

THE RELATIONSHIP BETWEEN PHYSICAL FITNESS AND ACADEMIC PERFORMANCE IN COLLEGE STUDENTS

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ABSTRACT

An emerging body of evidence has revealed a positive relationship between physical fitness and academic achievement in school aged children. However, few studies with college students have examined this relationship. The purpose of the current study aimed to assess various fitness data in college students using the Chinese National Student Physical Fitness Standards (CNSPFS) battery to investigate this relationship between physical fitness and academic performance in college students. Data including a total of 3,799 college students in China from 2014 to 2017 revealed that, relative to their counterparts, students who were higher in academic performance exhibited better fitness level in cardiorespiratory endurance, leg strength, and flexibility. No such difference was observed in other fitness measures. Our findings indicate that there might be selective associations between fitness and academic performance in college students.

Keywords: Physical fitness, academic performance, college students.

1. INTRODUCTION

Studies examining the relation among physical activity, fitness, cognitive function and academic achievement have been increasing recently. A systematic review has indicated that academic achievement may benefit from better cognitive functioning, which is related to physical fitness and physical activity (Donnelly et al., 2016). In particular with physical fitness, it has been shown to be positively associated with cognition (Chaddock et al., 2012; Donnelly et al., 2016), weight status (Shang et al., 2010), psychological well-being (LaVigne, Hoza, Smith, Shoulberg, & Bukowski, 2016), academic achievement (Cottrell, Northrup, & Wittberg, 2007; Davis & Cooper, 2011; Donnelly et al., 2016; Hsieh et al., in press), and performance of real-world tasks (Chaddock, Neider, Lutz, Hillman, & Kramer, 2012). In contrast, low fitness is likely to lead the development of cardiovascular disease risks across lifespan (Carnethon, Gulati, & Greenland, 2005; Ortega, Ruiz, Castillo, & Sjostrom, 2007).

The public health importance of physical fitness in school aged children has been drawing considerable attention. In China, the importance is even greater given the major social, demographic, and epidemiologic changes over the past 3 decades that have impacted the behavior lifestyle of many Chinese school children (Zhu, Yang, Kong, Zhang, & Zhuang, 2017). Preliminary data has revealed the prevalence of physical fitness in Chinese school-aged children, suggesting a clear trend of decline in physical fitness over a 20-year period (Research Group on Chinese School Students Physical Fitness and Health, 2007; 2012; 2016). However, none of these studies focused on college students. Regardless, the detrimental effect of stress on college students represents the major contributing factor of health issues and subsequently, academic performance. Specifically, Sorrentino (2015) has discovered that fifty percent of students had symptoms of high stress during regular class time. In contrast, studies including systematic reviews and meta-analyses have addressed the fitness – cognition relation, suggesting the role of fitness in brain health and academic success (Daniels, 2009; Smith et al., 2014). However, this relationship has been established in younger populations. For instance, in school-age children, a positive relationship between aerobic fitness and academic achievement has been found (Castelli, Hillman, Buck, & Erwin, 2007; Chomitz et al., 2009;

Donnelly et al., 2016). Furthermore, studies indicated that children with higher aerobic fitness have greater hippocampus volume (a region associated with memory) and perform better (i.e., higher accuracy and faster reaction time) in cognitive tasks requiring concentration and attentional control (Chaddock et al., 2014; Hillman, Bucks, Themanson, Pontifex, & Castellie, 2009; Moore et al., 2013; Wu et al., 2011). However, research on its relationship with college students has been limited. To date, only few studies have been conducted; however, when reviewed closely, they did not reveal the direct relationship between fitness and academic performance (Windschitl, 2008; McElveen & Rossow, 2013). Specifically, without assessing fitness data, instead, these studies examined the relationship of participation in recreational sports and previous high school grade point average (GPA) in university students. Results indicated that higher GPA scores were observed when students visited the campus recreational facilities. Given the lack of data in true fitness assessment, these studies fail to validate the relationship between fitness and academic performance. Therefore, further studies are needed using actual fitness assessment data to extend the relationship described above from children to young adults such as college students. Although factors such as aerobic fitness might play a role in academic achievement in university students, the relationship among other fitness indicators and academic performance in college student remains unclear. With that in mind, physical fitness consists of several categories including cardiorespiratory endurance, muscle strength endurance, flexibility, and body composition (Ortega et al., 2007). It is necessary for studies to further examine this relationship using various fitness measures. However, a systematic review has indicated that the fitness measures used and the way that fitness test results were categorized differed across the studies in the fields. In addition, measures of academic achievement also varied, from different standardized tests to specific scores on reading or writing (see Donnelly et al., 2016 for review), weakening the relationship between fitness and academic performance. Taken together, past research has examined the positive relation of specific fitness indicator (i.e., aerobic fitness) on academic achievement in children. However, the extent and specifics of the advantages in university students are yet to be understood.

As mentioned previously, preliminary data in China has revealed the prevalence of physical fitness in school-aged children. However, none of them focused on college students, resulting in the lack of research on the relationship between fitness and academic performance in college students in China. Therefore, the current study aimed to assess fitness data in college students using the Chinese National Student Physical Fitness Standards (CNSPFS) battery (MEPRC, 2014). With that in mind, various fitness indicators, such as cardiorespiratory endurance, muscle strength and endurance, flexibility, and body composition were assessed, providing a comprehensive data-set regarding the physical fitness. Furthermore, given that the way the academic achievement data collected varied across studies (see Donnelly et al., 2016 for review), the current study aimed to assess academic performance using a standardized testing on 5 subjects, which were required to take for all university students enrolled at the university in China during their sophomore year. As such, this study builds on the current body of research on the topic by addressing the following research questions: (a) would the positive relationship between aerobic fitness and academic performance extend its population from the previously observed school-aged children to college students? (b) would other fitness indicators, such as muscular strength and endurance, flexibility, and body composition be found positively associated with academic performance? Based on previous research findings on the topic, we developed the following hypotheses: hypothesis 1 – physical fitness indicator related to cardiorespiratory endurance (i.e., 1000- and 800-meter run) would be positively correlated with academic performance; hypothesis 2 – other physical indicators from CNSPFS data-set would be positively correlated with academic performance. It is hoped that the results of the study will stimulate more studies on the topic in the future.

2. METHODS AND MATERIALS

2.1 Experimental approach to the problem

A secondary analysis of data collected by Office of Institutional Effectiveness and the Department of Sports at the University of Electronic Science and Technology of China (UESTC) on sophomores from the year during 2014 to 2017 in Sichuan province, China was conducted. This cross-sectional study utilized a retrospective nonexperimental research design to examine the relationship between physical fitness and academic performance. To address the research questions, fitness data using the CNSPFS battery (MEPRC, 2014) and academic performance using a standardized achievement test on five study subjects (i.e., College Physics, Probability and Statistics, General English, Calculus, Linear Algebra and Geometry) were assessed. Academic performance was categorized into 5 levels, with the level of A (defined as having scores of ≥ 90.0), B (scores 80.0 – 89.9), C (scores 70.0 – 79.9), D (scores 60.0 – 69.9), and no pass (scores < 60.0) according to the average score from the five tested subjects. However, there were only 102

participants receiving an average score of A, and only 552 participants scoring an F which could not generate meaningful statistical results. Thus, the A group was combined with the B group, and the D group was combined with F group. Although age commonly account for the academic performance, this variable was excluded from the analysis due to its small variation ($SD = 0.8$).

2.2 Participants

No human subject committee approval was needed given that the Institutional Review Board affiliated with the lead authors determined that the analysis of the secondary dataset applied in the current study satisfactorily met the exemption criteria. Initial dataset included a total of 20,368 sophomores from 2014 to 2017 in School of Electronic Science and Engineering, School of Materials and Energy, School of Information and Communication Engineering, and School of Physics were accessed. Data screening was then performed to exclude cases with any missing data, resulting in a total of 3,799 participants (16 % females, $n = 607$). The sample was similar to the national population consisting of Han Chinese (90.8%), and other ethnic groups (9.2 %). All participants are full-time college sophomores. The average age of the sample was 19.64 ($SD = 0.80$).

2.3 Procedures

CNSPFS data have been collected nationwide in China to help universities promote physical education and evaluate student health. In this study, fitness data using CNSPFS (MEPRC, 2014) were part of the large data set required to submit to the Ministry of Education of the People's Republic of China. Measures of physical fitness were collected by trained physical education instructors affiliated with the lead authors. A comprehensive fitness assessment (described below) was taken using standard protocols on university campus during two physical education classes. Prior to assessment, college students were given detailed information and instructions on the fitness assessment and were provided with chances to ask questions. CNSPFS data collection was conducted in all 4 schools at UESTC concurrently in early September from 2014 – 2017. Institutional academic data was collected by the Office of Institutional Effectiveness. All students at UESTC were required to complete the standardized academic achievement test on five subjects (described previously) by the end of their sophomore year (in December). A cross-sectional design was applied in this study.

2.4 Measures

Physical fitness was assessed using the revised 2014 version of the CNSPFS (MEPRC, 2014), which involves a total of 7 fitness indicators described below. Each fitness indicator score was weighted by an age- and sex-specific percentage. BMI data were not included for data analysis as it may not provide an accurate measure of fitness.

2.4.1 BMI: BMI was used as a surrogate of body composition. Participants' height and weight were measured to the nearest 0.1 cm and 0.1 kg in bare feet, respectively. Both measures were assessed using a portable instrument (JH1221; China Sports & Tongfang, China). BMI values were then calculated as weight in kilograms divided by the square of height in meters (kg/m^2). This measure was assessed for all participants.

2.4.2 Vital Capacity of Lung: In a well ventilated and quiet assessment setting, participants' vital capacity (VC) was assessed via spirometry (JH1663; China Sports & Tongfang, China). VC is defined as the maximum volume of air (measured in milliliters) the participant can expel from the lungs after a maximum inhalation. The test was repeated 3 time on each participant, and the best performance from the 3 tests was recorded. This measure was assessed for all participants.

2.4.3 Fifty (50) m sprint: Multiple straight track lines on a flat and clear surface were provided to all participants, who were instructed to run as fast as possible for a 50 m distance. Each participant performed once as a single maximum sprint. The time for the run was recorded to the nearest 0.1 s. This measure was assessed for all participants.

2.4.4 Sit and Reach: To assess flexibility, a sit and reach test was administered. With a seated position, while both knees were fully extended, and feet were placed firmly against a vertical support, participants were instructed to reach forward as far as possible, with their hands along a measuring line. Two attempts

were given to each participant, and the best performance from the 2 trials was recorded to the nearest 0.1 cm. This measure was assessed for all participants.

2.3.5 Standing Long Jump: Participants were instructed to stand behind a line marked on the ground with feet slightly apart. He or she was then asked to vigorously push off with both feet and jump forward as far as possible. The jumping distance was measured from the take-off line to the nearest point of contact on the landing (back of the heels). Three attempts were allowed, with the longest distance jumped used as the measurement (in cm). This measure was obtained for all participants.

2.4.6 Timed Sit-Ups and Pull-Ups: This was a sex-specific test of strength. This test involved a timed sit-ups test for females and a pull-ups test for males. To assess muscle strength, female participants were instructed to perform a 1 min sit-up test. Participants were required to lay in a supine position with their knees bent and feet flat on a floor mat (secured by the test administrator), and with their hands placed on the back of the head and fingers crossed. Participants were instructed to raise their trunk until the elbows made contact with the thighs and then return to the starting position by lowering their shoulder blades to the mat. Participants were asked to perform as many sit-ups as possible during the 1 min test period. The test administrator counted and recorded the number of sit-ups. To assess muscle strength, male participants were instructed to perform a series of pull-ups. Being in an upright position, with a light jump (a lift was given, if needed, by the test administrator), participants grasped an overhead bar using an overhand grip (palms facing away from the body) with arms fully extended. Participants were asked to pull the body up until the chin cleared the top of the bar and then lower their body to a position with the arms extended. Participants were asked to perform as many pull-ups as possible, with the total number recorded.

2.4.7 100 m and 800 m Run: This was a sex-specific test of endurance, including running 1000 m for males and 800 m for females. Participants were instructed to run as fast as possible on a track line. Walking or slow jogging was allowed as an option for those who were not able to perform the test or had to stop for a rest during the test. The time for the run was recorded to the nearest second. This measure was assessed for all participants.

2.5. Statistical analysis

Data were entered centrally and verified by a trained group of research staff. Preliminary analyses were conducted to verify data discrepancies and check data distribution. Participants' physical fitness scores from the 7 fitness indicators were first calculated using age- and sex-specific weight defined by the 2014 revised CNSPFS. Final weighted scores were in the range 0 – 100, with the categories of excellent (defined as having scores of ≥ 90.0), good (scores 80.0 – 89.9), pass (scores 60.0 – 79.9), or no pass (scores < 60.0). Descriptive analyses (i.e., frequency) of the specific indicators of physical fitness and the standardized academic performance were conducted first by sex (female and male) and ethnicity (Han Chinese and others). Analyses were conducted using a one-way analysis of variance (ANOVA) for each academic group (AB, C, DF) to determine whether there were statistically significant differences between groups among the 7 CNSPFS fitness indicators. For significant ANOVA tests, post hoc pairwise comparisons with LSD correction were used to assess specific differences. Significance was set a priori at a p value of less than 0.05. All analyses were completed using SPSS 25.0.

3. RESULTS

Complete fitness data were obtained for a total of 3,799 college sophomores (aged 19.64 ± 0.80 years, mean \pm SD) on 7 indicators: BMI, VC, 50 m sprint, sit and reach, standing long jump, timed sit-ups/pull-ups (sex-specific), and 1000/800 m run (sex specific). Descriptive information on academic performance and CNSPFS fitness data are presented in table 1 for all participants and table 2 shown by academic group, respectively.

Table 1: Means (SD) of fitness data and academic performance

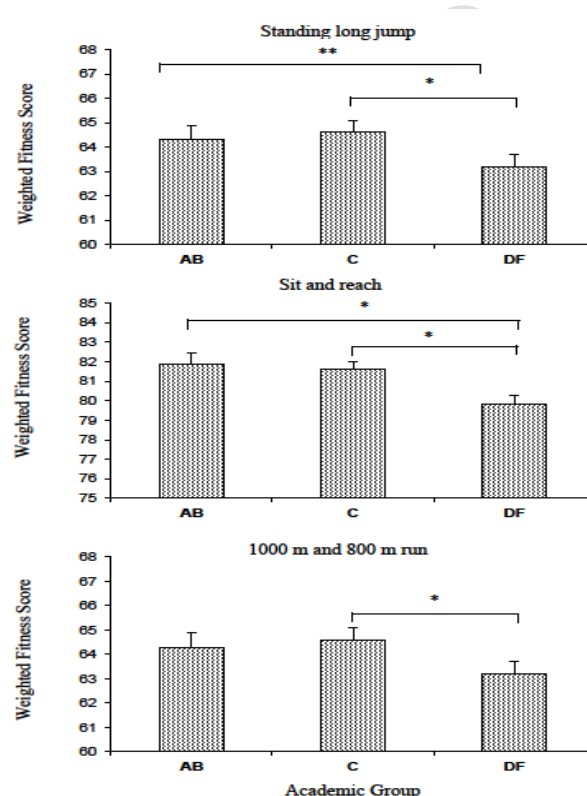
		CNSPFS Fitness Data (age- and sex-specific weighted score, 0 - 100)							
N	Academic Performance	BMI	vital capacity	50 m sprint	Sit and reach	Standing long jump	Timed sit-ups/ Pull-ups	1000/ 800 m Run	
Sample	3,799	71.9 ±11.6	93.3 ±11.5	71.6 ±12.8	69.2 ±17.8	80.1 ±16.6	59.5 ±15.3	40.8 ±13.6	65.0 ±18.1

Table 2: Means (SD) of fitness data by academic performance group

	N	CNSPFS Fitness Data (age- and sex-specific weighted score, 0 - 100)					
		vital capacity	50 m sprint	Sit and reach	Standing long jump	Timed sit-ups/ Pull-ups	1000/800 m Run
Academic Group							
AB	1021	72.2±21.8	69.9±27.1	80.9±16.8	61.9±26.3	41.2±16.9	65.4±18.2
C	1296	71.5±23.3	69.0±28.4	80.8±15.1	60.1±25.7	41.6±15.1	65.8±17.3
DF	1482	71.3±23.0	68.9±27.7	78.9±17.7	57.4±24.0	39.8±16.3	64.2±18.8

The results of one-way ANOVA revealed that there were significant differences in standing long jump performance by academic group [$F(2, 3796) = 9.91, p < 0.001$]. The post hoc test indicated differences between academic group AB and DF ($p < 0.001$) and group C and DF ($p = 0.005$) were significant. In addition, there were significant differences in sit and reach performance by academic group [$F(2, 3796) = 5.69, p = 0.003$]. The post hoc test indicated differences between academic group AB and DF ($p = 0.004$) and group C and DF ($p = 0.004$) were significant. Also, there was a marginal trend toward significant differences in sit and reach performance by academic group [$F(2, 3796) = 0.976, p = 0.056$]. The post hoc test indicated differences between academic group C and DF ($p < .05$) were significant. Significant results of CNSPFS fitness data shown by academic group are presented in Figure 1.

Figure 1: CNSPES fitness data (mean ± SE) by academic group. * $p < 0.05$, ** $p < 0.01$



4. DISCUSSION

Physical fitness has been widely utilized as an indicator associated with cognition, psychological well-being, and academic achievement (Donnelly et al., 2016; Chaddock, et al., 2012). While it is true that fitness components include cardiorespiratory endurance, muscle strength and endurance, flexibility, and body composition, previous studies that examined the relation between fitness and academic achievement limited measures of fitness to specific components such as muscular strength (Keating, et al., 2012) or utilized indirect fitness outcomes such as collegiate recreation participation (Sanderson, et al., 2018). As a result, the contribution of using the comprehensive Chinese National Student Physical Fitness Standard (CNSPFS) battery (MEPRC, 2014) on college students' physical health is better understood than our knowledge concerning its relationship with cognitive health, as represented by standardized academic test

performance in the current study. The contribution of this study to the knowledge base are twofold as follows: (a) the positive relationship between physical fitness and academic performance might provide a rationale for further investigating the cause and effect of exercise engagement on university students' academic performance using a randomized controlled trial; and (b) the selective relationship between fitness measures (i.e., leg strength, flexibility and cardiovascular endurance) and academic performance is important for future inventions regarding university student exercise involvement.

The current study extends the relationship between fitness and academic performance given that most studies were conducted with children (Castelli et al., 2007; Chomitz et al., 2009; Hillman et al., 2005; Kamijo et al., 2012). Similar to the early research in children, this study provided preliminary confirmation of the association between cardiovascular endurance and academic performance (a marginal trend toward significant). Specifically, for the first time in the literature, the results of the study supported the hypothesis 1 that those individuals who were higher in aerobic fitness level (reflected in 1000 m and 800 m run) were more likely to have a higher academic performance among university students. Further research is needed to investigate the mechanism of this fitness components positively associated with academic performance. Unfortunately, existing studies have focused on either invalid fitness measure such as Body Mass Index (Anderson et al., 2017) or the acute effects of exercise training (Pontifex et al., 2009) with few studies examining college student aerobic fitness level and their academic performance. To our best knowledge, the current study is the first research investigating the relationship between aerobic fitness and academic performance in college students using national student physical fitness standard. No studies have utilized such a fitness measure with a large sample size to examine this relationship. Furthermore, instead of self-reported Grade Point Average (GPA) data utilized by previous studies (Keating et al., 2012; Caletine, et al., 2017), the current study applied a university-wide standardized academic achievement test on 5 subjects, resulting in unbiased academic data. However, due to the nature of this study design (i.e., correlational study), caution needs to be taken when generalizing these results.

Given that Ministry of Education of the People's Republic of China has attempted to promote Chinese student's overall physical health since 2014 (MEPRC, 2014), it is important to track student's fitness data in their college years so that MEPRC can monitor the effects of physical education or physical activity interventions implemented on schools or universities. In addition, studies have suggested that tracking student's physical activity amount or health-related behavior, which contributes to their fitness outcome, may allow universities for early intervention on students who need more attention (De Bourdeaudhuij et al., 2002; Hall et al., 2002; Nakamura et al., 2009). Given the comprehensive fitness measures utilized in this study and the standardized academic performance data collected from a relatively large sample size, the results may provide fundamental information concerning student fitness changes by the end of their sophomore year in college.

The data from the study partly supported the hypothesis 2 that those individuals who were higher in leg strength (reflected in standing long jump) or flexibility (measured by sit and reach test) were more likely to have a higher academic performance among university students. Specifically, with regard to the relation of leg strength to academic performance, the results supported previous study where strength training frequency was found to be positively associated with GPA in college students (Keating et al., 2013). It is noted that Keating and her colleagues (2013) utilized self-reported GPA as the academic performance, which might cause the academic achievement data biased. The current results, which were collected college student academic performance based on a standardized achievement test on 5 subjects and administered by Office of Institutional Effectiveness within the university, may extend the study conducted by Keating et al (2013) given the more valid academic performance data. Although the nature of the current study design is cross-sectional, results taken together from previous study (Keating et al., 2013), the current study suggests that a strength training intervention or maintaining adequate strength may benefit academic performance in college students. Moreover, it is important that results from other strength measures in the current study including timed sit-ups (for females) and pull-ups (for males) did not show such relationship observed in leg strength. It is not surprising that there might be a selective relationship between fitness and academic performance. Specifically, previous studies that investigated relation of fitness to cognition have suggested that exercise might have a positive influence on academic achievement with an unsolved question on whether exercise improves all aspects of academic achievement or whether the effect is selective in nature. (see Donnelly et al. 2016 for a systematic review). In addition, given the nature of demanding muscle is different across the strength tests in the current study, with sit-ups test requiring abdominal muscle strength and the pull-ups requiring upper body strength, it might be possible that leg strength (reflected in long standing jump test) exhibits a strong correlation with academic performance. Further study is needed to investigate the mechanism on leg strength on academic performance. While it might be possible that a selective relationship between fitness and academic performance resulted in the insignificant difference in upper body strength and abdominal strength between academic groups, it is also noted that the

overall timed-sit-ups and pull-ups score were relatively poorer (40.8 ± 13.6) compared to any other fitness measures. This skewed data may be responsible for the insignificant difference between academic groups. Further study selecting participants with both higher- and lower strength might be necessary to explore this type of question.

Results from VC and 50 m sprint did not show any difference between academic groups. 50-meter sprint was measured as an index of anaerobic capacity. To date, studies examining this relationship with anaerobic capacity are rare, resulting in our limited knowledge about it. To our knowledge, however, the present study is the first to report a nonsignificant anaerobic difference by academic performance. Research on the topic warrants more attention by professionals in the anaerobic field. In addition, it is important to point out that anaerobic fitness tests consist of anaerobic power and anaerobic capacity. Anaerobic power tests include force-velocity tests, vertical jump tests, staircase tests, and cycle ergometer tests while anaerobic capacity tests are subdivided into maximal oxygen debt test, ergometric tests (all-out tests and constant load tests), measurement of oxygen deficit during a constant load test and measurement of peak blood lactate (Vandewalle et al., 1987). The CNSPFS fitness battery does not include any of the tests mentioned above. Thus, it is impossible for this study to comprehensively examine the anaerobic fitness between academic groups. In addition, results from VC did not show significant differences between academic groups. It is not surprising as VC is widely used for clinical applications other than being considered a physical fitness indicator. Specifically, Liang and colleagues (2012) mentioned the various components of lung function tests provide very important tools for the clinical evaluation of respiratory health and disease. It is possible that the overall vital capacity (71.6 ± 12.8) were relatively healthy across the sample, resulting in the insignificant differences between academic groups.

5. CONCLUSION

The cross-sectional study may accurately provide selective associations between fitness and academic performance but not causality. Therefore, this analysis of associations is only a starting point to explore whether maintaining a healthy level on certain fitness indicators has the potential to influence student academic performance. The study cannot, however, explain the mechanism of different types of exercise influencing student cognition directly as widely known, student academic achievement. In addition, comprehensive fitness indicators are influenced by factors too numerous to be controlled in a single experimental study. Although the current study intended to control several confounding variables (such as years in university, academic tests, ethnicity), further studies including genetic, demographic, psychosocial, and environmental variables are needed.

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