Social-Emotional Functioning Explains the Effects of Physical Activity on Academic Performance among Chinese Primary School Students: A Mediation Analysis

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Objective To examine the mediating effects of socioemotional and behavioral functioning in the association between physical activity and academic achievement in Chinese children.

Study design Chinese children (n = 17 318; aged 6-11 years) from the Shanghai Children's Health, Education and Lifestyle Evaluation study in 2014 were the source of data. Children reported the time spent in moderate-to-vigorous physical activities (MVPA) during weekdays and weekends. Parents rated their children's socioemotional and behavioral difficulties. Head teachers rated the academic performance of each student. A mediation analysis with multiple mediators was performed to test the mediation effects of 5 socioemotional and behavioral variables (emotional problems, conduct problems, hyperactivity and inattention, peer relationship, and prosocial behaviors) in the association between MVPA and academic achievement, adjusting for demographic and health-related variables.

Results Results revealed that MVPA was positively associated with academic performance ($b = 0.78$; SE = .01; $P < .001$). Conduct problems, hyperactivity and inattention, and peer problems showed significant mediating effects in the association between MVPA and academic achievement, with hyperactivity and inattention being the strongest mediator ($b = 0.38$; SE = 0.04; $P < .001$) accounting for 49% of the total effect.

Conclusions This study provides evidence that MVPA is associated with fewer socioemotional difficulties, which, in turn, is associated with better academic achievement. Promoting physical activity among school-aged children may benefit their overall development. *(J Pediatr 2019;208:74-80).*

See related articles, p 50 and p 66

Children and adolescents who are physically active have healthy bones and muscles, better physical fitness, a lower risk of being overweight and obese, fewer chronic diseases, and fewer mental disorders.[1-3] However, most children and adolescents in China do not meet the recommendations for 1 hour of moderate-to-vigorous physical activity (MVPA) daily.[4-6] To increase physical activity among children, the Chinese government carried out the "Sunshine Physical Exercise Project" in 2006 to mandate at least 60 minutes of daily physical exercise in primary schools. However, the evidence did not show a significant increase in children's overall levels of physical activity after school-wide physical activity promotion.[5]

Despite the implementation of policies and interventions promoting physical activity in Chinese schools, children remain physically inactive in general. Many schools have reduced physical education classes to maximize instructional time for mathematics, English and science, and used recess and other physical activity breaks for extracurricular study activities.[7,8] It is not surprising; schools in China give top priority to academic achievement. However, physical activity and academic instruction are not mutually exclusive; there is compelling evidence of the beneficial effects of physical activity, particularly MVPA, on children's cognition, brain development, and academic achievement in schools.[9-14] For example, several meta-analyses suggest that physical activity is associated with better performance on tests of intelligence, perceptual skills, mathematics-related skills, reading-related skills, and academic achievement in school-age children.[11,15,16]

MVPA	Moderate-to-vigorous physical activity
SEM	Structural equation modeling

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It is not entirely clear why physically active children perform better. Some researchers suggest that physical activity can promote academic achievement through structural and functional changes in the brain, including improved brain plasticity and stronger connections between brain regions that are related to faster and more efficient cognitive processing.[17] Other studies suggest that the association could be mediated by increased socioemotional development.[18,19] Physical activity promotes self-esteem,[20,21] decreases anxiety and depression,[21-24] builds cooperative peer relationships, and helps to burn off excess energy that otherwise leads to hyperactivity and externalizing problems.[25] Social emotional well-being benefits academic performance.[26,27] Although socioemotional and behavioral explanations are theoretically sound, few empirical studies have tested them.[20]

Using a large, population-based sample of Chinese primary school-aged children, this study aimed to examine whether MVPA is related to children's academic achievement and examine the mediating role of socioemotional and behavioral functioning in the association between MVPA and academic achievement. Based on a literature review, it was hypothesized that MVPA was positively associated with children's academic achievement, and that this relationship is mediated by improved socioemotional and behavioral functioning. Understanding the complex links between physical activities, socioemotional functioning, and academic well-being will provide policymakers, schools, and parents necessary data to continue to promote physical activity in children as well as inform strategies to promote optimal outcomes across developmental domains.

Methods

The participants in this study were drawn from the Shanghai Children's Health, Education and Lifestyle Evaluation study, a cross-sectional study designed to investigate lifestyles including physical activity, sleep, and nutrition of Shanghai primary school students. In 2014, we first obtained a complete list of primary schools in Shanghai with information on the number of students in each school from the Shanghai Education Commission and selected the study participants using a multistage cluster sampling approach. Briefly, the sampling procedure started with the 16 districts and 1 county in the Shanghai Municipality. Chongming County and Pudong New District were purposely selected because they are significantly different from the other regions and have unique modern urban planning. Five districts (3 urban, 1 periurban, 1 suburban) were then randomly selected from the remaining 15 districts in Shanghai (9 urban, 3 periurban, 3 suburban) using stratified random sampling. In total, 6 districts and 1 county were selected to represent the whole city. Second, we randomly selected 26 public primary schools, the primary sampling units, from the 7 districts and 1 county in proportion with population size. Third, we stratified the sampled schools by school size. All students from grades 1 to 5 were selected if a school had less than 1000 students, and one-half of the students in a school were selected if the number of students was greater than 1000, with random selection of classes. Finally, we interviewed the sampled students aged 6-11 years and also interviewed one of their parents and the head teacher of their classes.

The onsite investigation was carried out by medical students in their third or fourth year of study. We conducted training for the investigators and school administrators 2 weeks before the investigation. Onsite evaluation and questionnaire administration were completed within 2 weeks at the end of second semester. The initial sample consisted of 17 624 participants, and 17 318 of them answered the questionnaires. Sampling weights were computed using inverse probability weighting, which represented the inverse of the combined selection probability for each stage, including the nonresponse rate (1.74%). A total of 54 persons participated in the data entry. To control for the quality of data entry, we randomly selected 10 questionnaires for double entry from each data entry person at the beginning of this process. The rate of entry error was within 0.06%-9.55%. For the 5 data entry persons whose error rate was more than 5%, all of the data were double-entered and cross-checked. Details of the Shanghai Children's Health, Education and Lifestyle Evaluation study can be found in previous publications.[28,29]

All parents and teachers of the children who participated in the study gave written informed consent. This study was approved by the Institutional Review Board of the Shanghai Children's Medical Center, Shanghai Jiao Tong University (SCMCIRB-K2014033).

Participants

A total of 17 318 children recruited from grades 1 to 5 (9211 boys and 7923 girls) and their parents completed the study questionnaires. Because data were missing at random (ranging from 1.0% on academic achievement to 31.3% on family income), multiple imputation was performed to address missing data on study variables.[30]

Measures

MVPA. Children's physical activity was measured by the Children's Leisure Activities Study Survey Questionnaire-Chinese version, which was previously validated for Chinese children.[31,32] The Children's Leisure Activities Study Survey Questionnaire-Chinese version was used to access the frequency and duration of students' physical activity using a checklist of 31 physical activities and 14 sedentary activities. For each of the physical activities, students indicated the frequency and total duration (in hours and minutes) that they participated in that activity during weekdays, and, in a separate set of questions, during weekends. Based on the energy costs of human physical activities,[33] 14 activities were classified as moderate-intensity physical activities (3-5.9 metabolic equivalents), including, dance, gymnastics, hiking, table tennis, badminton, bowling balls, volleyball, bike riding, children's games, household chores, walking the dog, walking for exercise, physical education class, and travel by walking. Ten were classified as vigorous intensity physical activities (>6 metabolic equivalents), including tennis, soccer, basketball, swimming for fun,

swimming laps, squash, skipping rope, skating, martial art, and jogging or running. The daily time spent in MVPA was estimated by summing the total time spent in both vigorous and moderate intensity physical activities during weekdays and weekends and then dividing by 7.

Academic Achievement. Academic achievement was assessed using a questionnaire adapted from Oliviero Bruni's Teacher School Achievement Form.[34] The questionnaire includes 15 items covering different aspects of school achievement including attention, academic motivation, academic achievement in math and reading, and school engagement. The head teachers, who had supervised the students for more than 1 year, rated each student's performance on a 5-point scale ranging from 1 (excellent) to 5 (bad). Student's score on each item was reverse coded and then summed to form a composite index range from 0 to 75, with a higher score indicating better academic performance. The Cronbach alpha coefficient for this questionnaire was 0.962 (subscale alphas ranged from 0.905 to 0.961). The study used the total score of academic achievement as an outcome variable.

Socioemotional and Behavioral Functioning. Parents were asked to complete the Strengths and Difficulties Questionnaire. The Strengths and Difficulties Questionnaire is a 25-item emotional and behavioral screening questionnaire that consists of 5 subscales: emotional, conduct, hyperactivity and inattention, peer relationship problems, and prosocial behavior. Responses on each are made on a 3-point scale ranging from 0 (not true) to 2 (certainly true). Scores on each subscale range from 0 to 10. Higher scores on the first 4 subscales and lower scores on the prosocial subscale indicate greater difficulties. The Strengths and Difficulties Questionnaire was reported to have high test-retest reliability and good validity,[35] and has been used in large epidemiologic studies such as the British Child Mental Health Survey and the Millennium Cohort Study.[36,37] The scale was also validated for Chinese children.[31]

Covariates. Demographic characteristics assessed in the study include parent education (middle school or lower, high school, or college or higher) and household annual income (<¥30 000, ¥30 000-¥100 000, or ≥¥100 000) reported by parents. The child's age (<8 years, 8-10 years, or ≥10 years) and sex (male or female) were included as covariates in all analyses.

Statistical Analyses

Descriptive analyses were initially conducted to assess the percentage of missing values in all variables. We performed multiple imputations 5 times with a chained approach and separate regression model for each variable. In this procedure, a series of regression models are run whereby each variable with missing data is modeled conditional upon the other variables in the data.[38] Details of the process can be found in a previous study.[29] Using the multiple imputed sample, we first described the average time spent in MVPA, socioemotional and behavioral functioning, and academic performance. Zero-order correlations were calculated for the main study variables. Mediation analyses with multiple mediators was conducted using a structural equation modeling (SEM) framework. The SEM allows all 5 socioemotional and behavioral variables to be included simultaneously as mediating variables, and can also accommodate cases in which the mediators affect one another. The analysis produces traditional direct effects (ie, path *a, b, c*, and *c'*), as well as indirect effects (ie, total indirect effect of the mediators and specific indirect effect of each mediator, or *ab* paths). Robust estimation was used with sampling weights and multiple imputed data to estimate the SEs and CIs. Because age, sex, parent education, and family income have been shown to be related to academic performance, they were controlled for in the mediation analysis. All analyses were conducted with sampling weights to account for survey design features. Linear associations were tested between study variables because the variables were measured on a continuous scale, and assumptions on nonlinear associations (eg, a logistic regression model for a binary response variable) were not appropriate for the SEM in the present study. All analyses were performed using Stata (version 14.0; Stata Corp, College Station, Texas).

Results

Descriptive statistics of the student characteristics and key measurements based on the imputed data are shown in **Table I**. Participants in the sample were balanced on sex (53.4% males). Most were between the age of 8 and 10 years (41.4%), and approximately one-third were 10 years or older (31.8%). The majority of the participants (88.4%) had parents with an education beyond high school—29.2% had completed high school and 49.2% had completed college. Nearly one-half of the participants (46.4%) reported an annual household income of greater than ¥100 000, and 10.1% of less than ¥30 000. The average hours of MVPA per day was 94.9 (SE = 0.8) minutes.

Table I. Descriptive statistics of sample

	%	SE	M	SE
Child's sex				
Female	46.6	0.5		
Male	53.4	0.5		
Age, years				
<8	26.8	0.5		
8-10	41.4	0.5		
≥10	31.8	0.5		
Parents' education level				
Less than high school	21.6	0.4		
High school	29.2	0.5		
College or higher	49.2	0.5		
Household annual income, ¥				
<30 000	10.1	0.3		
30 000-100 000	43.6	0.6		
≥100 000	46.4	0.7		
MVPA (minutes/day)			94.9	0.8
Academic achievement			58.9	0.1
Emotional problems			1.8	0.0
Conduct problems			1.6	0.0
Hyperactivity and inattention			4.3	0.0
Peer relationship problems			2.6	0.0
Prosocial behaviors			7.4	0.0

Descriptive statistics were obtained with the imputed data (n = 17 318).

Table II. Descriptive statistics and correlations among study variables

	MVPA	APS	EMO	CON	HYP	PEE	PRO
MVPA	—						
APS	0.12*	—					
EMO	−0.07*	−0.10*	—				
CON	−0.04*	−0.21*	0.27*	—			
HYP	−0.14*	−0.38*	0.23*	0.45*	—		
PEE	−0.08*	−0.22*	0.31*	0.20*	0.19*	—	
PRO	0.11*	0.18*	−0.13*	−0.36*	−0.33*	−0.26*	—

APS, academic achievement; *CON*, conduct problems; *EMO*, emotional symptoms; *HYP*, hyperactivity; *PEE*, peer relationship; *PRO*, prosocial behaviors.
*$P < .001$.

Table II shows the correlations between MVPA, socioemotional, and behavioral variables, and academic achievement. Results revealed that MVPA was positively correlated with academic performance ($r = 0.12$; $P < .001$). MVPA was negatively correlated with emotional problems ($r = -0.07$; $P < .001$), conduct problems ($r = -0.04$; $P < .001$), hyperactivity and inattention ($r = -0.14$; $P < .001$), and peer relationship problems ($r = -0.08$; $P < .001$), and positively correlated with prosocial behaviors ($r = 0.11$; $P < .001$). The correlation matrix was established to guide the development of our SEM.

Mediation analysis with multiple mediators was performed to examine whether socioemotional functioning variables mediated the relationship between MVPA and academic performance. Correlations between mediators that are higher than 0.2 were taken into account in the model (**Figure**). For the direct effects from MVPA to mediators (ie, *a* paths), MVPA was significantly associated with each of the socioemotional functioning subdomains, including emotional problems ($b = -0.08$; $P < .001$), conduct problems ($b = -0.05$; $P < .001$), hyperactivity and inattention ($b = -0.25$; $P < .001$), peer relationship problems ($b = -0.09$; $P < .001$), and prosocial behaviors ($b = 0.15$; $P < .001$). For the direct effects from mediators to academic performance (ie, *b* paths), conduct problems, hyperactivity, and peer relationships were significantly associated with academic performance ($b = -0.28$ [$P < .05$], $b = 1.53$ [$P < .001$], and $b = -0.90$ [$P < .001$], respectively). Because the model was fit with vce(robust), therefore only stats of residuals are valid ($\chi^2 = 1542.35$ [$P < .001$], standardized root mean square residual (SRMR) = 0.044; coefficients of determination [R-square] = 0.124).

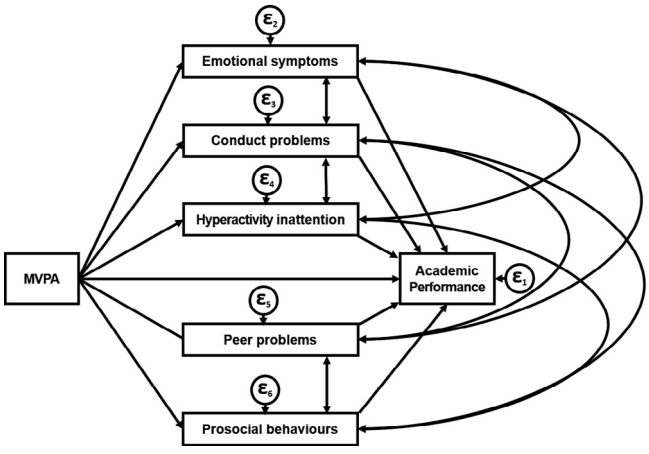

Figure. A multiple mediator model with 5 mediators. The independent variable (MVPA) is hypothesized to effect the dependent variable (academic performance) through the mediators (emotional symptoms, conduct problems, hyperactivity and inattention, peer problems, and prosocial behaviors). Correlations between mediators that are higher than 0.2 were taken into account in the model.

When the mediators were not included in the model, the association between MVPA and academic performance (ie, total effect) was significant ($b = 0.78$; $P < .001$). This suggested that a 1-hour weekly increase in MVPA was associated with a 0.78-point increase in academic performance measured on a 0- to 75-point scale (bad to excellent). Once the mediators were included, the association between MVPA on academic performance (ie, direct effect) was reduced ($b = 0.32$; $P = .006$). The indirect effect of MVPA on academic performance mediated through conduct problems, hyperactivity and inattention, and peer problems was also significant ($b = 0.01$ [$P < .05$]; $b = 0.38$ [$P < .001$]; $b = 0.08$ [$P < .001$]); they explained 1%, 49%, and 10% of the association between MVPA and academic achievement, respectively. Details of the analysis are presented in **Table III**.

Discussion

The purpose of this study was to examine socioemotional and behavioral functioning as mediators in the relationship between MVPA and academic achievement in a large, population-based sample of Chinese primary school children. Five socioemotional and behavioral variables were tested as potential mediators. We found that MVPA was positively associated with academic achievement in Chinese primary school children, after controlling for a range of confounders. Moreover, fewer conduct problems, hyperactivity-inattention, and peer problems are the mediators through which MVPA promotes better academic achievement. The mediating effect of the three mediators account for 1%, 49%, and 10% of the total effect. This study tested a range of noncognitive functions in the association between physical activity and academic performance.

This study was unique in that we examined physical activity in a large, population-based sample of children in Shanghai. Using the Children's Leisure Activities Study Survey Questionnaire-Chinese version questionnaire, we found that an average of 94.9 minutes was spent in MVPA daily among children in Shanghai, higher than a sample of children aged 9-12 years in Hong Kong (66.1 minutes of daily MVPA),[39] and lower than a sample in Australian children (128.1 minutes of daily MVPA)[40] that assessed MVPA using the same instrument. Studies have reported that most Chinese children do not adhere to the recommended guideline of 1 hour of MVPA per day.[4,41,42] In the current study, we found Shanghai children on average have met the recommended 1 hour of daily MVPA;

Table III. Mediation effects of MVPA on academic performance through control social emotional functioning

	Path coefficients		Indirect effects			
Mediators (n = 17 318)	IV to mediators (path a)	Mediators to DV (path b)	Point estimate (path ab)	SE	CI lower	CI upper
Emotional symptoms	−0.08†	0.16	−0.01	0.01	−0.03	0.00
Conduct problems	−0.05†	−0.28*	0.01*	0.01	0.00	0.03
Hyperactivity	−0.25†	−1.53†	0.38†	0.04	0.30	0.46
Peer relationship	−0.09†	−0.90†	0.08†	0.02	0.05	0.12
Prosocial behavior	0.15†	−0.05	−0.01	0.01	−0.03	0.02

DV, dependent variable; *IV*, independent variable.
CI estimated from robust method.
*$P < .05$.
†$P < .001$.

however, great variability exists within the sample—38.4% of children failed to meet the recommendation, which is similar to UK children.[43] Given the population of children in Shanghai public schools, it is clear that a large number of students do not engage in an adequate amount of physical activity. Future research is needed to examine sources of variability in physical activity among Chinese students and to plan effective strategies to increase physical activity both inside and outside the school setting.

This study has found a moderate, positive association between MVPA and academic achievement, consistent with the small to moderate effect sizes found in the US,[9] Taiwan,[44] and the Netherlands.[15] Our results are also consistent with several experimental studies in which aerobic exercise or MVPA predicts better performance on cognitive tasks and standardized test of academic achievement.[12,17,45,46] In a meta-analysis of 26 intervention studies, Álvarezbueno et al found that physical activity (PA) improves classroom behaviors and benefits several aspects of academic achievement, especially mathematics-related skills, reading, and composite scores in youth.[16] Zhang et al examined the association between physical activity and academic achievement in a sample of fifth-grade students in Shanghai.[8] They found that vigorous and minimal, but not moderate, intensity physical activity was positively associated with teacher-rated academic achievement. In that study, physical activity was assessed by asking the children to report the number of days per week they participate in vigorous, moderate, or minimal physical activities, and the children may lack a full understanding of what constitute vigorous, moderate, and minimal physical activities. The current study provides further evidence that spending time on various forms of MVPA have the potential to benefit children's academic achievement.

Increased MVPA might improve academic achievement in a number of ways. We found that socioemotional difficulties are potential mediators in this association. In our model, MVPA was associated with all the 5 subdomains of socioemotional functioning. A meta-analysis showed significant, small to moderate effects of physical activity interventions on externalizing problems and internalizing problems.[47] Also, strong evidence has been found that physical activity will improve self-esteem in children, which could lead to increased prosocial behaviors.[21]

In terms of the effect of mental health on academic performance, the findings are more complicated. Longitudinal and experimental studies have found that improved social emotional functioning would enhance academic performance[48-53]; however, differences existed in various domains. Cross-lagged models have been used to test the paths between teacher-reported internalizing and externalizing problems and parent-reported academic performance, and the result revealed pathways from mostly externalizing problems to academic performance; no paths emerged from internalizing problems to academic performance.[54] Other studies also found that high self-reported depression and anxiety at baseline did not hinder academic performance over time to a large extent.[55] These findings would explain why emotional symptoms are not significantly associated with academic performance in this study.

Hyperactivity and attention is the strongest mediator in the relationship between physical activity and academic achievement, which is consistent with prior findings that physical activity improves concentration and attention and leads to more on-task behaviors and better executive control.[56] For example, a study found that a high level of fitness was associated with better attention, working memory, and speed response in children.[45] Another review of several large-scale experimental studies suggests that physical activity has an effect on cognitive function.[57] The cognitive effect of physical activity might be attributable to a biological mechanism associated with MVPA, including increased blood and oxygen flow to the brain, increased levels of norepinephrine and endorphins, and improved synaptic plasticity.[15] We also found that the mediating effects of conduct problems and peer relationships, although smaller in effect sizes, are significant, highlighting the social and emotional pathways through which physical activity can influence academic achievement. The MVPAs that school-aged children participate in are typically organized by peer groups, and thus allow children to practice and improve social and emotional skills, such as self-esteem, self-efficacy, social competence, stress coping, and persistence in adversity.[58,59] Such socioemotional competence is crucial to academic achievement.

Although this study statistically tested the mediation effect of socioemotional functioning in the association between physical activity and academic achievement, causal inferences should be made with caution given the cross-sectional design of the study. For example, we cannot infer that an increase in MVPA would necessarily improve children's socioemotional

competence. Future studies with a longitudinal experimental design are needed to test the effects of physical activity on socioemotional and academic development in children. Second, although our measurement of physical activity aims to account for the frequency, duration, and types of physical activity a child participates in, children, particularly younger children, are subject to recall and desirability biases. We asked the parents to assist their children to finish the questionnaire, which might help to ensure comprehension of questions and reduce bias in self-report.

Despite these limitations, the study had several strengths. First, we used a unique, population-based dataset of approximately 17 000 children in Shanghai. By applying sampling weights, we were able to estimate the prevalence of MVPA that are representative of the school-aged population in Shanghai. Furthermore, we found mediating effects of multiple domains of socioemotional functioning in the association between MVPA and academic achievement, which has important implications for schools in China, because many professionals still believe more time needs to be allocated to academic instruction rather than to MVPA in primary schools. In addition, the data also allowed for the inclusion of key covariates such as demographic and health-related variables; thus, we were able to account for the variance from these variables to better disentangle the possible pathways through which MVPA relates to academic achievement.

This study provides additional evidence that MVPA is associated with fewer socioemotional difficulties, which in turn is associated with better academic performance. Therefore, promoting physical activity among school-aged children has the potential to benefit the overall development of children. ■

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Data Statement

Data sharing statement available at www.jpeds.com.

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