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ORIGINAL RESEARCH

# Can Moving More and Sitting Less Improve the Academic Engagement of Adolescents?- A Study Based on Junior High School Students in Shanghai, China

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**Purpose:** The purpose of this study was to examine the relationships between academic engagement and moderate-to-vigorous physical activity (MVPA), muscle-strengthening exercise (MSE) and sedentary behavior (SB) among adolescents, so as to provide evidence from the perspective of exercising for students to learn efficiently, teachers to improve classroom teaching, and schools to improve educational quality.

**Methods:** A questionnaire survey was conducted in 12 junior high schools in Shanghai, China, which were selected by a multi-stage stratified cluster sampling method. Then, with the valid data of 2078 students collected from the survey. A data analysis was performed using SPSS Statistics 26.0. Multiple linear regression models were adopted to analyze the factors affecting adolescent academic engagement and to determine whether MVPA, MSE, and SB play roles in it.

**Results:** (1) The differences in academic engagement depended on the exercise adherence to the recommended amount of MVPA, MSE, and screen-based SB. (2) In terms of the three independent variables of total time, MSE ($\beta = 0.206$) and MVPA ($\beta = 0.175$) showed a significant positive correlation with academic engagement, while SB ($\beta = -0.155$) was negatively correlated with academic engagement. (3) From the linear regression model of eight combination groups divided by the exercise adherence to the recommended amount of MVPA, MSE and SB, the group that met none of the recommendations ($\beta = -0.235$) showed a significant negative effect on academic engagement, while the groups that met any two or all three of the recommendations demonstrated strong positive correlations with academic engagement ($P < 0.001$).

**Conclusion:** Increasing adolescents' muscle-strengthening exercise and moderate-to-vigorous physical activity and reducing sedentary behavior can effectively promote academic engagement. Therefore, adolescents are suggested to reach the recommended amounts of physical activity, muscle-strengthening exercise, and sedentary behavior so as to improve academic engagement more effectively.

**Keywords:** moderate-to-vigorous physical activity, muscle-strengthening exercise, academic engagement, sedentary behaviors

## Introduction

Academic engagement as a positive learning behavior has been considered an effective measure of educational quality in Western countries since the 1990s.[1] Its importance has been widely recognized in the academic community nowadays, and some scholars have even explicitly pointed out its undoubted relevance in education. Educational quality is regarded as the lifeline of education. Since the 1980s, the US National Commission on Excellence in Education has issued a series of educational reform documents emphasizing improving the quality of basic education.[2] The Ministry of Education of the People's Republic of China (MOE of PRC) has also issued a number of policies, clearly stating the need to "increase students' academic engagement", marking the official incorporation of "academic engagement", an educational research term, into the national policy discourse system.[3] In 2017, the Canadian Joint Conference of Advanced Business Schools identified academic engagement as one of the "three pillars" of quality standards for school development.[4] In addition, in

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the past ten years, the research on the field of academic engagement has attracted wide attention in Europe, Oceania, South America and other regions.[5–8] While education quality is highly valued everywhere today, quitting school is yet a global challenge with millions of dropouts almost every year.[9] The learning problems of students matter to educational quality and the future of a country, and thus need to be prioritized and addressed. Academic engagement, as an indicator of educational quality, can accurately reflect students' learning ability and effectively predict their academic achievement.[10] It is also seen as a "cure" for students' study weariness and dropping out.[11] Therefore, paying attention to and improving academic engagement can promote students' academic growth, educational quality and even the overall development of schools.

However, there is a huge gap in the policies and research on academic engagement in primary and secondary schools in China, which is obviously unreasonable, given the important roles of primary and secondary education in the entire education system. Academic engagement, a key subject of positive psychology, refers to a state of mind where students feel sustained enthusiasm for learning.[12] Academic engagement can bring many benefits to students' healthy development, such as more effective learning, better academic achievement,[13] greater sense of self-control,[14] fewer negative psychological symptoms,[15] more happiness,[16] and prevention against dropping out and various risky behaviors.[17]

The junior high school stage is not only an important period in students' academic careers, which can be a watershed of academic performance and easily find study weariness arise, but also the puberty phase in students' life course where rapid biological and psychosocial changes take place just like "storming".[18] Effective academic engagement is the foundation and key to helping adolescents continue to enter high schools and universities and enjoy the long-term benefits brought by education.[19,20] But a large amount of research has found that as students move on to higher grades, their academic engagement tends to go down.[21,22] According to statistics from the MOE of PRC,[23] among dropouts in China, the proportion of junior high school students is higher than that of primary or high school students, and more than 60% of them (mainly in the second year and in the third year) report study weariness or learning difficulties. As a result, the junior high school stage is a critical period for paying attention to academic engagement.

Schools have long used academic performance as the key measure for student evaluation, excessively focusing on improving students' test scores and finally giving rise to an exam-oriented education mode.[24] Schools and parents place much greater emphasis on academic subjects than on physical education. Some parents even prevent their children from participating in physical exercise, claiming that it takes up study time.[25] To some extent, this has contributed to the current social phenomenon of insufficient physical activity and prolonged sedentary time for children and adolescents in China.[26] The Guidelines on Physical Activity and Sedentary Behavior (2020)[27] published by the World Health Organization (WHO) and the Physical Activity Guidelines for Chinese (2021)[28] issued by National Health Commission of the People's Republic of China both propose requirements for children and adolescents to do moderate-to-vigorous physical activity (MVPA) for no less than 60 minutes per day and muscle-strengthening exercise (MSE) no less than 3 times a week. Also, China points out that the screen time (ST) for children and adolescents should be less than 2 hours per day. According to WHO's definition,[27] MVPA is divided into two parts, on an absolute scale, one being moderate-intensity activity which refers to a physical activity that is performed between 3 and less than 6 times the intensity of rest, the other being vigorous-intensity activity which refers to a physical activity that is performed at 6.0 or more metabolic equivalent of task; MSE is defined as physical activity and exercise that increase skeletal muscle strength, power, endurance, and mass, such as strength training, resistance training, and muscular strength and endurance exercises; ST is defined as time spent in watching screen-based entertainment, but active screen-based games where physical activity or movement is required are not included.

There have been studies that look at the importance of moving more and sitting less in schools and put forward the idea of promoting healthy living and behavior change by engaging students, their families, the school environment and the neighboring communities, but none of these studies have revealed the relevance of academic engagement, one of the variables.[29] Therefore, this study focuses on the relationships between academic engagement and moving more and sitting less. Firstly, physical activity has significant implications for adolescents' positive emotions, attention, memory, and academic performance.[30,31] All of which are closely related to academic engagement, but global epidemiological data show that 80% of teenagers do not meet the recommended standards for physical activity. [32] Secondly, regular MSE can strengthen the hearts, musculoskeletal systems, and cognitive outcomes of children and adolescents, and reduce their

negative emotions,[33–35] but a national survey in China finds that the number of junior high school students who meet the recommended amount of MSE is even smaller than that of primary school students.[36] Thirdly, sedentary behavior (or SB,[27] which is defined as any waking behavior characterized by energy expenditure of 1.5 metabolic equivalent of task or less while sitting, reclining, or lying) among teenagers has surged in the past decade with the emergence of mobile technologies.[37] In the context of Chinese education, students start to use mobile phones typically in junior high schools,[38] but research shows that about 37% of children and adolescents in China do not meet the ST recommendations.[39] In addition, a large number of studies suggest that there is a strong correlation between high levels of ST and anxiety symptoms, fatigue, lack of energy and inattention in adolescents,[40,41] among which absorption and vigor are important components of academic engagement. However, there is still a lack of empirical studies on the relationships between academic engagement and MVPA, MSE, and SB.

Adolescence, which WHO refers to as "the second chance of the second decade", is a crucial period in life.[42] Doing physical exercise during this period will greatly affect students' academic careers and even their life-long development.[43] Can moving more and sitting less really improve the academic engagement of adolescents? To figure out this question, based on the above theoretical evidence, we proposed the following hypotheses:

Hypothesis 1. Adolescents' academic engagement has positive correlations with the total time of MVPA and of MSE, and has a negative correlation with the total time of SB.

Hypothesis 2. Adolescents' academic engagement has positive correlations with different types of MVPA and MSE, and has negative correlations with different types of SB.

Hypothesis 3. Adolescents' academic engagement has positive correlations with different combinations of MVPA, MSE and SB that meet the recommendations, and has a negative correlation with the combination where all the three variables meet none of the recommendations.

# Methods

## Participants and Procedures

A multi-stage stratified cluster sampling method was adopted to select a total of 2200 students from 12 junior high schools in Yangpu District, Putuo District, Minhang District, and Pudong New Area in Shanghai. Only students in the first and second years were included because students in the third year were preparing for high school entrance exams. This study was reviewed and approved by the Ethics Committee of the Shanghai University of Sport. Before the assessments, all children were required to assent and their parents were required to provide informed consent.

Firstly, the researchers contacted the teachers from those 12 schools and arranged a survey at a designated time period and a designated place for each school. Secondly, the 2200 selected students were gathered in their schools and received detailed guidance for the survey from trained researchers. Then, each participating student filled out the paper questionnaires independently with adequate time and returned them on site. The execution in each school was supervised by 3 teachers, and the questionnaires were collected by 5 graduate students. Finally, we made a review on the 2200 questionnaires distributed. A total of 2105 questionnaires were collected (96% of response rate), comprised of 2078 valid ones and 27 invalid ones (about 94.5% of effective response rate). The valid questionnaires were from 1076 male students and 1002 female students.

## Measures

### Demographic Variables

The following demographic information was collected: gender, age, ethnicity (Han or minority), height, weight, and BMI.

### Moderate-to-Vigorous Physical Activity (MVPA)

The measurement of MVPA was based on the Chinese version of the Health Behavior in School-aged Children (HBSC) survey questionnaire. It was adapted by the National Physical Health Standards for Students testing project led of the MOE of PRC, and the testing of validity and reliability was performed in a sample of adolescents.[44] In the adapted HBSC

questionnaire, MVPA was divided into two questions for school days and weekends: "During the past 7 days, did you spend at least 60 minutes each day from Monday to Friday on moderate to vigorous physical activity?" and "During the past 7 days, did you spend at least 60 minutes each day from Saturday to Sunday on moderate to vigorous physical activity?". This item shows acceptable test-retest reliability (ICC = 0.77) and concurrent validity (p = 0.40, using the accelerometer as the standard) for children and adolescents.[45] The guidelines of WHO and the Physical Activity Guidelines for Chinese (2021) point out that more than 60 minutes of MVPA per day is in line with the recommended amount for children and adolescents.[27,28]

### Muscle-Strengthening Exercise (MSE)

For the data of students' MSE, the following question was introduced: "How many days in the past week did you spend on muscle-strengthening exercise (such as push-ups, sit-ups, and weightlifting)?" This item has been used in the United States,[46] Canada[47] and other countries[48] for monitoring daily health behaviors. This item has shown acceptable test-retest reliability (ICC = 0.55).[36] According to the guidelines of WHO and the Physical Activity Guidelines for Chinese (2021), children and adolescents reporting at least 3 days of MSE (no more than 7 days) in the past week meet the recommended amount.[27,28]

### Sedentary Behaviors (SB)

SB were introduced from the Chinese version of HBSC survey questionnaire.[44,49] The survey requires participants to report the time they spend during the past 7 days on the three main categories of SB, namely playing computer / video games, using computers for activities other than gaming, and watching TV, on school days and on weekends, respectively. Daily screen time was calculated using the formula: (total screen time on school days * 5 + total screen time on weekends * 2) / 7. According to the Physical Activity Guidelines for Chinese (2021), the recommended amount of screen-based SB for children and adolescents is no more than 2 hours per day.[28] This item shows acceptable average test-retest reliability (ICC = 0.59).[44]

### Academic Engagement

The level of adolescent academic engagement was measured using the Chinese version of the Utrecht Work Engagement Scale for Students (UWES-S),[50] which was drafted by Schaufeli et al (2002)[12] and revised by Fang et al (2008). The scale consists of 17 items which are categorized into three subscales: vigor (eg, at my job, I feel strong and vigorous), dedication (eg, I feel the work that I do full of meaning and purpose), and absorption (eg, when I am working, I forget everything else around me). Each item is measured by a 7-point Likert scale, ranging from "1" representing "ever" to "7" standing for "always". A higher point indicates a higher level of academic engagement. Given the good reliability and validity of the Chinese version of UWES-S, the questionnaire can be used to measure the level of academic engagement among Chinese adolescents and be adopted by related studies. The overall Cronbach's alpha coefficient for this scale was 0.95 (0.86 for vigor, 0.91 for dedication and 0.91 for absorption).[50]

## Data Analyses

According to our assumptions. First, descriptive statistics was introduced to analyze the profile of all the dimensions of academic engagement, MVPA, MSE, SB, as well as participants' gender, age and BMI. Then, an independent-samples *t*-test was used to compare the differences in the means of academic engagement between the groups that met the recommended amount of MVPA, MSE, and screen-based SB, and the groups that did not. After that, multiple linear regression models were adopted to analyze the factors affecting adolescent academic engagement and to determine whether MVPA, MSE, and SB play roles in it. The models were tested using the following sets of independent variables: total time, types and time periods, and exercise adherence that was further categorized into 8 combination groups including 1 group of "None" (none of the items met the recommendations), 3 groups of "One" (only one of the items, ie, MVPA, SB, or MSE, met the recommendations), 3 groups of "Two" (only two of the items, ie, MVPA and SB, MVPA and MSE, or SB and MSE, met the recommendations), and 1 group of "Three" (all the items met the recommendations). Finally, data arrangement and statistical analyses were performed using SPSS Statistics 26.0 (IBM, Chicago, IL, USA) The level of statistical significance was set at $p < 0.05$.

# Results

## Sample Characteristics

The sample characteristics are shown in Table 1. The samples were evenly distributed in terms of gender, with males and females accounting for 51.8% and 48.2%, respectively. In terms of age, the percentages of those aged 12 and under, 13, and 14 and over were 33.9%, 47.9%, and 18.2%, respectively.

All measurement data included in this study were tested and showed a normal distribution. The mean day of overall MVPA was 3.96, including 2.90 on school days and 1.06 on weekends; the mean day of MSE was 2.44; the mean hour of screen-based SB was 5.88, including 2.26 on school days and 3.63 on weekends; the average point for academic engagement was 68.63, including 23.83 in vigor, 21.01 in dedication, and 23.77 in absorption.

**Table 1** Demographic Information and Descriptive Statistics of Independent and Dependent Variables

| **Categorical Variables** | **n** | **%** |
|---|---|---|
| Sex | | |
| Boys | 1076 | 51.8 |
| Girls | 1002 | 48.2 |
| Age (years) | | |
| 12 and younger | 705 | 33.9 |
| 13 | 995 | 47.9 |
| 14 and older | 378 | 18.2 |
| Nationality | | |
| Han | 2043 | 98.3 |
| Minority | 35 | 1.7 |
| **Continuous variables** | **Mean** | **SD** |
| Height | 1.63 | 0.08 |
| Weight | 55.70 | 17.78 |
| BMI | 20.82 | 6.31 |
| Total | | |
| MVPA | 3.96 | 1.90 |
| MSE | 2.44 | 2.10 |
| SB | 5.88 | 5.32 |
| School days | | |
| MVPA | 2.90 | 1.59 |
| SB | 2.26 | 2.75 |
| TV | 0.49 | 0.95 |
| GAME | 0.97 | 1.23 |
| PC | 0.80 | 1.23 |
| Weekends | | |
| MVPA | 1.06 | 0.65 |
| SB | 3.63 | 3.07 |
| TV | 0.98 | 1.27 |
| GAME | 1.57 | 1.50 |
| PC | 1.08 | 1.37 |
| Academic Engagement | 68.63 | 12.57 |
| Vigor | 23.83 | 4.80 |
| Dedication | 21.01 | 3.80 |
| Absorption | 23.77 | 4.88 |

**Abbreviations**: SB, sedentary behaviors; MSE, muscle-strengthening exercise; MVPA, moderate-to-vigorous physical activity; TV, watching TV; GAME, playing computer/video games; PC: using computers for activities other than gaming; BMI, Body Mass Index.

## Difference Analysis

Each item of MVPA, SB, and MSE was divided into a Not Met group (where the recommended amount is not met) and a Met group (where the recommended amount is met). Then, an independent-samples *t*-test was performed on the academic engagement points (Table 2). Significant differences ($p < 0.001$) were found in academic engagement and its three dimensions of vigor, dedication, and absorption, with all the Met groups performing better than the Not Met groups.

## Correlations Between Academic Engagement and the Total Time of MVPA, MSE, and SB

Hypothesis 1 assumed that adolescents' academic engagement has positive correlations with the total time of MVPA and of MSE, and has a negative correlation with the total time of SB. To test the hypothesis, a multiple linear regression model was built using the total time of MSE, SB, and MVPA as independent variables (Table 3). The results showed that all three independent variables had a significant impact on academic engagement: MSE (β = 0.206, 95% CI: 0.948, 1.528) and MVPA (β = 0.163, 95% CI: 0.837, 1.478) had significant positive correlations with academic engagement, while SB (β = 0.048, 95% CI: 0.461, −0.271) had a significant negative correlation with academic engagement. The results supported Hypothesis 1.

## Correlations Between Academic Engagement and Different Types of MVPA, MSE, and SB

Hypothesis 2 assumed that adolescents' academic engagement has positive correlations with different types of MVPA and MSE, and has negative correlations with different types of SB. To test the hypothesis, a multiple linear regression model was built using different types of MSE, SB, and MVPA as independent variables (Table 4). In terms of all SB dimensions, playing games on school days (β = −0.076, 95% CI: −1.300, −0.246) and on weekends (β = −0.114, 95% CI: −1.397, −0.523) showed significant negative correlations with academic engagement, while watching TV and using computers on school days and on weekends demonstrated no significant correlation with academic engagement. MSE (β = 0.202, 95% CI: 0.921, 1.499), MVPA on school days (β = 0.139, 95% CI: 0.716, 1.471), and MVPA on weekends (β = 0.068, 95% CI: 0.479, 2.152) were positively correlated with academic engagement. The hypothesis of positive correlations between adolescents' academic engagement and different types of MVPA and MSE was supported, while the hypothesis of negative correlations between adolescents' academic engagement and different types of SB was partly supported, as watching TV and using computers on school days and on weekends was not significantly correlated with academic engagement.

## Correlations Between Academic Engagement and Different Combinations of MVPA, MSE, and SB Recommendations

Hypothesis 3 assumed that adolescents' academic engagement has positive correlations with different combinations of MVPA, MSE and SB that meet the recommendations, and has a negative correlation with the combination where all the three variables meet none of the recommendations. To test the hypothesis, a linear regression model was built using eight combination groups as independent variables (Table 5), which were categorized by exercise adherence to the recommended amount of MVPA, MSE, and SB. "None" (β = −0.235, 95% CI: −7.921, −5.524) was negatively related to academic engagement. "One" for MVPA (β = 0.190, 95% CI: 6.208, 9.755), for MSE (β = 0.295, 95% CI: 6.458, 8.551), and for SB (β = 0.144, 95% CI: 2.562, 4.721) all showed significant positive correlations with academic engagement. "Two" for MVPA and SB (β = 0.169, 95% CI: 6.445, 10.772), for MVPA and MSE (β = 0.195, 95% CI: 6.883, 10.685), and for SB and MSE (β = 0.260, 95% CI: 6.362, 8.784) all showed significant positive correlations with academic engagement. "Three" (β = 0.165, 95% CI: 6.668, 11.298) revealed a strong positive correlation with academic engagement. Therefore, Hypothesis 3 was supported.

# Discussion

To test the hypothesis that MVPA, MSE, and SB will affect academic engagement of junior high school students. This study analyzed a sample of 2078 junior high school students in Shanghai by using a multi-stage stratified cluster sampling method and tested different models using the following sets of independent variables: (1) total time of MVPA, MSE, and SB; (2) types

**Table 2** The Difference Between the Satisfaction of MVPA, SB and MSE Recommendations and Academic Engagement

| | MVPA Recommendation | | | | | | SB Recommendation | | | | | | MSE Recommendation | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Not met | | Met | | t | *p* | Not met | | Met | | t | *p* | Not met | | Met | | t | *p* |
| | Mean | SD | Mean | SD | | | Mean | SD | Mean | SD | | | Mean | SD | Mean | SD | | |
| Vigor | 23.51 | 4.78 | 26.71 | 3.99 | 9.26 | <0.001 | 4.60 | 0.13 | 4.96 | 0.16 | 5.87 | <0.001 | 4.54 | 0.15 | 4.60 | 0.13 | 14.55 | <0.001 |
| Dedication | 20.82 | 3.81 | 22.75 | 3.21 | 7.05 | <0.001 | 3.50 | 0.10 | 4.06 | 0.13 | 6.90 | <0.001 | 3.55 | 0.12 | 3.80 | 0.11 | 10.60 | <0.001 |
| Absorption | 23.48 | 4.85 | 26.35 | 4.35 | 8.16 | <0.001 | 4.58 | 0.13 | 5.15 | 0.17 | 5.82 | <0.001 | 4.49 | 0.15 | 4.80 | 0.14 | 13.65 | <0.001 |
| Academic engagement | 67.83 | 12.50 | 75.81 | 10.81 | 8.83 | <0.001 | 11.83 | 0.35 | 13.20 | 0.44 | 6.62 | <0.001 | 11.68 | 0.39 | 12.26 | 0.35 | 14.06 | <0.001 |

**Abbreviations**: Met, the recommended amount is met; Not met, the recommended amount is not met.



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**Table 3** Association Between All MSE, SB, MVPA Times and Academic Engagement

| | Unstandardized Coefficients | | Standardized Coefficients | t | p | 95% CI |
|---|---|---|---|---|---|---|
| | B | Std. Error | β | | | |
| MSE | 1.238 | 0.148 | 0.206 | 8.37 | <0.001 | [0.948, 1.528] |
| SB | −0.366 | 0.048 | −0.155 | −7.58 | <0.001 | [−0.461, −0.271] |
| MVPA | 1.158 | 0.163 | 0.175 | 7.09 | <0.001 | [0.837, 1.478] |

**Table 4** Association Between Different Types of MSE, MVPA, SB and Academic Engagement

| | Unstandardized Coefficients | | Standardized Coefficients | t | p | 95% CI |
|---|---|---|---|---|---|---|
| | B | Std. Error | β | | | |
| **MSE** | 1.210 | 0.148 | 0.202 | 8.201 | <0.001 | [0.921, 1.499] |
| **Weekends** | | | | | | |
| MVPA | 1.315 | 0.427 | 0.068 | 3.083 | 0.002 | [0.479, 2.152] |
| GAME | −0.960 | 0.223 | −0.114 | −4.306 | <0.001 | [−1.397, −0.523] |
| **School Days** | | | | | | |
| MVPA | 1.093 | 0.192 | 0.139 | 5.683 | <0.001 | [0.716, 1.471] |
| GAME | −0.773 | 0.269 | −0.076 | −2.879 | 0.004 | [−1.300, −0.246] |

**Table 5** Association Between Different Types of MSE, MVPA, SB Recommendation and Academic Engagement

| | Unstandardized Coefficients | | Standardized Coefficients | t | p | 95% CI |
|---|---|---|---|---|---|---|
| | B | Std. Error | β | | | |
| None | −6.723 | 0.611 | −0.235 | −11.001 | <0.001 | [−7.921, −5.524] |
| One | | | | | | |
| MVPA | 7.982 | 0.904 | 0.190 | 8.826 | <0.001 | [6.208, 9.755] |
| MSE | 7.504 | 0.534 | 0.295 | 14.060 | <0.001 | [6.458, 8.551] |
| SB | 3.642 | 0.550 | 0.144 | 6.616 | <0.001 | [2.562, 4.721] |
| Two | | | | | | |
| MVPA and SB | 8.608 | 1.103 | 0.169 | 7.803 | <0.001 | [6.445, 10.772] |
| MVPA and MSE | 8.784 | 0.969 | 0.195 | 9.063 | <0.001 | [6.883, 10.685] |
| SB and MSE | 7.573 | 0.617 | 0.260 | 12.266 | <0.001 | [6.362, 8.784] |
| Three | 8.983 | 1.180 | 0.165 | 7.610 | <0.001 | [6.668, 11.298] |

of MVPA, MSE, and SB; (3) combinations of MVPA, MSE, and SB Recommendations, which includes "None" representing meeting none of the recommendations, "One" (MVPA / SB / MSE) representing meeting only one of the recommendations, "Two" (MVPA and SB / MVPA and MSE / SB and MSE) representing meeting only two of the recommendations, and "Three" representing meeting all the recommendations. The results showed that there were different correlations between academic engagement and MVPA, MSE and SB.

## Correlations Between Academic Engagement and the Total Time of MVPA, MSE, and SB

This study analyzed a multiple linear regression model using the three items' respective total time as independent variables and found that they all had a significant effect on academic engagement. Specifically, the total time of MVPA and that of MSE were both positively correlated with academic engagement. Previous research has shown that

adolescents with higher levels of muscle strength have better psychological health than those with lower levels,[51,52] and positive psychological health contributes to greater academic engagement. Physical activity can also improve adolescents' learning behaviors, such as attention, motivation, and self-control, as well as reduce inappropriate classroom behavior,[53] which can help adolescents improve their academic engagement. Studies have shown that exercising can change the dorsal striatum and hippocampus in the brain, and these exercise-induced plasticity changes in relevant cerebral regions are conducive to the implementation ability, cognitive control, and memory of children and adolescents.[54] From a neurotransmitter perspective,[55] the increasing levels of norepinephrine and dopamine during exercise can add vigor not only to our bodies but also to our brains, enhancing our memory and learning ability. The increase of exercise-generated brain vigor, which is one of the measures of academic engagement, can effectively promote academic engagement.

This study also found that the longer time of screen-based SB, the lower level of academic engagement among adolescents. A large amount of research indicates that the decrease of adolescents' physical activity is accompanied with the increase of ST during adolescence.[56,57] Previous studies have revealed a negative correlation between academic engagement and excessive use of social media on electronic devices like computers and mobile phones.[58,59] According to the report released by China Internet Network Information Center (CNNIC), students account for the largest proportion of Chinese netizens (24.8%). Excessive use of the Internet exposes adolescents to a sea of information and communication demands, which usually require cognitive processing beyond their capabilities and have adverse effects for them.[60] Screen-based SB needs to get special attention. Studies find that watching TV for more than 1 hour per day increases the risks of poor sustained attention, learning difficulties, and long-term poor academic performance; in addition to that, watching TV for more than 3 hours a day even adds the risks of attention deficit and dropping out.[61] Analysis of three large-scale surveys conducted on adolescents in the UK and the US (n = 221,096) shows that adolescents who use screens for less than 1 hour per day have better psychological health than those use screens for more than 5 hours per day.[62] Such activity, which does not require much cognitive engagement, will take up normal learning time, distract attention, and cause anxiety, negatively affecting adolescents' absorption, dedication, and vigor in learning and thus dragging down their academic engagement level.

## Correlations Between Academic Engagement and Different Types of MVPA, MSE, and SB

In the above independent-variable analysis of different types of the three items on school days and on weekends, MSE as well as MVPA on school days and on weekends were all found positively correlated with academic engagement. For students who face academic pressure on school days, adopting a "weekend warrior" physical activity pattern, which means concentrating three days of MSE in Fridays and weekends in a week, can also bring health benefits.[63] But research has found that children are actually less physically active on weekends and holidays, and on the contrary, indulge more in screen-based SB.[64] Therefore, in order to improve academic engagement through exercise, only paying attention to the opportunities for physical activity in schools is yet enough; we also need parents, communities, and local governments to play their positive roles on weekends. The social ecological model, when explaining adolescent health behavior, reveals that the factor of parental support has a mediating effect on the relationship between community sports environment and children's health behavior.[65] The support from parents for their children's physical activity can influence their children's cognitive and behavioral development. Therefore, parents need to help teenagers reasonably arrange their exercise time on weekends and actively participate in physical activity with them. Communities and local governments also need to create conditions for students to engage in sufficient physical activity after school and improve safe road traffic infrastructures. Improving the social sports environment is an effective approach to promote adolescents' outdoor activities and reduce their SB on weekends,[66] making important contributions to outside-school physical activity for adolescents.

One of the results demonstrated that in all the dimensions of SB, playing games on weekends and on school days both had significantly negative correlations with academic engagement, while watching TV on school days and on weekends, and using computers on school days and on weekends did not show significant correlations with academic engagement. These findings can be explained by the "SOBC paradigm": different purposes for teenagers to use screens will produce different effects.[67] The SOBC model, derived from social learning theory, points out that every aspect of the environment

affects individuals' internal states, which in turn guide their behaviors and resulting consequences. A large-scale survey of internet use in China showed that about 67% of minors believe that the internet plays a positive role as a "window to the outside world" and a "daily learning assistant".[68] Therefore, teenagers should control their screen time and select positive content when using computers and watching TV.

Another result showed that playing computer games on school days and on weekends both affected academic engagement. Many video games are so highly exciting and involve so rapid changes in focus that adolescents find it difficult to stay vigorous in less exciting school learning and to maintain focus on less attracting tasks,[69] and thus having lower academic engagement level. Additionally, video games with unrealistic images and aggressive content can cause anxiety and depression more easily than other screen-based activities in adolescent students who tend to be more sensitive.[70] Violent games, in particular, can also lead to emotional instability, weaker concentration ability, and aggressive behaviors, and thus need stricter control. Evidence at the brain mechanism level shows that violent video games can impair adolescent cognitive function.[71] As a result, it is important to strictly control the amount of time adolescents spend in playing video games on both school days and weekends, and at the same time to avoid choosing excessively violent games.

## Correlations Between Academic Engagement and Different Combinations of MVPA, MSE, and SB Recommendations

MVPA, SB, and MSE were divided into eight different combinations based on exercise adherence. Judging from the standardized coefficients, all of these combinations, whether none was met, only one was met, only two were met, or all three were met, had significant impacts on the dependent variable. The interaction between SB and MVPA and between SB and MSE in the "Two" groups resulted in higher standardized coefficients than the one of SB alone. This suggested that meeting the ST recommendation alone, which was no more than two hours per day, had a less significant effect on improving academic engagement for adolescents than meeting both SB and MVPA or MSE recommendations. To the traditional public understanding and in previous studies, these three items have been considered to act independently and affect independently on physical health.[36,72] In recent years, however, more and more scholars have believed that only a balance of moderate physical activity (including MSE) and high-quality SB can be beneficial for physical health.[73,74] The new understanding has been followed by activity guidelines for children and adolescents issued by many countries, which all recommend MVPA for no less than 60 minutes per day, MSE no less than three times per week, and ST for no more than 2 hours per day.

The study results showed that among the "One" groups, meeting the recommended amount of MVPA alone or MSE alone had greater effects than meeting the recommendation of SB alone on improving academic engagement; among the "Two" groups, the standardized coefficients of MVPA and SB, and of MSE and SB were lower than that of MVPA alone or MSE alone; the "Three" group showed a smaller effect on academic engagement than any of the "Two" groups. In other words, when the SB recommendation was met, SB interacted with MVPA and MSE, changed the linear relationship between academic engagement and MVPA and MSE, and altered their standardized coefficients, indicating that there were high-level academic engagement samples among adolescents who did not meet the recommended amount of SB. One possible reason for this was related to a question in the survey that asked: "How long do you use a laptop or desktop computer each day for online chatting, browsing webs, sending and receiving email, or doing homework?" According to the ten data analyses of the Internet Use by Minors in China Survey, adolescents generally consider that the Internet plays a positive role in their learning, as online learning is their main use with the Internet.[75] With over 200 million users, China currently has the most and the largest adoption scale of MOOC courses in the world.[76] An analysis of the MOOC experience of Chinese secondary students shows that more than 90% of the students think that "it is very interesting" and "time flies during learning."[77] It proves that using computers for positive online learning can make adolescents feel interested and immerse in learning, and thus improve their academic engagement level, which explains the statistical result mentioned above.

## Limitations and Implications

This study had some limitations. Firstly, it was a cross-sectional study, so it only examined the correlations between academic engagement and MSE, MVPA, and screen-based SB. A further longitudinal study will be needed in the future for stronger support. Secondly, this study used self-reported questionnaires when collecting information, so there might be unavoidable biases. Lastly, this study only analyzed the number of days of MVPA and MSE in a week and did not further separate the specific ways of performing them. Therefore, the relationship between academic engagement and different ways of MVPA and MSE should be further examined in future studies.

This study also had some important implications. Due to academic burdens, teenagers spend most of their day in school. This study further confirmed the benefits of "moving more and sitting less" on their learning engagement through data analysis, providing evidence for the recommended MVPA, MSE, and SB amounts proposed by mainstream guidelines in various countries. We recommend that schools and parents pay attention to increasing the level of physical activity and reducing sedentary behavior of adolescents, which is helpful for students to learn efficiently, teachers to improve classroom teaching, and schools to improve educational quality.

## Conclusion

This study found significant correlations between academic engagement and physical activity, muscle-strengthening exercise, and sedentary behavior among adolescents. Therefore, exercise can effectively help adolescents improve their academic engagement. Increasing adolescents' MSE and MVPA and reducing SB are effective factors in promoting academic engagement. Doing MSE and MVPA on school days and on weekends are both conducive to academic engagement, but the game time should be strictly controlled because it was found to have serious negative impact on academic engagement, and the longer the time, the greater the impact. As a result, adolescents are suggested to reach recommended amounts of physical activity, muscle-strengthening exercise, and sedentary behavior so as to improve academic engagement more effectively.

## Ethics Approval and Written Consent

This study survey was also approved by the Institution of Review Board at Shanghai University of Sport (102772021RT072). The procedures performed were in accordance with the Declaration of Helsinki. Parents or guardians of all participants signed written consent which described the purpose, process, methods and publication plans of the study.

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## Disclosure

The authors report no conflicts of interest in this work.

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