Analysis of the Correlation between Physical Health and Academic Performance of Primary School Students in Zhejiang Province and the Mediating Effect of Executive Function

Hanchen Shao, Wang Shu and Xu Borui

***Abstract-* Background: Under the long-term influence of the traditional culture, physical exercise is conducive to the improvement of physical fitness, but not conducive to the improvement of academic performance. Encouragingly, a number of recent studies, whether cross-sectional or longitudinal, have also pointed to the beneficial effects of physical activity on the academic performance of elementary school students. This will undoubtedly provide theoretical support for the improvement of elementary school students' physical health. Therefore, this thesis intends to take primary school students in Zhejiang Province as an example, collect relevant data for empirical research, verify the *relationship* between physical health and academic performance, and explore the mechanism of physical health affecting academic performance by introducing the concept of executive function. It aims to change the traditional concept, eliminate the prejudice and negative attitude towards physical education, and promote the healthy and high-quality development of school physical education. Methods: The subjects were 417 primary school students in Hangzhou, Ningbo and Jiaxing of Zhejiang Province, including 215 boys and 202 girls. The Flanker task was used to evaluate the inhibition function of the student's executive function, the 1-back task was used to evaluate the refresh function of the student's executive function, and the More-Odd shifting task was used to evaluate the transformation function of the student's executive function. The scores of students' physical fitness test items were collected and converted into standard scores according to the national physical health standards. The standard scores of Chinese, mathematics and English at the end of the last semester are collected as the academic performance indicators. AMOS23.0 and SPSS27.0 were used to analyze the data. Results: (1) There were gender differences in physical health and academic performance of primary schools in Zhejiang Province. In terms of physical fitness, the scores of female students in seated forward bend and 50m×8 round trip race are significantly higher than those of male students, while in other physical fitness events, although there is no significant difference, the average scores of female students are higher than that of male students. In terms of academic performance, male students are significantly higher than female students in mathematics, but there is no significant gender difference in Chinese and English. The subfunctions of executive function did not show significant gender differences. (2) The physical health level of primary school students in Zhejiang Province has a significant positive correlation with their academic performance; (3) Executive function mediates the relationship between physical health and academic performance; The model was well fitted ($\chi 2/df$ = 1.306, NFI = 0.94, CFI = 0.985, RMSEA = 0.027). Conclusion: (1) The physical health level of primary school students in Zhejiang Province is positively correlated with their academic performance, which can be predicted positively; (3) Executive function partially mediates the relationship between physical health and academic performance;**

Hanchen Shao, City University of Malaysia, Malaysia (Email address.shao230317@163.com)
Wang Shu City University of Malaysia, Malaysia (Email address.1223688223@qq.com)
Xu Borui City University of Malaysia, Malaysia (Email address.757653963@qq.com

***Keywords* – Physical Fitness, Academic Performance, Executive Function**

I. INTRODUCTION

The traditional educational view, while affirming the promoting effect of physical education on physical health, denies the possibility of its coordinated development with intellectual education. This perspective has bred public prejudice against sports and led to the neglect of students' physical health. Moreover, whether it is a cross-sectional experiment or a longitudinal tracking experiment, it has instead been concluded that physical exercise has a beneficial effect on the academic performance of primary school students (Carl & Joel, 1979; Heidi, 2018; Joseph, 2016). This has led the academic community to re-examine the impact of physical exercise on academic performance. This has led the academic community to re-examine the impact of physical exercise on academic performance.

II. PROBLEM STATEMENT

In summary, the content of this study is to take the group of primary school students in Zhejiang Province as the research object, to further verify whether there is a direct correlation between physical health level and academic performance. If the result is positive, the mechanism of mutual influence between the two will be explored: whether executive function plays a mediating role between them.

Question 1: Is there a significant correlation between the physical health level and academic performance of primary school students in Zhejiang Province?

Question 2: In the path where physical health level affects academic performance, does executive function play a mediating role?

III. LITERATURE REVIEW

Physical Fitness

The term "physical fitness" is defined by contemporary scholars as health-related fitness, which mainly includes the components of physical fitness that can be scientifically linked to health: aerobic endurance, muscular endurance and strength, flexibility, and body composition, etc. (Lian, 2009). The "physical fitness level" of students evaluated in this article refers to the national student physical fitness test items, including body mass index (BMI), 50-meter shuttle run, one-minute sit-ups, 50-meter dash, sit and reach, and one-minute rope skipping.

Academic performance

Academic performance refers to the overall learning situation of students in various subjects at school. Shaik Shamshuddin proposed that academic performance is a direct reflection of whether the learning is up to standard and generally requires examination results (S. Shamshuddin, n.d.). This study uses the scores of Chinese, mathematics, and English from the subjects' most recent unified formal final exams in the district.

Execution Function

The Executive Function (EF for short) is essentially the process in which an individual's brain recruits a variety of basic cognitions and integrates and optimally allocates these cognitive resources when performing specific and complex tasks. The process of matching flexible and coordinated advanced cognition (Shintaro Funahashi, 2001). What is currently widely accepted in the academic circle is the view proposed by Miyake et al. In 2000, He divided the structure of executive functions into inhibition, updating and Shifting/Switching (Akira, 2000; Marcel & Patricia, 1992).

Inhibition, also known as inhibitory control, is the ability of an individual to suppress thoughts, behaviours, attention, and emotions during cognitive processes (Liisa, 2001).

Updating refers to the ability of executive function to continuously revise the content of existing working memory based on newly presented information, thereby integrating new working memory content. In general, it is the ability to grasp information (Nelson, 2014; Rebecca & Kimberly, 2006)

Shifting, also known as cognitive flexibility, is an important subfunction of executive function. It refers to an endogenous attentional control mechanism guided by instructions, specifically manifested as the control process of shifting between two tasks when they compete for the same cognitive resource. It can also be understood as an individual's ability to switch rapidly, frequently, and repeatedly between mental set and target operation in complex task situations. In general, it is the ability to change thinking (Edward & John, 1999; Harvey, 1991).

Research on Physical Health and Academic Performance

Physical activity enhances individual physical health, and there is indeed a significant positive correlation between physical health and academic performance (Joseph, 2016).

Results from longitudinal studies support this positive correlation (R. J. Shephard, 1984). If scholars have confirmed through a two-year follow-up study of students with low physical fitness and high physical fitness that students in the high physical fitness group showed significantly better performance in mathematics and English than those in the low physical fitness group over time, this advantage will be preserved (Antonio, 2016; Mikkel, 2016; Richard, 2012). Cross-sectional studies also support this assertion of correlation. An experimental study of 7,961 children aged 7 to 15 in Australia confirmed a positive correlation between physical health and academic performance (Terence, 2001). Another study also found that primary school students who received 30-minute and 40-minute walk interventions performed significantly better in mathematics than the control group that received 20-minute walk (Dennis & Carl, 1993).

Research on Physical Health and executive Function

Existing evidence suggests that long-term scientific physical exercise will improve an individual's physical health level while promoting the development and improvement of individual executive function, such as significantly enhancing students' creativity and shortening reaction time (Yannis, 1991). Recent studies on the impact of physical health factors on executive function have shown that the improvement of aerobic endurance in children and adolescents promotes the development of some advanced cognitive functions in individuals, including the executive function that this paper focuses on (Charles, 2009; Sarah, 2008). For example, some scholars used questionnaires and psychological tests to evaluate students' cognitive abilities, and used the shuttle run test to evaluate students' aerobic endurance levels. After correlation analysis, it was concluded that there was indeed a significant correlation between aerobic endurance and cognitive function (Darla, 2007). Hillman et al. from the United States used the event-related potential (ERP) technique to explore the correlation between physical exercise and cognitive ability. His team also found that students with high levels of aerobic endurance had shorter P3 response times, greater amplitudes and better cognitive abilities in the event-related potential test (Charles, 2005). Some scholars also used magnetic resonance imaging to study the problem and found that students with high levels of aerobic endurance had larger volumes of dorsal striatum and higher scores on memory tests (Laura, 2010). Some researchers also found the significant role of body mass index in influencing students' cognitive abilities (Yanfeng, 2008). By reviewing 26 studies on the correlation between adolescent IQ and obesity, it can be found that adolescent IQ may be negatively correlated with obesity (Yu., 2010).

Studies on Executive Function and academic performance

Studies have shown that executive function significantly affects the academic performance of primary school students, with the greatest impact on mathematics and reading (John, 2011; Rebecca Bull & Gaia Scerif, 2001). Not only that, when studying the correlations between each sub-function of executive function and academic performance, it was also confirmed that the better the sub-function of executive function, the better the individual's academic performance (Liao, 2022). Li et al. collected academic performance, refresh function, inhibition function and conversion function in executive function of 320 subjects from primary school, junior high school and senior high school, and found that all sub-functions of executive function were correlated with academic performance to varying degrees (Li & Bai Xuejun, 2008).

In the case of inhibitory function, some foreign scholars asked 23 children with mathematical learning disabilities to complete multiple tasks that required suppressing irrelevant information in an experiment, and the scores of the subjects were all low. There may be a certain correlation between inhibitory control and mathematical academic performance (M.Chiara & Linda, 2001). The refresh function has also been shown to be associated with academic performance in children and adolescents (Li Meihua, 2006). Swanson et al. compared the differences in reading comprehension performance between children with language working memory deficits and normal children and concluded that children with language working memory deficits could predict lower reading comprehension performance. And children with language working memory deficits performed significantly lower comprehension of long sentences than short ones (Swanson & Lee, 2001).

The Relationship among Physical Health, Executive Function, and Academic Performance

Researchers have found that the improvement of physical health not only enhances brain plasticity (Chen, 2013), but also develops students' advanced cognitive functions. And these improvements in advanced cognitive functions boost academic performance (John, 2011; Laura, 2014). For instance, some scholars believe that aerobic capacity, an essential element of physical health, plays a significant positive predictive role in students' academic performance. This is most likely because the improvement of aerobic capacity promotes the development of students' advanced cognition, such as executive function level, which in turn promotes academic performance (Laura, 2012; M.W. Voss, 2011; Richard, 2012). Studies from short-term or long-term physical activity also support this view, and these findings prompt scholars to further verify whether the improvement in physical health helps students improve advanced cognitive abilities such as executive function. And these advanced cognitive abilities mediate to improve students' academic performance (C.H. Hillman, 2009; Charles, 2008).

IV. METHOD

Participants

In this study, a cluster sampling method was used to randomly select one ordinary primary school each from Hangzhou, Ningbo and Jiaxing in Zhejiang Province. The subjects were determined to be sixth graders, taking into account whether students could independently complete the executive function test, whether they had relatively stable academic performance, and the participation of as many physical students as possible in the evaluation of physical health. The screening criteria for the subjects were :1) No intellectual disability; 2) No severe physical disability; 3) No history of serious illness. Four students with a history of mild autism or cardiopulmonary disease were excluded after confirmation with the school and parents. A total of 417 students participated in the study, including 215 boys and 202 girls. The demographic characteristics of the sampled subjects are detailed in Table I.

TABLE I: BASIC INFORMATION OF THE STUDENTS

Variables	Basic Information Name	Number of people	Percentage (%)
Gender	male	215	51.5
	female	202	48.5
Region	Hangzhou	150	36
	Ningbo	153	36.7
	Jiaxing	114	27.3

Experimental Methods and Procedures Physical fitness Test methods

According to the National Student Physical Health Standard, physical health data will be collected from the students in the 2025 academic year. The test items include 1) body mass index (BMI); 2) 50-meter run; 3) Sit and reach; 4) One-minute skipping rope; 5) One-minute sit-ups; 6) 50-meter ×8 shuttle run.

Body Mass Index (BMI) item: First test your height by placing a standard steel ruler on a level ground and close to a wall that is sure to be vertical. The student should stand barefoot with his back close to the side of the scale marked on it, with an upright body and eyes looking straight ahead to keep the shoulders, back, hips and heels in a straight line on the scale. The test results will be measured in centimetres (cm) and one decimal place will be retained. The weight will be measured using an electronic weighing scale. The student will stand on the scale barefoot, wearing short sleeves and shorts, and the reading will be taken when the scale shows and stabilizes. The reading will be in kilograms (kg), with one decimal place retained. Finally, the height and weight data of each subject were inserted into the BMI formula: BMI= weight (kg) divided by height (m) squared. 50-meter race: The test was conducted using an intelligent 50-meter tester. The subject stood behind the starting line, the tester pressed the

"Confirm" button, the machine made a "bang" sound, the subject started running, and the instrument displayed the timing. When the subject reaches the finish line, the timing stops and the result is given. The results are in seconds, with one decimal place retained. And the second decimal place is rounded up by the principle of non-0 to 1. The test should be conducted in pairs, twice, and the better score should be collected.

Sit and reach: The subject is tested using a sit and reach instrument. They sit on a sit-up mat, keep their legs straight and together, with the soles of their feet fully touching the instrument's pedals. Their hands are together and stretched forward, and they bend forward. They use the tips of their middle fingers to push the cursor forward smoothly at a constant speed until they can no longer push. When recording, if the cursor exceeds the "0" point, it is recorded as a positive value; If the cursor does not exceed "0", a negative value is recorded. The subjects were tested twice, and the testers recorded the maximum value in centimetres, accurate to one decimal place.

One-minute rope skipping: The subject jumps with the front part of the foot, completes an arc swing of the wrist, and jumps over the rope in a loop. Each jump over the rope is counted as one, and the test lasts for one minute. Test twice in total and record the best one.

One-minute sit-ups: The subject lies on a soft mat with legs slightly apart, knees bent at a 90-degree Angle, and fingers crossed behind the head. The companion presses on the ankle to fix the lower limb. One session was completed when the subject sat up and the elbows touched or exceeded the knees. The test lasts for 1 minute and is conducted twice in total, with the best result taken.

50 m ×8 round trip: Set up a turnaround marker in the middle of the track 0.5 meters from the finish line and the turnaround line. The subjects started the race in pairs using a standing start. After the test began, run to the opposite turnaround marker, reach the marker and go around counter-clockwise, then run back to the marker pole near the starting point and go around the marker counter-clockwise again for one lap; Run a total of 4 laps. Results are measured in seconds and rounded to one decimal place. The second decimal place is rounded up by the principle of "non-0" to "1".

Collect the results of the students' physical health test items and import them into the National Student Physical Health Network, which assigns scores to the results of each test item in accordance with the National Student Physical Health Standard (revised Edition 2014) as an indicator of physical health.

Perform Functional Testing Methods

Testing Methods for Inhibitory Functions

This study used the Flanker task to assess the inhibitory ability of the students in the subjects. Flanker tasks were divided into consistent tasks and inconsistent tasks, and the two tasks were presented immediately. During the experiment, a "+" fixation point is presented for 1000 milliseconds, followed by a string of five English letters that lasts for 1500 milliseconds. The consistency task presents "FFFFF" and "LLLLL" cases; Inconsistent tasks will present both "LLFLL" and "FFLFF". Students are required to respond to the middle letter of the string as quickly as possible while ensuring it is correct. If it is an "F", press the "F" key; if it is an "L", press the "L" key. The test consists of 48 judgment responses, and the test score is the average reaction time of the inconsistent task minus the average reaction time of the consistent task. The smaller the value, the less the difference in the performance of the subjects in the two tasks, and thus the better the inhibitory ability can be judged.

A Test Method for The Refresh Function

This study used the 1-back task to assess the refreshing ability of the students in the subjects. In the experimental task, the five numbers "1, 2, 3, 6, 9" were used as the stimulus. During the task, a single number will be displayed in the center of the screen one after another. The stimulus letter will be displayed for 2000ms, and the stimulus interval (ISI) is 1000ms. If the displayed number is the same as the previous one, press the "F" key; if not, press the "J" key. There are 25 judgments in the formal test. The test score is the average response time, and the smaller the value, the better the refresh ability is evaluated.

A Test Method for Switching Functionality

This study used the Odder shifting task to assess the shifting ability of the students in the subjects. The task consists of three subtasks presented in the order of ABC. Task A is to compare the size of the numbers: Randomly present black numbers 1 to 9 in the center of a gray screen, excluding 5, and ask the participants to compare the size of the presented numbers with 5 within 2000ms. If the number is larger than 5, respond the "F" key; otherwise, respond the "D" key, for 16 attempts; Task B: Distinguishing Odd Numbers: In this case, green numbers 1 to 9 were randomly presented in the center of the gray screen, excluding 5. The subjects were required to distinguish whether the current number was odd or even within 2000ms. Odd numbers responded to the "J" key, and even numbers responded to the "K" key. A total of 16 attempts; C is a comprehensive conversion task: Show the numbers 1 to 9 in the center of the screen, excluding 5. When the displayed number is black, the subject is required to compare the size of the number with 5 within 2000ms. When the displayed number is green, the subject is required to distinguish the parity of the number. The test score is the difference between the average reaction time of the conversion task and the average reaction time of the non-conversion task. The smaller the number, the smaller the difference, and the better the conversion ability.

Methods for Academic Performance Testing

This study retrieved the final academic performance (out of 100) test results of sixth graders from three selected primary schools in the three locations, including Chinese, mathematics and English. $Z = (X - X')/\sigma x$To eliminate the bias in academic performance caused by different school test papers and grading standards, the academic performance was standardized. For the raw score, for the average score of the subject in the class, for the standard deviation of the subject in the class, and for the corresponding standard score. $XX'\sigma xZX$ Taking into account that values often have decimals and negative values, for the convenience of statistical analysis, further transformations are made: that is. $ZT = 10Z + 50T = (X - X')/\sigma x \times 10 + 50T$The values are included in the statistics as academic performance for that subject.

Experimental procedures

Each subject was required to complete the physical health project test, the executive function test, and the academic performance evaluation test. The physical fitness test included height, weight, one-minute sit-ups, one-minute rope skipping, 50-meter run, and sit and reach. The executive function test includes tests for inhibitory function, refresh function, and conversion function. Executive function tests are conducted in school computer rooms. Academic performance requires students to take the final tests of Chinese, mathematics and English in the previous semester.

Statistical Analysis

In this study, data were statistically analyzed using Excel, SPSS27.0, and Amos 23.0, with P < 0.05 indicating a significant difference. Descriptive statistical analysis of the characteristics of each indicator was performed using SPSS22.0, and independent sample t-tests were used to analyze gender differences among the indicators; After controlling for grade and gender of the subjects, a correlation analysis of the main indicators was conducted to explore whether there was a correlation between physical fitness, academic performance, and executive function indicators, and based on the research hypothesis and the results of the correlation analysis, the Structural Equation Model of the hypothesis was established using Amos 23.0 software. The model was evaluated and modified based on the goodness of fit indicators of the analysis until all indicators met the structural equation model construction criteria. After the final model is determined, the model results are interpreted based on the path coefficients of the model, and whether physical health has a direct effect on academic performance and whether physical health has an indirect effect on academic performance through executive function are explored based on the path coefficients presented by the model.

V. FINDINGS

Physical health level

Basic description of physical health status

The basic information on the physical health status of the students under test is presented in Table II.

TABLE II: BASIC CONDITION OF PHYSICAL FITNESS

Physical Health ingredients	Minimum	Maximum	M	SD
Body Mass Index (BMI)	60	100	92.85	12.926
50-meter run score	0	100	77.13	13.762
Sit and reach score	0	100	79.51	16.047
Sit-up score	0	100	85.83	11.854
Skipping rope score	70	100	96.9	6.751
50m×8 shuttle run score	0	100	78.35	14.805

Gender differences in physical health

Independent sample t-tests were used in this study to determine the gender dimension differences in the physical health test items of the subjects, as shown in Table 5.2. There were no significant outliers in the study data, and the distribution was close to normal within each group. The results showed that except for the scores of sit and reach and 50m×8 shuttle run, which were significantly different by gender, all other physical health components were not significantly different by gender. It is also worth noting that girls performed better than boys in both of the two significantly different physical health components.

TABLE III: SEX DIFFERENCES IN PHYSICAL FITNESS

Physical health ingredients	Gender	N	M	SD	t	Sig.(bilateral)
Body Mass Index (BMI)	Boys	215	91.91	13.658	-1.552	0.122
	Girls	202	93.86	12.050		
50-meter run rating	Boys	215	76.70	16.887	-0.664	0.507
	Girls	202	77.58	9.377		
Sit and reach score	Boys	215	74.91	17.236	-6.321	0
	Girls	202	84.41	13.031		
One-minute sit-up score	Boys	215	86.59	12.857	1.362	0.174
	Girls	202	85.02	10.657		
One-minute rope skipping score	Boys	215	96.33	8.052	-1.828	0.068
	Girls	202	97.51	4.956		
50m×8 round trip score	Boys	215	76.33	18.362	-2.954	0.003
	Girls	202	80.50	9.257		

The body mass index (BMI) test results were (91.91±13.658) for boys and (93.86±12.050) for girls, with a difference of 1.95, indicating non-uniform variance. An independent sample t-test of the body mass index (BMI) revealed that t（415）=-1.552, 95%CI= (-4.43, 0.522), p=0.122 > 0.05, suggesting no statistically significant difference in BMI between boys and girls, as shown in Figure 5.1.

The result of the 50-meter run was (76.70±16.887) for boys and (77.58±9.377) for girls, with a difference of 0.88, indicating non-homogeneity of variance. An independent sample t-test of the 50-meter run results revealed that t（415）=-0.664, 95%CI= (-3.493, 1.729), p=0.507 > 0.05, suggesting that there was no statistically significant difference in the 50-meter run results between boys and girls, as shown in Figure 5.1.

The test results of sit and reach for male students were (74.91±17.236), and for female students, they were (84.41±13.031), with a difference of 9.50, indicating homogeneity of variance. An independent sample t-test for sit and reach results revealed t（415）=-6.321, 95%CI= (-12.459, 0.522), p=0.000 < 0.05, suggesting a statistically significant difference in sit and reach results between boys and girls, with girls performing significantly better than boys in this test, as shown in Figure 1.

The results of the sit-up test were (86.59±12.857) for male students and (85.02±10.657) for female students, with a difference of 1.57, indicating non-homogeneity of variance. An independent sample t-test of sit-up scores revealed that t（415）=1.362, 95%CI= (-0.697, 3.839), p=0.174 > 0.05, suggesting no statistically significant difference in sit-up scores between boys and girls, as shown in Figure 1.

The one-minute skipping rope test results were (96.33±8.052) for boys and (97.51±4.956) for girls, with a difference of 1.18 and non-homogeneity of variance. An independent sample t-test of one-minute skipping rope scores revealed that t（415）=-1.828, 95%CI= (-2.469, 0.09), p=0.068 > 0.05, suggesting that there was no statistically significant difference in one-minute skipping rope scores between boys and girls, as shown in Figure 5.1.

The results of the 50m×8 shuttle run were (76.33±18.362) for boys and (80.50±9.257) for girls, with a difference of 4.17 and non-homogeneity of variance. An independent sample t-test of the 50m×8 shuttle run results revealed that t（415）=-2.954, 95%CI= (-6.947, -1.393), p=0.003 < 0.05, suggesting a statistically significant difference in 50m×8 shuttle run results between boys and girls, with girls performing significantly better than boys in this event, as shown in Figure 1.

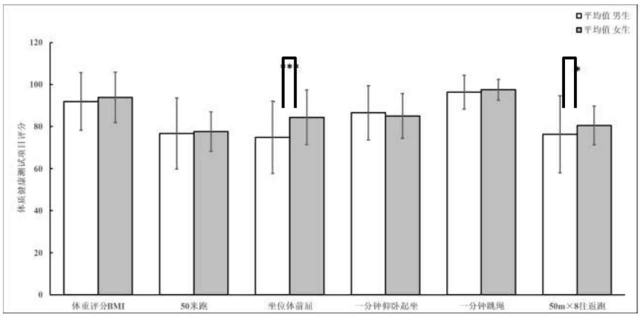

Figure 1 The difference of physical fitness level in gender dimension
Note: "*" indicates P<0.05, "**" indicates P<0.01, "***" indicates P<0.001.

Academic Performance

Basic description of academic performance

The basic information of the students' academic performance is presented in Table IV.

TABLE IV: BASIC CONDITION OF ACADEMIC RECORD

	Measured scores		Standard score	
	M	**SD**	**M**	**SD**
Chinese Language	87.56	5.208	56.64	5.208
Mathematics	83.99	13.676	52.93	13.676
English	91.65	9.945	60.36	9.945

Gender differences in academic performance

The study used an independent sample t-test to examine the gender dimension differences in Chinese, mathematics, and English academic performance among the subjects, as shown in Table V. The results indicated that only mathematics showed significant differences in the gender dimension, with boys performing significantly better than girls in this subject, while Chinese and English did not suggest significant gender differences.

TABLE V: SEX DIFFERENCES IN ACADEMIC RECORD

	Gender	N	M	SD	t	Sig.(bilateral)
Chinese	Male	215	57.26	5.251	-1.202	0.229
	Female	202	57.87	5.157		
Math	Male	215	56.48	12.359	3.894	0
	Female	202	51.33	14.515		
English	Male	215	61.12	10.681	-1.118	0.264
	Female	202	62.21	9.089		

The Chinese test results were (57.26±5.251) for boys and (57.87±5.157) for girls, with a difference of 0.61, indicating homogeneity of variance. An independent sample t-test of Chinese scores revealed that t（415）=-1.202, 95%CI= (-1.616, 0.389), p=0.229 > 0.05, suggesting that there was no statistically significant difference in Chinese scores between boys and girls, as shown in Figure 1.

The test results for mathematics were (56.48±12.359) for boys and (51.33±14.515) for girls, with a difference of 5.15, indicating non-homogeneity of variance. An independent sample t-test of math scores revealed that t（415）=3.894, 95%CI= (2.553, 7.760), p=0 < 0.05, suggesting a statistically significant difference in math scores between boys and girls, as shown in Figure 5.2.

The English test results were (61.12±10.681) for boys and (62.21±9.089) for girls, with a difference of 1.09, indicating homogeneity of variance. An independent sample t-test of English scores revealed that t（415）=-1.118, 95%CI= (-3.004, 0.825), p=0.264 > 0.05, suggesting no statistically significant difference in English scores between boys and girls.

Executive Function

Basic Description of the Executive Function

The basic information of the executive function of the test students is presented in Table VI.

TABLE VI: BASIC CONDITION OF EXECUTIVE FUNCTION

	N	Minimum	Maximum value	M	SD
Inhibition	417	-99.28	142.59	12.82	36.598
Refresh	417	496.79	6930.00	951.72	364.502

Conversion	417	-382.785	1085.155	292.05	193.006

Gender differences in executive function

This study used the independent sample t-test to determine the gender dimension differences in each sub-function of executive function (inhibitory function, refresh function, switching function) of the subjects, as shown in Table VII. The results showed no significant differences in executive function between genders, as shown in Table VII.

TABLE VII: SEX DIFFERENCES IN EXECUTIVE FUNCTION

	Gender	N	M	SD	t	Sig.(bilateral)
Inhibition	Male	215	13.21	38.613	.225	.822
	Girls	202	12.40	34.416		
Refresh	Boys	215	983.27	464.555	1.829	.068
	Girls	202	918.14	207.388		
Conversion	Boys	215	294.66	189.370	.285	.776
	Girls	202	289.27	197.236		

The test results for inhibitory function were (13.21±13,658) for boys and (12.40±34.416) for girls, with a difference of 0.81, showing homogeneity of variance. Independent sample t-tests for inhibitory function revealed t（415）=0.225, 95%CI= (-6.249, 7.865), p=0.822 > 0.05, suggesting no statistically significant difference in inhibitory function between boys and girls, as shown in Figure 5.3.

The refresh function test results were (983.27±464.555) for boys and (918.14±207.388) for girls, with a difference of 65.13, indicating homogeneity of variance. An independent sample t-test of refresh function revealed that t（415）=1.829, 95%CI= (-4.882, 135.140), p=0.068 > 0.05, suggesting that there was no statistically significant difference in refresh function between boys and girls, as shown in Figure 5.3.

The results of the conversion function test were (294.66±189.370) for boys and (289.27±197.236) for girls, with a difference of 5.39, indicating homogeneity of variance. Independent sample t-tests for conversion function revealed that t（415）=0.285, 95%CI= (-31.828, 42.605), p=0.776 > 0.05, suggesting that there was no statistically significant difference in conversion function between boys and girls.

Test of the Correlation Between Physical Health, Academic Performance and Executive Function

To explore the correlations among physical health, academic performance and executive function of primary school students in Zhejiang Province, Pearson correlation was used to handle each variable separately.

In the correlation between physical health and academic performance, all physical health components showed significant correlations with academic performance in Chinese, mathematics, and English, except for sit-ups which were not significantly associated with Chinese and mathematics scores in academic performance. And the correlation coefficient is positive, indicating a positive correlation between the two, suggesting that academic performance improves as the level of physical health increases.

The specific data showed a significant correlation between BMI scores and Chinese language scores, r=0.125, p<0.01; There was a significant correlation between BMI scores and math scores, r=0.120, p<0.05; There was a significant correlation between BMI scores and English scores, r=0.137, p<0.01; There was a significant correlation between the 50-meter run score and the Chinese score, r=0.203, p<0.01; There was a significant correlation between the 50-meter run score and the math score, r=0.147, p<0.01; There was a significant correlation between the 50-meter run score and the English score, r=0.127, p<0.01; There was no significant correlation between sit and reach and Chinese scores, r=0.088, p>0.05; There was no significant correlation between sit and reach and math scores, r=0.036, p>0.05; There was a significant correlation between sit and reach and English scores, r=0.106, p<0.05; There was a significant correlation between sit-ups and Chinese scores, r=0.208, p<0.01; There was a significant correlation between sit-ups and math scores, r=0.145, p<0.01; There was a significant correlation between sit-ups and English scores, r=0.239, p<0.01; There was a significant correlation between skipping rope and Chinese scores, r=0.281, p<0.01; There was a significant correlation between skipping rope and math scores, r=0.185, p<0.01; There was a significant correlation between skipping rope and English scores, r=0.224, p<0.01; There was a significant correlation between the 50m×8 shuttle run score and the Chinese score, r=0.212, p<0.01; There was a significant correlation between the 50m×8 shuttle run score and the math score, r=0.104, p<0.05; There was a significant correlation between 50m×8 shuttle run scores and English scores, r=0.227, p<0.01.

In the correlation test between physical health and executive function, except for no significant correlation between 50-meter running and refreshing, and rope skipping and inhibition, all other physical health components showed significant correlations with the three sub-components of executive function. It is notable that since executive function is evaluated by the difference in average reaction time between inconsistent and consistent tasks, the smaller the difference, the better the executive function, the correlation coefficient between them is negative.

The specific data showed a significant correlation between BMI scores and inhibitory function, r=-0.132, p<0.01; There was a significant correlation between BMI scores and refresh function, r=-0.115, p<0.05; There was a significant correlation between BMI score and conversion function, r=-0.189, p<0.01; There was a significant correlation between 50-meter run scores and inhibitory function, r=-0.167, p<0.01; There was no significant correlation between 50-meter run scores and refresh function, r=-0.095, p>0.05; There was a significant correlation between the 50-meter run score and the conversion function, r=-0.156, p<0.01; There was a significant correlation between sit and reach scores and inhibitory function, r=-0.105, p<0.05; There was a significant correlation between sit and reach scores and refresh function, r=-0.102, p<0.05; There was a significant correlation between sit and reach scores and conversion function, r=-0.103, p<0.05; There was a significant correlation between sit-up scores and inhibitory function, r=-0.175, p<0.01; There was a significant correlation between sit-up scores and refresh function, r=-0.178, p<0.01; There was a significant correlation between sit-up scores and conversion function, r=-0.214, p<0.01; There was no significant correlation between skipping rope scores and inhibitory function, r=-0.087, p>0.05; There was a significant correlation between skipping rope scores and refresh function, r=-0.117, p<0.05; There was a significant correlation between jump rope scores and conversion function, r=-0.184, p<0.01; There was a significant correlation between 50m×8 shuttle run scores and inhibitory function, r=-0.106, p<0.05; There was a significant correlation between 50m×8 shuttle run scores and refresh function, r=-0.179, p<0.01; There was a significant correlation between 50m×8 shuttle run scores and the conversion function, r=-0.190, p<0.01.

In the test of the correlation between executive function and academic performance, except for inhibitory function and math performance which did not show a significant correlation, all other executive function sub-functions and academic performance showed a significant correlation overall. It is worth noting that since the evaluation of executive function is based on the difference in average response time between inconsistent and consistent tasks, the smaller the difference, the better the executive function, the correlation coefficient between them is negative.

The specific data show that there is a significant correlation between Chinese language scores and inhibitory function, r=-0.187, p<0.01; There was a significant correlation between Chinese scores and refresh function, r=-0.201, p<0.01; There is a significant correlation between Chinese scores and conversion function, r=-0.230, p<0.01; There was no significant correlation between math scores and inhibitory function, r=-0.083, p>0.05; There was a significant correlation between math scores and refresh function, r=-0.177, p<0.01; There is a significant correlation between math scores and conversion function, r=-0.201, p<0.01; There was a significant correlation between English scores and inhibitory function, r=-0.165, p<0.01; There was a significant correlation between English scores and refresh function, r=-0.180, p<0.01; There is a significant correlation between English scores and conversion function, r=-0.223, p<0 5.5 Verification of the mediating effect of executive function on the impact of physical health on academic performance.

Build the model

Using AMOS statistical software and structural equation modeling, the theoretical model of executive function as a mediating variable of physical health affecting academic performance was tested, and fitting indices such as NNFI, CFI, and RMSEA were calculated to verify the mediating effect of executive function in the relationship between physical health and academic performance. The model was constructed using the plotting tools provided by AMOS.

Validate the model with corrections

When using Amos 23.0 software to build a structural equation model for hypothesis testing (SEM), when conducting path analysis to test whether the model fits the data, two aspects must be considered simultaneously, namely the overall model fit index and the model intrinsic structure fit index.

The criteria for the overall model fit test are mainly based on model fitting indicators, including: adjusted chi-square value (CMIN/DF), fit index (GFI), comparative fit index (CFI), standard fit index (NFI), and root mean square error (RMSEA), etc.

As shown in Table 5.7, all the indicators of the structural equation model have reached the excellent standard. The chi-square ratio of degrees of freedom is less than 3, the RMSEA value is less than 0.08, and the values of GFI, RFI, CFI, NFI, TLI, IFI and other indicators are all greater than 0.9, reaching the excellent standard. It indicates that the data fits well with the model.

TABLE VIII: STRUCTURAL EQUATION MODEL FITTING TEST

CMIN /DF	GFI	NFI	RFI	IFI	TLI	CFI	RMS EA
1. 306	0 .974	0 .94	0 .922	0 .985	0 .981	0 .985	0 .027

It can be seen from Table IX that the standardized path coefficient of physical health on executive function is -0.241, and the corresponding p value is less than 0.05. This indicates that physical health has a significant negative impact on executive function, and the hypothesis holds.

The standardized path coefficient of executive function for academic performance is -0.302, and the corresponding p value is less than 0.05. The hypothesis holds that executive function has a significant negative impact on academic performance.

The standardized path coefficient of physical health for academic performance is 0.352, and the corresponding p value is less than 0.05. The hypothesis holds that physical health has a significant positive impact on academic performance

Table IX: Structural equation model path analysis

Path relationship			Path coefficients	Standardized path coefficients	S.E.	C.R.	P
Executive	---	Physical health	0.217	-0.241	0.106	-2.047	0.041

function							
Academic performance	<---	Executive function	-0.102	-0.302	0.05	-2.045	0.041
Academic performance	<---	Physical health	0.107	0.352	0.021	5.051	***

VI. DISCUSSION

Gender differences in each indicator

Gender differences in physical health levels

The results showed that among the elements of physical health, there were significant gender differences in the sit and reach and 50m×8 shuttle run events, and girls performed significantly better than boys. This is similar to previous research results. As Sun Huanhuan did in his study, she also observed a highly significant advantage for girls in sit and reach (Fan & Yang, 2018). The possible reason is that, first of all, girls have significantly better flexibility than boys, so they have a significant advantage in the scores of the sit and reach. Secondly, in the upper grades of primary school, girls have entered puberty, a period of rapid physical development, and their cardiopulmonary function is more developed than that of boys. Therefore, they also have a significant gender advantage in the 50m×8 shuttle run, which focuses on cardiopulmonary endurance.

The study did not find significant gender differences in all elements of physical health except for sit and reach and 50m×8 shuttle run. Previous studies have also supported this view. Li Jidong found no significant gender difference in one-minute rope skipping performance after testing 240 primary school students (Li , 2016), and Zhu Lin also supported this view in her study (Zhu Lin, 2012). The study's inference that there was no gender difference in one-minute sit-ups among primary school students was also supported by Li Jidong et al. (Li, 2016), and Li Jidong's research also confirmed the study's conclusion that there was no gender difference in the 50-meter run (Li, 2016). The study's assertion that there was no gender difference in BMI was supported by previous researchers such as Liao Yingying. The possible reason for the above results is that in the sixth grade of primary school, the advantages of these men in body type, speed, and strength were compensated by the girls' bodies entering the development stage first, so there was no gender difference.

Differences in academic performance based on gender

In terms of academic performance, data from the independent sample t-test show that there is a significant gender difference in mathematics scores, with boys performing significantly better than girls in mathematics. Some previous research results support the assertion in this paper that men are better than women in logical thinking, which makes men perform better than women in science subjects such as mathematics, physics and chemistry.

The findings show no significant gender differences in language and English. This is contrary to previous studies. Previous similar studies have mostly concluded that girls perform significantly better than boys in language subjects such as Chinese and English (Allison, 2012), They attribute it to girls' innate talent for language expression and the natural advantage of imagination and empathy brought by their rich and delicate emotions to language subjects. The findings of this study do not yield similar results, possibly because the students in this study are located in provinces like Zhejiang where basic education is well developed, where parents generally attach great importance to their children's education, involve them in various language-related activities and interest classes, and the average educational attainment of parents here is relatively high. The subtle nurturing and influence on children in daily life, these postnatal changes invisibly bridge the huge gender gap in language ability.

Gender Differences in Executive Function

In terms of executive function, the argument of this paper is consistent with that of most related studies that there is no gender difference in executive function among primary school students. For example, Chen Aiguo found no difference in executive function between third-grade and fifth-grade students of different genders in the effect of short moderate-intensity aerobic exercise on children (Chen Aiguo et al., 2011). This is most likely because the samples were all from sixth-grade students of the same age, and the comparison samples were all in the same school and the same teaching environment, so the difference in their executive function did not reach a significant level.

The Relationship Between Physical Health, Executive Function, And Academic Performance and its Mechanism

Correlation Between Physical Health and Academic Performance

In the correlation between physical health and academic performance, except for sit-ups which showed no significant correlation with Chinese and mathematics scores, all other physical health components showed significant correlations with Chinese, mathematics, and English scores. And the correlation coefficient is positive, indicating a positive correlation between the two, suggesting that academic performance improves as physical health levels rise. This is in line with the assumption mentioned earlier in this paper: there is a significant positive correlation between physical health and academic performance, and it has a good predictive effect. When intervening in physical health, the academic community often uses physical exercise as a method, and many similar conclusions have been drawn.

For example, studies have shown that skipping rope not only tests students' cardiopulmonary system ability and body coordination, but also has a positive predictive effect on their academic performance (Fan & Yang 2018). Wen

Xu found in his study that one minute of rope skipping had a highly significant regression coefficient for academic performance in all subjects ($p < 0.01$) (Wen, 2018).

The results of this study on sit-ups are in dispute with those of previous studies. Sit-ups, as a test of response strength quality, are not just the subject of this study; there are many different opinions in the academic circle. Such as Brandi, DuncanP.vanDusen, and others in the discussion on whether sit-ups can significantly improve academic performance, based on their positive results, are more inclined to give affirmative answers (Brandi M. Eveland-Sayers et al., 2007; Duncan P. Van Dusen et al., 2011). Further research suggests that muscle strength can enhance an individual's working memory ability, thereby having a positive enhancement effect on academic performance (Shih-Chun, 2017). However, data from Darla gave the opposite view, arguing that there was no significant correlation between strength quality components in physical fitness tests, including sit-ups and push-ups, and academic performance (Darla, 2007). And this pessimistic speculation about the impact of strength quality on academic performance seems to be increasingly confirmed. Some scholars have changed the measurement of strength quality to grip strength, but still have not found a significant correlation with academic performance (Brandi M. Eveland-Sayers et al., 2007). Of course, some scholars believe that strength qualities such as sit-ups have a separate effect on academic performance in various subjects and only have a positive predictive effect on academic performance in certain subjects, which is more in line with the results of this experiment. As Brandi's study found, sit-ups were positively correlated with math scores, but not with language scores (Brandi, 2007). Therefore, this study still holds the inference that sit-ups have no significant correlation with Chinese and math scores, but a significant correlation with English scores.

The 50m run, which reflects students' speed quality, is considered to have a significant correlation with academic performance in this study. This has been supported by predecessors. Irene et al. evaluated students' speed quality with 4×10m round-trip running results and found that it was significantly positively correlated with Chinese and mathematics scores (Irene, 2014).

The relationship between BMI and academic performance has also been controversial in the academic circle. Most literatures support the negative correlation between BMI and academic performance, but a considerable number of literatures also attempt to deny such a view (Ashlesha Datar et al., 2004). Although the study by Jennifer showed weak positivity (Jennifer, 2014), they all gave a cautious attitude that their correlation could not be judged based on data alone because of the obesity problem caused by BMI, The impact of negative social and psychological factors on academic performance is also worthy of attention (Jennifer, 2014). That is to say, if BMI is associated with academic performance, it is more likely that it is not an abnormality of BMI itself, but rather through the effect of some derivative or mediating factor, which is worthy of further study in the future. This study is more inclined to suggest a significant negative correlation between BMI and academic performance.

The study suggests that the score of the 50m×8 shuttle run can positively predict academic performance in Chinese, mathematics and English. There seems to be little controversy on this point, as the 50m×8 shuttle run reflects students' aerobic endurance ability, and the existing literature basically gives a consistent positive opinion on the positive impact of aerobic endurance on academic performance. A longitudinal follow-up study of adolescents aged 11-14 also expressed this view: students with higher levels of aerobic endurance mean they perform better in Portuguese and foreign language tests (Antonio, 2016).

The Correlation Between Physical Health and Executive Function

In the test of the correlation between physical health and executive function, except for no significant correlation between 50m running and refreshing and rope skipping and inhibition, all other physical health components showed significant correlations with the three sub-components of executive function. It should be noted that since the evaluation of executive function is based on the difference in average reaction time between inconsistent tasks and consistent tasks, the smaller the difference, the better the executive function, the correlation coefficient between them is negative. Based on the changes in cerebral cortex activation in children from the perspective of FMRI, Davis et al. applied short-term moderate-intensity aerobic exercise intervention five times a week for fifteen consecutive weeks and found significant improvement in executive function in children (Catherine, 2011). Ames' (1992) suggested that students who performed well in physical activity tasks might also use the same task orientation to achieve good results in cognition and academic performance (Carole, 1992).

The possible reason for these results is the improvement in physical health under physical exercise intervention, which promotes the optimization of brain structure and the activation of regional functions, thereby enhancing the level of executive function.

Correlation Between Executive Function and Academic Performance

In the correlation test between executive function and academic performance, except for the inhibitory function and mathematics performance which did not show a significant correlation, all other sub-functions of executive function and academic performance generally showed a significant positive correlation. This is largely similar to the results of previous studies. Swanson et al. found that abnormalities in the refresh function of executive function led to poor reading comprehension performance in children, especially struggling in the context of long sentence comprehension tasks (Swanson & Carole, 2001).

But there are also studies that have different conclusions from the results of this experiment. In terms of inhibitory control, Passolunghi found in a study of children with math learning difficulties that they generally did not perform well in inhibitory tasks, so he believes that inhibitory ability is related to math academic performance. The study is cautious about this inference and hopes that it will be further confirmed by future generations.

Mechanisms of the Mediating Effect of Physical Health on Academic Performance and Executive Function

This study verified the mediating effect of executive function in the path of physical health influencing academic performance through structural equation model analysis. That is, the improvement of physical health has a beneficial effect on students' cognitive function, and the improvement of cognitive function helps students improve their academic performance. There is no consensus in the academic community on its internal mechanism of action. But most of the literature attempts to be self-consistent from the dimensions of physiological and psychological mechanisms.

From the perspective of neurophysiology, it is a consensus among recent studies that the first explanation is that physical exercise intervention in physical health leads to the optimization of brain structure and the activation of regional functions, thereby affecting academic performance. But the academic community is clearly not content with simply explaining the mechanisms related to physical health function, executive function, and academic performance from the macroscopic perspective of brain structure and brain function. They are more eager to find theoretical breakthroughs in this mechanism of action from research results at the cellular or molecular level. And as research progresses, people are beginning to notice the microscopic mechanisms that bring about this improvement in brain function and plasticity: Physical exercise, especially aerobic exercise, promotes nerve growth factors such as brain-derived neurotrophic factor (BDNF) and insulin-like growthfactor-1 Expression and release of IGF-1 (Huang Tao et al., 2006) Promoting neuronal survival and differentiation (Cassilhas R C, Viana V A R, Grassmann V) et al. The Impact of Resistance Exercise on the Cognitive Function of the Elderly.[J]. Med Sci Sports Exerc, 2007, 39(8):1401-1407., n.d.; DeAnna L. Adkins et al., 2006), increased blood supply to related brain regions (Adam G. Thomas et al., 2012; Andrew S. Whiteman et al., 2014; C Cotman, 2002) and metabolic efficiency (Bente K. Pedersen & Mark A. Febbraio, 2012), thereby improving students' cognitive and memory functions. Studies suggest that BDNF is abundantly present in the hippocampus, which is associated with memory formation and spatial orientation, and in the brain regions responsible for advanced cognitive functions (Robert H. Lipsky & Ann M. Marini, 2007).

VII. CONCLUSION (OR LIMITATION OR SUGGESTION FOR FURTHER STUDIES

There are gender differences in physical health and academic performance among primary schools in Zhejiang Province. In terms of physical health, girls scored significantly higher than boys in sit and reach and 50m×8 shuttle run, while in all other physical health items, although there was no significant difference, girls scored higher than boys on average in each item. In terms of academic performance, boys scored significantly better than girls in mathematics, but there was no significant gender difference in Chinese and English scores; Finally, there were no significant gender differences in the sub-functions of executive function;

The overall physical health level of primary school students in Zhejiang Province was significantly positively correlated with their academic performance;

Executive function plays a mediating role between physical health and academic performance.

REFERENCES

Adam G. Thomas, Andrea Dennis, Peter A. Bandettini, & Heidi Johansen-Berg. (2012). The Effects of Aerobic Activity on Brain Structure. Frontiers in Psychology, 3.

Akira Miyake, Naomi P. Friedman, Michael J. Emerson, Alexander H. Witzki, Amy Howerter, & Tor D. Wager. (2000). The Unity and Diversity of Executive Functions and Their Contributions to Complex "Frontal Lobe" Tasks: A Latent Variable Analysis, Cognitive tended, 41 (1), 49-100.

Allison R. Lombardi, Christopher Murray, & Hilary Gerdes. (2012). Academic Performance of First-Generation College Students with Disabilities. Journal of College Student Development, 53 (6), 811-826.

Andrew S. Whiteman, Daniel E. Young, Xuemei He, Tai C. Chen, Robert C. Wagenaar, Chantal E. Stern, & Karin Schon. (2014). Interaction between serum BDNF and aerobic fitness predicts recognition memory in healthy young Adults. Behavioural Brain Research, 259, 302-312.

Antonio Labisa Palmeira, Sandra Martins, Luis B. Sardinha, Adilson Marques, Claudia S. Minderico, Diana A. Santos & Ulf Ekelund. (2016). Longitudinal Relationship between Cardiorespiratory Fitness and Academic Achievement. Medicine & Science in Sports & Exercise: Official Journal of the American College of Sports Medicine, 48(5), 839–844.

Ashlesha Datar, Roland Sturm, & Jennifer L. Magnabosco. (2004). Childhood Overweight and Academic Performance: The National Study of Kindergartners and First - Graders. Obesity Research, 12 (1), 58-68.

Bente K. Pedersen & Mark A. Febbraio. (2012). Muscles, exercise and obesity: Skeletal muscle as a secretory organ. Nature Reviews Endocrinology, 8(8), 457-465.

Brandi M. Eveland-Sayers, Richard S. Farley, Dana K. Fuller, Don W. Morgan, & Jennifer L. Caputo. (2007). Physical Fitness and Academic Achievement in Elementary School Children: 2214 Board #127 June 1 9:00 AM - 10:30 AM. Medicine & Science in Sports & Exercise, 39(5), S399.

C Cotman. (2002). Exercise: A behavioural intervention to enhance brain health and plasticity. Trends in Neurosciences, 25(6), 295-301.

Carl Gabbard & Joel Barton. (1979). Effects of Physical Activity on Mathematical Computation among Young Children. Journal of Psychology, 103, 287–288.

Carole Ames. (1992). Classrooms: Goals, structures, and student motivation. Journal of Educational Psychology, 84(3), 261-271.

Cassilhas R C , Viana V A R , Grassmann V , et al. The impact of resistance exercise on the cognitive function of the elderly.[J]. Med Sci Sports Exerc, 2007, 39(8):1401-1407. (n.d.).

Catherine L. Davis, Phillip D. Tomporowski, Jennifer E. McDowell, Benjamin P. Austin, Patricia H. Miller, Nathan E. Yanasak, Jerry D. Allison, & Jack A. Naglieri. (2011). Exercise improves executive function and achievement and alters brain activation in Overweight children: A randomized, controlled trials. The Health tended, 30 (1), 91-98.

C.H. Hillman, M.B. Pontifex, L.B. Raine, D.M. Castelli, E.E. Hall, & A.F. Kramer. (2009). The effect of acute treadmill walking on cognitive control and academic achievement in Preadolescent children. Neuroscience, 159 (3), 1044-1054.

Charles H. Hillman, Darla M. Castelli, & Sarah M. Buck. (2005). Aerobic Fitness and Neurocognitive Function in Healthy Preadolescent Children. Medicine & Science in Sports & Exercise, 37 (11), 1967-1974.

Charles H. Hillman, Kirk I. Erickson, & Arthur F. Kramer. (2008). Be smart, exercise your heart: Exercise effects on brain and cognition. The Nature Reviews Neuroscience, 9 (1), 58-65.

Charles H. Hillman, Sarah M. Buck, Jason R. Themanson, Matthew B. Pontifex, & Darla M. Castelli. (2009). Aerobic fitness and cognitive development: Event-related brain potential and task performance indices of executive control in preadolescent children. Developmental Tended, 45 (1), 114-129.

Darla M. Castelli, Charles H. Hillman, Sarah M. Buck, & Heather E. Erwin. (2007). Physical Fitness and Academic Achievement in Third- and Fifth-Grade Students. Journal of Sport and Exercise tended, 29 (2), 239-252.

DeAnna L. Adkins, Jeffery Boychuk, Michael S. Remple, & Jeffrey A. Kleim. (2006). Motor training induces experience-specific patterns of plasticity across motor cortex and Spinal cord. The Journal of Applied Physiology, 101 (6), 1776-1782.

Dennis McNaughten & Carl Gabbard. (1993). Physical Exertion and Immediate Mental Performance of Sixth-Grade Children. Perceptual and Motor Skills, 77 (3 _suppl), 1155-1159.

Duncan P. Van Dusen, Steven H. Kelder, Harold W. Kohl, Nalini Ranjit, & Cheryl L. Perry. (2011). Associations of Physical Fitness and Academic Performance Among Schoolchildren*. Journal of School Health, 81 (12), 733-740.

Edward E. Smith & John Jonides. (1999). Storage and Executive Processes in the Frontal Lobes. Science, 283(5408), 1657-1661.

Harvey S. Levin, Kathleen A. Culhane, Joel Hartmann, Karen Evankovich, Audrey J. Mattson, Harriet Harward, George Ringholz, Linda Ewing-Cobbs, & Jack M. Fletcher. (1991). Developmental changes in performance on tests of purported frontal lobe functioning. Developmental Neuropsychology, 7 (3), 377-395.

Heidi J. Syvaoja, Anna Kankaanpaa, Jouni Kallio, Harto Hakonen, Janne Kulmala, Charles H. Hillman Anu-Katriina Pesonen, & Tuija H. Tammelin. (2018). The Relation of Physical Activity, Sedentary Behaviours, and Academic Achievement Is Mediated by Fitness and Bedtime. Journal of Physical Activity and Health, 15(2), 135-143.

H.Lee Swanson & Carole Sachse-Lee. (2001). Mathematical Problem Solving and Working Memory in Children with Learning Disabilities: Both Executive and Phonological Processes Are Important. Journal of Experimental Child Psychology, 79(3), 294-321.

Irene Esteban-Cornejo, Carlos Ma Tejero-Gonzalez, David Martinez-Gomez, Juan del-Campo, Ana Gonzalez-Galo Carmen Padilla-Moledo, James F. Sallis, & Oscar L. Veiga. (2014). Independent and Combined Influence of the Components of Physical Fitness on Academic Performance in Youth. The Journal of Pediatrics, 165 (2), 306-312. E2.

Jennifer Caird, Josephine Kavanagh, Alison O'Mara-Eves, Kathryn Oliver, Sandy Oliver, Claire Stansfield, & James Thomas. (2014). Does being overweight impede academic attainment? A systematic review. The Health Education Journal, 73 (5), 497-521.

John R. Best, Patricia H. Miller, & Jack A. Naglieri. (2011). Relations between executive function and academic achievement from ages 5 to 17 in a large, representative national sample. Learning and Individual Differences, 21(4), 327-336.

Joseph E. Donnelly, Charles H. Hillman, Darla Castelli, Jennifer L. Etnier, Sarah Lee, Phillip Tomporowski, Kate Lambourne, & Amanda N. Szabo-Reed. (2016). Physical Activity, Fitness, Cognitive Function, and Academic Achievement in Children: A Systematic Review. Medicine & Science in Sports & Exercise, 48(6), 1197-1222.

Laura Chaddock, Charles H. Hillman, Matthew B. Pontifex, Christopher R. Johnson, Lauren B. Raine, & Arthur F. Kramer. (2012). Childhood aerobic fitness predicts cognitive performance one year later. Journal of Sports Sciences, 30 (5), 421-430.

Laura Chaddock, Kirk I. Erickson, Ruchika Shaurya Prakash, Matt VanPatter, Michelle W. Voss, Matthew B. Pontifex, Lauren B. Raine, Charles

H. Hillman, & Arthur F. Kramer. (2010). Basal Ganglia Volume Is Associated with Aerobic Fitness in Preadolescent Children. Developmental Neuroscience, 32 (3), 249-256.

Laura Chaddock-Heyman, Charles H. Hillman, Neal J. Cohen, & Arthur F. Kramer. (2014). The importance of physical activity and aerobic fitness for cognitive control and memory in Children. Monographs of the Society for Research in Child Development, 79 (4), 25-50.

Liisa Klenberg, Marit Korkman, & Pekka Lahti-Nuuttila. (2001). Differential Development of Attention and Executive Functions in 3- to 12-Year-Old Finnish Children. Developmental Neuropsychology, 20 (1), 407-428.

Marcel A. Just & Patricia A. Carpenter. (1992). A capacity theory of comprehension: Individual differences in working memory. Psychological Review, 99(1), 122-149.

M.Chiara Passolunghi & Linda S. Siegel. (2001). Short-Term Memory, Working Memory, and Inhibitory Control in Children with Difficulties in Arithmetic Problem Solving. Journal of Experimental Child Tended, 80 (1), 57. 44

Mikkel P. Andersen, Rikke N. Mortensen, Henrik Vardinghus-Nielsen, Jesper Franch, Christian Torp-Pedersen, & Henrik Bøggild. (2016). Association Between Physical Fitness and Academic Achievement in a Cohort of Danish schools Pupils. Journal of School Health, 86 (9), 686-695.

M.W. Voss, L. Chaddock, J.S. Kim, M. VanPatter, M.B. Pontifex, L.B. Raine, N.J. Cohen, C.H. Hillman, & A.F. Kramer. (2011). Aerobic fitness is associated with greater efficiency of the network underlying cognitive control In preadolescent children. Neuroscience, 199, 166-176.

Nelson Cowan. (2014). Working Memory Underpins Cognitive Development, Learning, And Education. Educational tended to Review, 26 (2), 197-223.

R. J. Shephard, M. Volle, H. Lavallee, R. LaBarre, J. C. Jequier & M. Rajic. (1984). Required Physical Activity and Academic Grades: A Controlled Study. In Juhani Ilmarinen & Ilkka Valimaki (Eds.) The Children and Sport (pp. 58-63). Springer Berlin Heidelberg.

Rebecca Bull & Gaia Scerif. (2001). Executive Functioning as a Predictor of Children's Mathematics Ability: Inhibition, Switching, and Working Memory. Developmental Neuropsychology, 19(3), 273-293.

Rebecca Bull & Kimberly Andrews Espy. (2006). Working Memory, Executive Functioning, and Children's Mathematics. In Working Memory and Education (pp. 93–123). Elsevier.

Richard A. Wittberg, Karen L. Northrup, & Lesley A. Cottrell. (2012). Children's Aerobic Fitness and Academic Achievement: A Longitudinal Examination of Students During Their Fifth and Seventh Grade Years. American Journal of Public Health, 102 (12), 2303-2307.

Robert H. Lipsky & Ann M. Marini. (2007). Brain-Derived Neurotrophic Factor in Neuronal Survival and Behaviour-Related Plasticity. Annals of the New York Academy of Sciences, 1122 (1), 130-143.

S. Shamshuddin, D Bhaskara Rao, & V. D. Reddy. (n.d.). Values and academic achievement. Retrieved January 27, 2023, from

Sarah M. Buck, Charles H. Hillman, & Darla M. Castelli. (2008). The Relation of Aerobic Fitness to Stroop Task Performance in Preadolescent Children. Medicine & Science in Sports & Exercise, 40 (1), 166-172.

Shih-Chun Kao, Daniel R. Westfall, Andrew C. Parks, Matthew B. Pontifex, & Charles H. Hillman. (2017). Muscular and Aerobic Fitness, Working Memory, and Academic Achievement in Children. Medicine & Science in Sports & Exercise, 49(3), 500-508.

Shintaro Funahashi. (2001). Neuronal mechanisms of executive control by the prefrontal cortex. Neuroscience Research, 39 (2), 147-165.

Terence Dwyer, James F. Sallis, Leigh Blizzard, Ross Lazarus, & Kimberlie Dean. (2001). Relation of Academic Performance to Physical Activity and Fitness in Children. Pediatric Exercise Science, 13 (3), 225-237.

Yanfeng Li, Qi Dai, James C. Jackson, & Jian Zhang. (2008). Overweight Is Associated With Decreased Cognitive Functioning Among School-age Children and Adolescents. Obesity, 16 (8), 1809-1815.

Yannis Zervas, Apostolos Danis, & Vassilis Klissouras. (1991). Influence of Physical Exertion on Mental Performance with Reference to Training. Perceptual and Motor Skills, 72 (3 _suppl), 1215-1221.

Z. B. Yu, S. P. Han, X. G. Cao, & X. R. Guo. (2010). Intelligence in relation to obesity: A systematic review and meta-analysis: Intelligence aspect in base to. Obesity Reviews, 11 (9), 656-670.

Liao Yingying, Liu Hui, Xu Xia, Zhu Jie, Zou Rong, Liu Jirong, & Hong Xiaobin. (2022). The relationship between physical health and academic performance in children and adolescents: A moderated model. Journal of wuhan sports college, 56 (3), 70-78.

Zhu Lin. (2012). Methodological study on energy consumption measurement of common Physical activity in adolescents aged 11-14 [Ph.D. The Shanghai sports institute].

Li Jidong. (2016). Research on the Relationship between Physical Activity, Physical Health and Executive Function of Primary School students [Master] Yangzhou university].

Li Meihua. (2006). Research on Executive Function Development in children and Adolescents of Different Grades and Academic performance

[Doctoral Dissertation] Tianjin Normal University.

Li Mei-hua & Bai Xuejun. (2008). Executive function development of Students with different academic performance types. Psychological science, 4, 866-870 + 855.

Fan Qixue & Yang Jiapeng. (2018). An empirical study on the Relationship between students' Physical fitness and academic performance. Journal of guangzhou institute of sports, and (3), 120-124 + 128.

Wen Xu, Zhang Ying, Zhou Lu, & Hua Jun. (2018). The impact of physical health on academic performance of adolescents and its mechanism of action: Evidence from longitudinal studies. Journal of Beijing sports university, 41 (7), 70-76.

Chen Aiguo, Yin Hengchan, Wang Jun, Li Xinnan, & Song Zheng. (2011). A magnetic resonance imaging study on the improvement of executive function in children by short moderate-intensity aerobic exercise. Sports science, 31 (1), 35-40.

Chen Aiguo, Yan Jun, & Zhao Feng. (2013). Sports and national quality improvement: New evidence from brain science. Journal of east China normal university (education science edition), 31 (2), 63-68.

Huang Tao, Xu Bo, Yang Yifei, & Bai Junwei. (2006). The promoting effect of BDNF-mediated movement on advanced brain functions - learning and memory ability. Sports science, 9, 82-85.