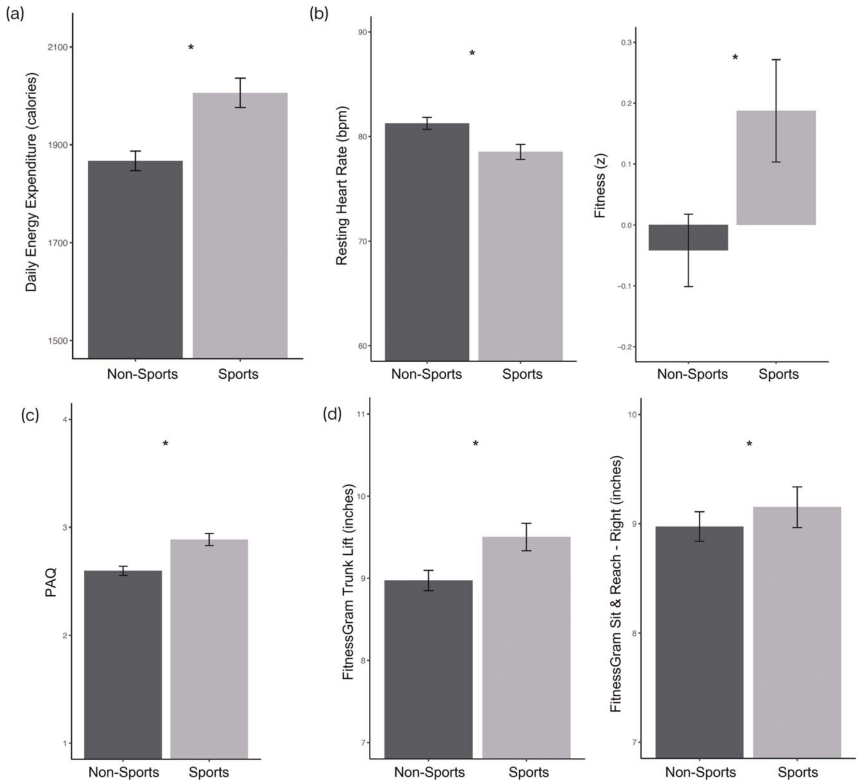

Figure 1. Significant differences (*asterisks*; $P > 0.05$) in the between-group analyses of physical health indices. (a) Bioelectrical impedance assessment of daily energy expenditure (calories; more calories expended is associated with better health). (b) Resting heart rate (HR) (bpm; lower resting HR is associated with better health) and *z*-scored fitness from the aerobic assessments (greater fitness is associated with better health). (c) Self-reported physical activity from the Physical Activity Questionnaire (PAQ) (greater PAQ scores are associated with better health). (d) FitnessGram assessments of muscular strength (trunk lift; inches) and flexibility (sit and reach; inches). Greater flexibility is demonstrated through greater length achieved in both tasks. The non-sports group is in *dark gray* and the sports group is in *light gray* with standard-error *bars*.

cognitive functioning, academic performance, and mental health traits in children (2,3), and emerging research that suggests that demographic factors contribute to the variance in PA opportunities and brain health (38), we sought to investigate the isolated effects of participating in after-school sports and PA on brain health.

Overall, the results of the current study support our hypothesis that children who participate in additional PA after school demonstrate greater performance on specific tasks of cognitive function and academic achievement, more positive outcomes on some assessments of mental health and mood, and greater outcomes in several unique physical health domains compared to their peers. For cognitive function, unique differences were observed in children in the sports group, who had better performances on tasks of executive function and processing speed. For academic performance, children in the sports group demonstrated greater language comprehension skills compared to children in the non-sports group. For mental health outcomes, unique differences were also observed on assessments that reflected co-occurring signs of executive dysfunction, such as ADHD symptoms, attentional problems, and social awareness. Children in the non-sports group showed significantly more

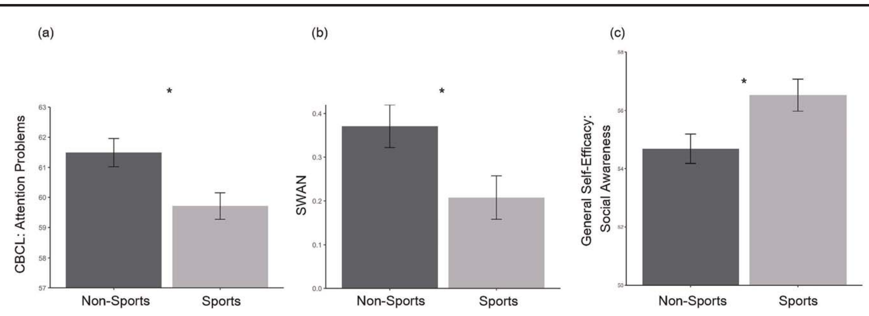

Figure 2. Significant differences (*asterisks*; $P > 0.05$) in the between-group analyses of mental health assessments. (a) The Child Behavior Checklist (CBCL): attention problems. (b) The Strengths and Weaknesses Assessment of Normal Behavior (SWAN) rating scale for attention-deficit/hyperactivity disorder. (c) The General Self-Efficacy Scale: social awareness. The non-sports group is in *dark gray* and the sports group is in *light gray* with standard-error *bars*.

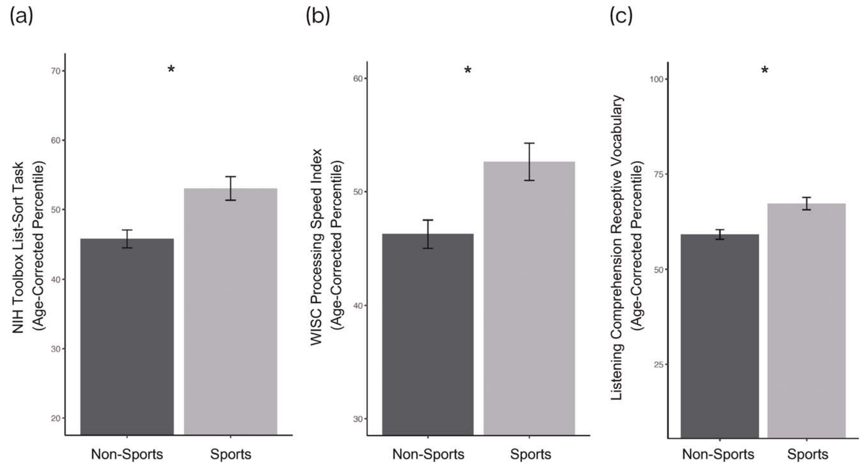

Figure 3. Significant differences (*asterisks*; $P > 0.05$) in the between-group analyses of cognitive function and academic achievement assessments. (a) The National Institutes of Health (NIH) Toolbox: list-sort task. (b) The Wechsler Intelligence Scale for Children (WISC): processing speed index. (c) The Wechsler Individual Achievement Test: listening comprehension receptive vocabulary. Values are represented as age-corrected percentiles. The non-sports group is in *dark gray* and the sports group is in *light gray* with standard-error *bars*.

signs of behavior and focus trouble. These differences in global brain health were further supported by differences in physical health, such that children in the sports group demonstrated greater daily energy expenditure, PA levels, aerobic fitness, muscular strength and flexibility, and lower resting HR.

Interestingly, after eliminating the effect of socioeconomic and sociodemographic influences on our outcomes with our matching process, we saw unique differences in academic, cognitive, and mental health assessments of attention and executive function. Notably, even in our neurotypical sample, attention dysfunction and signs of ADHD were worse in children who did not participate in after-school sports and related activities compared to their more active peers. Previous work has demonstrated that more active children also experience fewer symptoms of anxiety and depressive symptoms (39), a result not seen in the current study. Although they are often comorbid, anxiety and depression are more severe mental health considerations compared to executive dysfunction, and previous evidence suggests that mental disorders are tightly linked to SES (40). It is possible that our matching process eliminated the effect of SES-related mental health disparities between our two groups, thus providing sensitive information about attentional behaviors in children supported by our results from standardized assessments of mental health, cognitive function, and academic achievement.

Several key strengths of the current study include the statistically matched samples on socioeconomic and demographic factors, a large sample size with high statistical power, a representative sample with families recruited from all five boroughs of New York City, and a wide battery of assessments allowing us to analyze task sensitivity of cognitive, academic, and mental health outcomes as they relate to physical health and sports participation.

Although the strengths of this study are notable, the results reported herein should be taken in light of several limitations. First, we note that descriptions of how children in the non-sport group spend their time are limited. For example, children could be not participating in after-school sports or PA for a variety of different reasons outside of SES-related factors, such as classes for art, language, music, or other interests. Additionally, there is emerging literature suggesting that the positive experience of participating in other after-school activities is beneficial for later life cognitive function (41). For example, activities that do not typically meet PA requirements (e.g., arts, language, music, cooking) also provide enriching educational experiences, cognitive stimulation, and social opportunities for children, which are important as they progress into young adulthood (42). Although not addressed in the current study, future work should investigate the importance of alternative positive early life experiences as they relate to domains of cognitive function, academic achievement, and mental health. We also highlight that there was no direct measure of the mechanistic influence on sports and PA participation. Although our data suggest that children who participate in after-school PA have greater fitness, PA levels, muscular strength, flexibility, and facets of brain health compared to their peers, we cannot determine that the differences in brain health are directly due to the physiological aspect of PA participation or the intensity or time of PA involvement. Although PAQ provided insight into the levels of PA engagement among children, the data lack a description of the intensity and time spent in PA and whether these children meet the 60 $min \cdot d^{-1}$ recommended PA guidelines. Future work should include patterns of activity (including bouts, intensity, frequency, time, and steps) throughout the day, such as with accelerometry. Importantly, Tomporowski and Pesce (43) demonstrate that the beneficial effects of sports and PA participation may arise from many pathways, including positive physiological adaptations from movement and energy expenditure, the process of skill learning and acquisition, the practice of skill development in flexible and cognitively demanding environments, motivational and affective factors in children who decide to participate in sport, and/or long-term benefits of procedural learning obtained during early experiences in sport participation. Therefore, future work should continue to address the questions in our field regarding the mechanistic effect of PA on brain health.

The overarching aim of public health advocacy is to continue promoting PA guidelines for the optimal health and development of all families. Given this, future research should implement PA programs that reduce the financial, time, transport, and family barriers to participation via (i) increased opportunities for in-school PA time or (ii) community-driven PA programs out of school. Such programs would continue to eliminate the disparities between children and families who can participate in PA and sport-related activities.

Here we highlight the wide range of health benefits that after-school sports and PA provide for children. We saw unique differences in the attentional components of brain health among children who participate in sports and related PA, along with greater aerobic fitness, muscular strength and flexibility, and energy expenditure. Although the mechanistic effects of PA on brain health remain elusive, there are clear widespread health benefits for children who engage in greater levels of activity. Although we controlled for the influence of socioeconomic and demographic factors in this investigation, health disparities do still exist for the children of families with fewer financial resources. PA opportunities and the subsequent health benefits should be equitable for all families. Our results support encouraging more PA opportunities within the school system and at the community level, thus promoting healthy brains and bodies for all children.

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CONFLICTS OF INTEREST AND SOURCE OF FUNDING

The authors report no conflicts of interest or financial support for this work.

DATA AVAILABILITY

The datasets analyzed in the current study are available from the Child Mind Institute Healthy Brain Network data descriptor and here: https://github.com/loganlaburi/CMI_Sports.

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