Physical fitness and academic performance: empirical evidence from the National Administrative Senior High School Student Data in Taiwan

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Abstract

This study examined the relationship between the changes of physical fitness across the 3-year spectrum of senior high school study and academic performance measured by standardized tests in Taiwan. A unique dataset of 149 240 university-bound senior high school students from 2009 to 2011 was constructed by merging two nationwide administrative datasets of physical fitness test performance and the university entrance exam scores. Hierarchical linear regression models were used. All regressions included controls for students’ baseline physical fitness status, changes of physical fitness performance over time, age and family economic status. Some notable findings were revealed. An increase of 1 SD on students’ overall physical fitness from the first to third school year is associated with an increase in the university entrance exam scores by 0.007 and 0.010 SD for male and female students, respectively. An increase of 1 SD on anaerobic power (flexibility) from the first to third school year is positively associated with an increase in the university entrance exam scores by 0.018 (0.010) SD among female students. We suggest that education and school health policymakers should consider and design policies to improve physical fitness as part of their overall strategy of improving academic performance.

Introduction

There is incontrovertible evidence that regular physical activity reduces the risk of cardiovascular disease, type 2 diabetes, metabolic syndrome, colon and breast cancers, dying prematurely and obesity [1–3]. Being physically active has beneficial influences on psychological health, including depression, anxiety, stress and self-confidence [2, 4]. Regular physical activity in adolescence is particularly important because it helps to build and maintain healthy bones, muscles and joints [2]. Regular physical activity in adolescence helps to develop good physical activity habits and stay active into adulthood reducing incidences of chronic diseases in adulthood, such as obesity and hypertension [5, 6].

School-based physical education classes serve as an ideal avenue to provide opportunities for students having regular physical activity as students spend more time at school than anywhere else except home. However, physical education in schools is sometimes regarded as an extracurricular activity despite the acknowledgement of the benefits of physical activity for adolescents. Many schoolteachers, parents and students believe that taking time for physical education detracts from academic performance [7–10]. Hence, physical education classes are usually being replaced with more classroom instructional time in an effort to improve students’
academic achievements measured by standardized tests [8, 9, 11, 12]. Physical education time declines sharply as senior high school students progress through grades, because they have to spend more time on college admissions process. For example, 47% of ninth-grade students and only 22% of 12th-grade students attended physical education class daily in the USA in 2009 [13]. Similar information on daily participation in physical education among Taiwan’s senior high school students is not available; however, we might expect a much lower daily participation rate in physical education, because Taiwan’s senior high school students are only required to take 2 hours of physical education classes as a minimum every week [14]. If there is evidence that physical education plays a critical role in the academic success of students, one can argue that physical education is not an extracurricular activity [12].

Numerous previous studies have correlated physical activity/physical fitness/physical education with academic performance; however, the findings are, at best, inconclusive. Before we proceed further, it is worthwhile to clarify the terms for physical activity, physical fitness and physical education, as they are usually confused with one another. According to Caspersen, Powell and Christenson [15], physical activity is ‘any bodily movement produced by skeletal muscles that results in energy expenditure’ and physical fitness is defined as ‘a set of attributes that people have or achieve that relates to the ability to perform physical activity. The degree to which people have these attributes can be measured with specific tests’. Health education is ‘the instruction in physical exercise and games, especially in schools’ [16].

To the best of our knowledge, there are only two known published studies involving random assignment of students to experimental and control conditions to address the causal effect [11, 17]. Both studies did not find evidence that spending more time on physical activity at schools leads to improved standardized test scores. Both studies, however, conducted a randomized controlled trial within a specific school/region and suffered from a small-sample problem. Using age-cohort data, some studies have found that physical activity/physical fitness/physical education is an important contributor to academic achievements [18–21]. These studies, however, focused on younger cohorts from kindergarten to ninth grade. Due to the lack of suitable age-cohort data, the majority of published research relies on cross-sectional data. Numerous studies used cross-sectional population-representative data and observed that the participation in physical activity is significantly positively associated with academic performance [22–29]; however, none of these studies assessed academic performance with objective standardized test scores.

Our study supplements to the existing literature in several ways. First, the data used in this study are unique. We merge two of Taiwan’s nationwide administrative datasets, physical fitness test performance and the university entrance exam academic scores. The two datasets are on public records and not self-reported. Hence, our physical fitness and academic performance measures are objective and free of self-reported bias. Second, the university entrance exam is the necessary hurdle for all university-bound seniors to be admitted into an undergraduate program in Taiwan. The university entrance exam is uniform across the country, which leads our estimates based on the national scope of standardized tests. Third, this study focuses on senior high school adolescents who have not been extensively discussed before. Fourth, this study attempts to go one step beyond a commonly used cross-sectional analysis. In addition to the physical fitness of the first school year of each student, we also have information on the changes of physical fitness test performance from the first to third year of senior high school study period of each student. The availability of this unique information allows us to not only control for the baseline physical fitness status but also relate ‘changes’ in physical fitness performance over time to the academic performance measured by standardized tests. Moreover, as school identification is available in the data, we are able to take the school level of hierarchy, such as a school’s geographical location and annual budget, into account.
by estimating hierarchical linear models. Finally, Taiwan’s education system is heavily exam-oriented, owing to which physical education is often cut back or eliminated. Our analysis is of policy relevance and it may help to justify the Taiwanese government’s recent proposal that physical fitness performance should be included as part of university entrance exam scores.

The purpose of this study is to understand the relationship between the changes of physical fitness across the 3-year spectrum of senior high school study and academic performance measured by the university entrance exam scores in Taiwan. In particular, the heterogeneous relationships by gender are examined. Male and female students may differ in the physiological and/or psychological levels at baseline. Hence, it is important to explore the gender heterogeneity when documenting the relationship between the changes of physical fitness and academic performance. For the purposes of this study, it is hypothesized that improved physical fitness would relate to better academic performance and this relationship would be stronger among female students who tend to have lower levels of physical fitness at baseline [20, 30].

### Materials and methods

This study explores the relationship between changes in physical fitness performance across the 3-year spectrum of senior high school study and academic performance measured by the university entrance exam in Taiwan. Descriptions of the data used and matching procedures, measures of physical fitness and academic performance, characteristics of the participants and statistical analyses are illustrated below.

### Procedures

Two population-based datasets are used. The first dataset is the physical fitness profile of the senior high school students collected by the Department of Physical Education, Ministry of Education (MOE), Taiwan. Aiming at evaluating and enhancing senior high school students’ physical fitness performance, the MOE has required each senior high school to conduct the physical fitness tests for their students and submit the test results to the MOE. This dataset contained information on physical fitness assessments (including muscular fitness, anaerobic power and flexibility), gender and grade level of each student.

The second dataset is the total score of the university entrance exam, the General Scholastic Ability Test (GSAT), administered by the College Entrance Examination Center (CEEC), Taiwan. The GSAT is the necessary hurdle for all Taiwan’s university-bound seniors to pursue their studies at the tertiary level after 3-year senior high school education. This dataset also contained information of the examinee’s age and family economic status, as low-income students are free of charge for GSAT registration fees.

In this study, we matched the physical fitness profile and the university entrance exam scores of each student based on the personal identification and name with the supervision and the technical support from the MOE and CEEC. The most recent three waves of university-bound seniors who took the university entrance exam in 2009, 2010 and 2011 were chosen. For each year dataset, we first matched each university-bound student’s exam performance and his/her physical fitness test results in the same year. The physical fitness test results then represented each student’s third year fitness performance. For each student, we traced back their physical fitness test results in his/her first high school year. In doing so, we were able to construct the changes of physical fitness of each student from his/her first (freshman) to the third (senior) high school year. Taking the students who took the 2011 university-bound exam for instance, we had their GSAT scores in 2011 and the physical fitness test results of their third (2011) and first senior high school year (2009) as well. The same procedure was conducted for students who took the university entrance exam in 2009 and 2010.

Based on the usual path of senior high school education in Taiwan, we restricted our observations to students who took the university entrance exam between the ages of 17 and 18 to eliminate potential
exam-retakers and talented students who skip grades. The final sample comprised 149,240 observations, of which 71,000 were male and 78,240 were female students. We have received approval by the ethics review panel of the MOE and CEEC to use the data.

**Measures**

*Physical fitness*

All physical fitness tests were conducted by physical education instructors. The physical education instructors were required to participate in a 3-day training program hosted by the MOE to learn detailed instructions of the physical fitness tests. Only those physical education instructors who passed the certification tests were qualified to carry out students’ physical fitness tests. The physical fitness tests were completed in physical education classes during the first 4 weeks of the first academic semester and once per year over the 3-year senior high school study period.

Three physical fitness assessments were used in this study: muscular fitness, anaerobic power and flexibility [in addition to these three measures of physical fitness, information of the aerobic fitness test is also available in the dataset. This component was assessed by a 1600- and 800-m run/walk test for male and female students, respectively. Each student was encouraged to give his/her best effort to run or walk to complete the distance as fast as possible. We did not accommodate this information into our analysis, because the test results of the aerobic fitness contained significant amount of missing values (~15% of the total sample). Including aerobic fitness will then significantly drop our sample size, which further affects the national representativeness of our sample.]. Muscular fitness was measured by a 1-min bent knees curl-up test. The score of muscular fitness was the total number of correctly performed (both elbows touching both knees) curl-ups within 1 min. Anaerobic power was assessed by jumping distance in centimeter in a standing long jump test. The distance was measured from the take-off line to the nearest point of contact to the ground. Flexibility was conducted in a sit-and-reach test, which measures the distance from the fingertips to the edge of a ruler [31]. A higher score indicates better performance for each physical fitness test.

Before the tests began, the physical fitness instructors would explain in detail the descriptions regarding each physical fitness test and provide a demonstration. The students were asked to perform warm-up exercises and had a chance to practice. All the instructions, demonstrations and practices helped students to be familiarized with each test. The students had two trials for the formal test; the best test result was recorded. The physical fitness test was halted if the student did not feel well physically during the testing process. For this case, a makeup test was held at an appropriate time (more detailed procedure of the physical fitness test can be found in the government guidelines of the Ministry of Education web site (http://www.fitness.org.tw/measure02.php).

Units of the assessment scores differ for muscular fitness, anaerobic power and flexibility tests and physical fitness performance may not be comparable across gender [12]. In addition, the physical fitness data used in this analysis are skewed (to the right). Hence, we normalized the physical fitness assessment scores separately for different physical fitness tests, gender and academic years by using Z-scores to obtain an aggregate score of the overall physical fitness of each student. The Z-score measures the number of standard deviations from the mean score and transforms different physical fitness tests, gender and academic years into standard scales. We aggregated the individual Z-scores on muscular fitness, anaerobic power and flexibility to derive the overall physical fitness measure of students [32]. Each Z-score of different physical fitness levels can be compared and summed up to reflect the overall physical fitness performance.

**Measures**

*Academic performance*

The GSAT consists of five subjects: Chinese, English, Mathematics, Science and Social Studies. Each subject test mainly contains
computer-readable multiple-choice questions. Mathematics includes short-answer questions and the language subjects contain essay tests. The score of each subject ranges from 0 to 15 points where 75 points is the highest total score. The higher the score on the GSAT, the better the chances to attend more selective universities. Similar to the physical fitness data, the GSAT scores are not normally distributed (skewed to the left). Hence, we normalized the GSAT total scores separately for different gender and academic years by using Z-scores as well. We used the GSAT Z-scores to measure students’ academic performance.

Characteristics of the participants

Table I presents detailed definitions of the selected variables and summary statistics of the participants. As shown in Table I, the average total score of the university entrance exam varied from 2009 to 2011. This may suggest us to include year dummy variables in the estimation to control for any unobserved factors that vary across time and are related to the total score of the university entrance exam, such as the difficulty level of the exams. Given the same cohort of the male students, it seems that the average scores of anaerobic power and flexibility increased from the first to the third year of senior high school. In contrast, more mixed messages emerge from the female students, in which only flexibility increased over time. In addition, physical fitness performance seems not comparable across gender. That is, male students performed better in muscular fitness and anaerobic power, whereas female students had a better flexibility. This further suggests us to separate estimations for male and female students. The majority (~70%) of the students took the university entrance exam at the age of 18 years according to the usual path of senior high school education in Taiwan. Students from low-income families account for 1–2% of the data from 2009 to 2011.

Statistical analysis

As school codes are available in the MOE physical fitness profile, we estimate hierarchical linear models to deal with the issue of hierarchical (nested) data structure. That is, there are lower level units (e.g. the student-level variables) nested within higher level units (e.g. school-level variables). In other words, the students are nested within the same school and share the impact of school-level variables. For example, students’ academic performance is influenced by the school level of the hierarchy, such as a school’s geographical location and annual budget. We estimate two hierarchical linear regression models seeking to answer two questions. First, how do the changes in the overall physical fitness across the 3-year spectrum of senior high school study relate to male and female students’ academic performance? Second, how do the changes in the individual physical fitness (muscular fitness, anaerobic power and flexibility) relate to male and female students’ academic performance in different ways?

The dependent variable in each regression model was the Z-score of the university entrance exam in the third year of senior high school. Our key predictor variable in the first model was the changes in the overall physical fitness status across the 3-year spectrum of senior high school study (Zscore_3–Zscore_1). In the second model, the key predictor variables included changes in muscular fitness (ZMuscular_3–ZMuscular_1), anaerobic power (ZAnaerobic_3–ZAnaerobic_1) and flexibility (ZFLEXIBILITY_3–ZFLEXIBILITY_1) from the first to third year in senior high school, respectively. In addition, the Z-score of the university entrance exam also relied on students’ initial physical fitness status in the first year of senior high school, Age18 (a dummy variable equal to one if the student took the university entrance exam at the age of 18 years and the reference group is the students who took the university entrance exam at the age of 17 years), interaction terms between the changes in physical fitness and Age18 (to control for the potential effect of age on physical fitness), family economic status and two dummy variables for 2010 and 2011 (the reference group is 2009). All models were estimated using STATA version 11 (StataCorp, College Station, TX, USA).
Table I. Definitions of study variables and summary statistics of participants

<table>
<thead>
<tr>
<th>Year</th>
<th>Male students</th>
<th></th>
<th>Female students</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sample size</td>
<td>Variable</td>
<td>Sample size</td>
<td>Variable</td>
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<tr>
<td></td>
<td></td>
<td>Definition</td>
<td>N</td>
<td>Definition</td>
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<td>Mean (SD)</td>
<td>Mean (SD)</td>
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<td></td>
<td></td>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grade</td>
<td>Overall grade of the university entrance exam (0–75)</td>
<td>49.74 (12.92)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Muscular_3</td>
<td>Muscular fitness (total count), third year</td>
<td>43.04 (10.95)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Muscular_1</td>
<td>Muscular fitness (total count), first year</td>
<td>45.32 (28.18)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Anaerobic_3</td>
<td>Anaerobic power (centimeter), third year</td>
<td>210.90 (29.19)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Anaerobic_1</td>
<td>Anaerobic power (centimeter), first year</td>
<td>199.59 (40.22)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flexibility_3</td>
<td>Flexibility (centimeter), third year</td>
<td>28.16 (10.08)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flexibility_1</td>
<td>Flexibility (centimeter), first year</td>
<td>27.98 (9.59)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Zscore_3</td>
<td>Aggregated Z-score of muscular fitness, anaerobic power and flexibility, third year</td>
<td>0.00 (2.00)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Zscore_1</td>
<td>Aggregated Z-score of muscular fitness, anaerobic power and flexibility, first year</td>
<td>0.00 (1.52)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Age18</td>
<td>Dummy variable (= 1) if the student took the university entrance exam at age 18 years</td>
<td>0.73 (0.44)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lowinc</td>
<td>Low-income students</td>
<td>0.01 (0.11)</td>
</tr>
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</table>

$Z$-score = (value - mean)/standard deviation, so the sample mean of the $Z$-score of each physical fitness should be zero by design.
Results

Table II shows the regression results that point to a stronger relationship between the changes in overall physical fitness and academic performance for female students. An increase of 1 SD on the overall Z-score from the first to third year of senior high school is associated with an increase of the university entrance exam by 0.007 SD among male students while that is associated with a larger increase of the university entrance exam scores by 0.010 SD among female students. The Age18 dummy variable is significant and somehow negatively associated with the academic performance. Compared with those who took the university entrance exam at the age of 17 years (the reference group), students who took the exam at the age of 18 years averagely scored less by 0.047 and 0.054 SD for male and female students, respectively. Family condition also matters for the academic performance of students. Results show that male and female students from low-income households have poorer performance in the university entrance exam by 0.109 and 0.089 SD, respectively. It is not unexpected that low-income students’ academic performance is inferior to that of their counterpart peers, because low-income students tend to have fewer resources available, such as financial resources, educational resources and community involvement.

Table III presents the regression results from individual physical fitness estimations. The different levels of relationships between the three physical fitness tests and academic performance between male and female students are observed. The changes in muscular fitness, anaerobic power and flexibility from the first to third year in senior high school students are not associated with the scores of the university entrance exam among male students. In contrast, among female students, improvements of anaerobic power and flexibility are significantly associated with the scores of the university entrance exam. On average, 1 SD increase on the anaerobic power and flexibility Z-scores from the first to third year of senior high school are associated with an increase in the university entrance exam by 0.018 and 0.010 SD, respectively. Results of the Age18 dummy variable and low-income status in both genders are similar to those in Table II. Finally, the significantly negative coefficient of \((Z_{Flexibility_3} - Z_{Flexibility_1}) \times Age18\) suggests that the change in flexibility from the first to third year in senior high school yields a smaller increase among male students who took the exam at the age of 18 years, compared with that of those who took the exam at the age of 17 years. In other words, there is an interaction effect between the changes in flexibility over time and age among male students.

Discussion

We have combined two unique national datasets in Taiwan and investigated how the changes in the overall and individual physical fitness across the 3-year spectrum of senior high school study relate to male and female students’ academic performance. Our results point to the evidence that the
changes in overall physical fitness across time and the scores of the university entrance exam are positively related, with a stronger relationship among female students. In addition, the improvements of anaerobic power and flexibility are positively associated with the university entrance exam scores among female students and not male students.

The stronger relationship between physical fitness and academic performance for female students is consistent with some previous studies [12, 18, 33]. The difference in our findings between male and female students may be explained by physiological and psychological mechanisms and developmental domains. The physiological mechanisms, such as increased blood flow to the cortex of the brain and alterations in brain-derived neurotransmitter activity, are prompted by exercise [34–36]. Female students tend to have lower levels of physical fitness at baseline [20, 30]. Hence, the physiological effect stimulated by physical activities is likely to be larger in female students than in male students. Enhanced self-esteem and reduced feelings of anxiety, depression and stress are some potential psychological mechanisms that may explain why the relationship between physical fitness and academic performance is stronger for female students [2, 4]. Lower levels of self-esteem were observed for girls compared with boys throughout childhood and adolescence [37, 38]. As a result, physical fitness may play a more important role in elevating self-esteem for girls. In addition, physical fitness is an important factor to influence other developmental domains, such as cognitive development, concentration, memory and school functioning [36, 39–42]. These effects may also differ between male and female students. The physiological and psychological mechanisms and developmental domains are all possibly related to academic performance. Nevertheless, we cannot conclude which component could explain our results.

Some potential mechanisms may support our statistical associations between anaerobic fitness/flexibility and academic performance. For example, intense anaerobic physical exercise elicits the increases in levels of brain-derived neurotrophic factor, dopamine and epinephrine. These mediators induced by anaerobic physical exercise are related to better learning success [43]. The unique of

<table>
<thead>
<tr>
<th>Table III. Hierarchical linear model analyses: relationships between individual physical fitness tests and the university entrance exam Z-scores by gender</th>
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<tbody>
<tr>
<td><strong>Variable</strong></td>
</tr>
<tr>
<td>ZMuscular_1</td>
</tr>
<tr>
<td>ZAnaerobic_1</td>
</tr>
<tr>
<td>ZFlexibility_1</td>
</tr>
<tr>
<td>(ZMuscular_3 – ZMuscular_1)</td>
</tr>
<tr>
<td>(ZAnaerobic_3 – ZAnaerobic_1)</td>
</tr>
<tr>
<td>(ZFlexibility_3 – ZFlexibility_1)</td>
</tr>
<tr>
<td>Age18</td>
</tr>
<tr>
<td>(ZMuscular_3 – ZMuscular_1) × Age18</td>
</tr>
<tr>
<td>(ZAnaerobic_3 – ZAnaerobic_1) × Age18</td>
</tr>
<tr>
<td>(ZFlexibility_3 – ZFlexibility_1) × Age18</td>
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<tr>
<td>LowInc</td>
</tr>
<tr>
<td>Year 2011</td>
</tr>
<tr>
<td>Year 2010</td>
</tr>
<tr>
<td>Constant</td>
</tr>
<tr>
<td>Sample size</td>
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<tr>
<td>Number of schools</td>
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Standard errors are in parentheses.  
*P < 0.1; **P < 0.05; ***P < 0.01.
flexibility exercise encourages a broad range of neural and chemical adaptations in the brain, which increases people’s executive central command ability of critical thinking [44].

Policy implications inferred from our findings are worthwhile to be discussed. Education and school health policymakers should implement policies to improve physical fitness as part of their overall strategy of improving academic performance. The MOE views physical education as an important contributor in the academic success of students. Therefore, their latest proposal counting physical fitness performance as part of university entrance exam scores for university-bound seniors seems to be legitimate. Physical education should be considered in curricular schedules and promoted for its numerous physical and psychological benefits. The MOE can consider increasing the current requirement of 2 hours of physical education per week and strictly ask schools to adhere to the weekly workload. Moreover, schools should provide a wider range of curricular activities, other than traditional team games, to meet the needs and interests of students, especially for female students who tend to have lower levels of physical fitness at baseline [20, 30] and demonstrate the stronger relationship between physical fitness and academic performance in our study. For example, school activities that are more attractive to girls, such as dance and yoga, should be encouraged. These activities are less competitive than mixed gender activities that are usually dominated by boys, resulting in more physical education participation and confidence for girls. High-quality sports facilities and changing rooms may also encourage sports participation for girls as well.

This study links two unique nationwide and population-based datasets: physical fitness performance and the university entrance exam scores. In addition, because of our data design, we are able to relate changes in physical fitness performance across the 3-year spectrum of senior high school study to the academic performance measured by standardized tests. Higher levels of changes in physical fitness (i.e. overall, anaerobic power and flexibility) are associated with better scores of the university entrance exam, particularly among female students, even after we have controlled for the relevant predictor variables and the issue of hierarchical (nested) data structure. These are the strengths of this study; however, two potential research limitations should be mentioned. First, we do not have much information on the family background to further control for the factors that may affect students’ academic performance at the household level (such as the educational attainment and ethnicity of parents). Our findings can be more robust if this type of information is available. Second, the university entrance exam score is the only measure to compare the academic achievement of students in this study. However, a 2-day exam may not precisely capture the actual achievement of students. A wider range of students’ achievements such as task persistence, eagerness to learn, extracurricular activity participation, community service and interpersonal skills are other possible indicators of academic success of students. Future research can aim at collecting more comprehensive data and obtaining a more clear understanding of the relationship between physical fitness and academic performance in students.

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Conflict of interest statement

None declared.

References


