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Dissertation Title

The Relationship between Physical Fitness and Academic Achievement in Middle School Students in Shanghai

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Supervisor: Professor Lars-Erik Malmberg

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Abstract

The relationship between physical fitness and academic achievement in relation to children and adolescents has received attention from an increasing number of researchers in various fields across the world. Large bodies of literature based on insights from neuroscience have reported a positive relationship between the overall or some specific components of physical fitness and academic achievement in different educational contexts. Furthermore, many neuroscientists have revealed that the mind and body are connected through the mechanisms of neurochemistry. It has been found that performing physical exercise can optimise the brain's cognitive functions by stimulating brain-derived neurotrophic factor (BDNF) release, thus contributing to brain development. Physical exercise can also increase the level of neurotransmitters such as dopamine, serotonin and noradrenaline, which can improve concentration and positive emotional states for learning. However, the research findings are still under debate due to inconsistencies between studies conducted in school settings, where the results are more likely to be influenced by various confounding factors.

Although numerous studies have been conducted on K-12 school-aged children in different educational settings around the world, few have been implemented in the specific context of Chinese adolescents in the middle school period of their education. It is necessary to pay more attention to this group of students experiencing considerable body shape changes in the developmental stage of puberty. Many previous studies employed a single cohort, cross-sectional design for their inquiries into this research topic. Such a design fails to explore the longitudinal trajectory in the course of the process. In order to further explore and extend knowledge regarding this topic, the present study aimed to examine the longitudinal relationship between each component of physical fitness and academic performance in three core subjects in the context of an urban middle school in Shanghai, China. This study utilised secondary data from one public middle school in Shanghai. The Chinese National Student Physical Fitness Standard (CNSPFS), which covers body mass index (BMI), agility fitness, muscular strength fitness and aerobic endurance fitness, was adopted. Standardised tests for Chinese (as a native language), Mathematics and English (as a foreign language) were also used. Data were drawn from two cohorts (Class 2015 and Class 2016) of now-graduated students from between Years 7 and 9, when they were aged 12–15 years old. The total sample of 557 participants (312 boys, 245 girls) was utilised for all data analyses by taking advantage of the statistical techniques of correlation and structural equation modelling (SEM). The researcher analysed the data by gender and controlled for cohorts and BMI in the longitudinal SEM models for the purpose of minimising the confounding factors.

The results from correlation analysis showed that there were some weak but positive relationships between physical fitness and academic achievement in the three core subjects among middle school students from Years 7 to 9 (r range from .11 to .28, $p < .05$). Interestingly, the relationships were generally found more frequently among boys than girls, and fewer associations were found between BMI and academic achievement compared to the other three types of performance-related physical fitness. In addition, more positive correlations were found between the level of aerobic endurance fitness and academic attainment for both boys and girls. The results from the longitudinal SEM analysis indicated more than one component of physical fitness could significantly predict academic achievement to some degree at one or more time points across the three academic years (β range from .09 to .33). Although the effect of each component of physical fitness was found to be unstable across three years and slightly different by gender, it is worth mentioning that aerobic endurance fitness could significantly predict academic achievement in all three subjects for both boys and girls, particularly in English.

Although positive relationships were found in this study, direct causality cannot be determined. The findings of this present study may provide recommendations for future studies on this research topic. In addition, the results may provide useful suggestions for educational practice in schools and for curriculum reform. It is hoped the findings will help to improve the physical fitness level of adolescents and enhance the effectiveness of academic learning, thus facilitating healthier education in the middle school stage.

Keywords: academic achievement, physical fitness, middle school students, Shanghai

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List of Abbreviations

BDNF: Brain Derived Neurotrophic Factor

BMI: Body Mass Index

CNSPFS: Chinese National Student Physical Fitness Standard

MRI: Magnetic Resonance Images

NPFMC: National Physical Health Management Centre

SEM: Structural Equation Modelling

SES: Socioeconomic Status

SLJ: Standing Long Jump

Chapter 1 Introduction

1.1 Background of the Study

Along with the current climate of academic accountability in China, the academic achievement of students is a high-priority criterion for evaluating the quality of education in school. Many other important aspects of education, such as physical education, have been downgraded in the educational system (Li & Ji, 2016). In order to promote higher performance in academic standardized tests, schools are spending more effort and time on academic learning and improvement, which gives rise to fewer opportunities for physical exercise to be provided in schools: this may sacrifice the body health of school-aged students (Lai et al., 2007). A students' health report shows that the overall physical fitness level among school-aged students had declined significantly since 2004, especially for adolescents in the urban areas of China (Jiang and Wang, 2014). The obesity rate among adolescents in the urban cities of China reached 13.3 per cent, which exceeded the 10 per cent safety threshold according to the World Health Organization standard (Jiang and Wang, 2014). For the purpose of monitoring the fitness status of school-aged students, the Chinese Ministry of Education released the Chinese National Student Physical Fitness Standard (CNSPFS) and required every public school in China to report the fitness test results to the National Physical Health Management Centre (NPFMC) every year (Ministry of Education of the People's Republic of China, 2014). A large project, the Youth Study, conducted by a Chinese research team in 2016, investigated roughly 200,000 children in primary and middle school stages in 32 provinces of China across urban and rural areas (Zhu et al., 2017). This survey utilized CNSPFS as its measurement, which covered various types of physical fitness including BMI, agility fitness, muscular strength fitness, and aerobic endurance fitness. The results indicated that about 8 per cent of the compulsory school-aged students failed to meet with the physical fitness standards. Furthermore, the fitness level of middle school students in urban areas was found to be worse than that of students in rural areas. Compared to girls, the fitness crisis was more serious among boys (Zhu et al., 2017).

The Chinese government has started to spread and encourage the implementation of the 'Sunshine Sports' policy since 2006, in order to promote the physical health and fitness of school-aged students (Ministry of Education of the People's Republic of China, 2006). However, the effects of this policy have been unsatisfactory. An investigation regarding the daily time spent doing physical exercise among Chinese school-aged students reported that only 32.2 per cent students meet with the guidance given by the 'Sunshine Sports' policy: 60 minutes of physical activity time in school every day (Li & Wang, 2016). A government report pointed out that the high-stakes nature of academic standardized test leads to the phenomenon of exam-orientated education in schools and, thus, the school administrators and teachers have to sacrifice the time allocated for students' physical activities, in order to spend more time on academic improvement (Central Committee of the Communist Party of China, 2007).

There are many debates on the effect of physical activity on academic performance among children and adolescents (e.g., Hansen, 2017; Ratey & Hagerman, 2008; Sun, 2002; Suzuki, 2015). Sun (2002) claims that the high intensity of physical training may impair academic learning due to the effect of physical fatigue. Suzuki (2017) argues that physical exercise can be transformative in protecting and strengthening the brain's functions. Hansen (2017) added that, theoretically, only moving creatures have brains and that being physically active can promote the growth of the brain through stimulating brain cell proliferation and releasing more BDNF (Brain Derived Neurotrophic Factor), which facilitates the cognitive functions for learning effectively. In addition, Ratey & Hagerman (2008) and Hansen (2017) also point out the impacts of physical fitness training on non-cognitive factors, such as controlling negative mood, the improvement of concentration, and the triggering of motivation for learning new things, due to the increased level of neurotransmitters in the brain. As a result of an increasing number of studies on animals and humans (e.g., Chaddock 2010; Erickson et al., 2011; Van Praag, et al., 2005), many neuroscientists believe that our minds and bodies are connected (Hansen, 2017; Ratey & Hagerman, 2008; Suzuki, 2015): "The better your fitness level, the better your brain works" (Hagerman, 2008, p 247).

A large number of researchers from different countries have reported that there is a positive association between the overall physical fitness level and the academic achievement of children and adolescents (e.g., Chomitz et al., 2008; Eveland-Sayers et al., 2009; London & Castrechini, 2010). Some researchers have conducted more granular studies by employing the statistical techniques of correlation or regression to explore the degree of relationship between each component of physical fitness and the standarized test performance in one or more core subjects (e.g., Castelli et al., 2007; Sasayama et al., 2019; Wittberg et al., 2012). A report published in 2014 from Public Health England highlighted that aerobically fit students have higher academic performance in standarized tests, such as GCSE results, among adolescents aged 15 (GOV.UK, 2014). In addition, some interventional studies indicate a cause-and-effect relationship between the impacts of physical fitness training on the improvement of academic performance among adolescents. An interventional programme, Zero Hour PE, carried out in Naperville Central High School, USA, impressed the world with the results obtained. Students in that school lifted their academic performance from below the avarage in the state up to the top rank on the TIMSS (Trends in International Mathematics and Science Study) tests (Ratey & Hagerman, 2008). The secret of this success was attributed to the physical fitness sessions which were implemented before academic lessons (Ratey & Hagerman, 2008).

Although large amounts of findings have indicated that a positive association was found across K-12 academic stages, this research topic is still under debate due to the inconsistency of these findings (Donnelly et al., 2016). Some research findings show that the results differed by gender (e.g., Eveland-Sayers et al., 2009). Other findings, from longitudinal studies, indicate varying levels of correlation across grade years and related fitness test events (e.g., Sasayama et al, 2019; Wittberg et al., 2012). One of the reasons for this inconsistency may be due to differences in the fitness test instruments for evaluating each component of physical fitness level. For example, in the USA, most of the researchers (e.g., Bass, et al., 2013; Castelli et al., 2007; Chomitz, et al., 2008; Hermoso et al., 2017) applied the FitnessGram assessment and PACER test. In China, the criteria of Chinese National Student Physical Fitness Standard (CNSPFS) were utilized for measuring the physical fitness level of all students in the stages of compulsory education (Ministry of Education of the People's Republic of China, 2014). Thus, the different test events and criteria may affect the consistency of the research findings. Furthermore, confounding factors may give rise to inconsistent results.

Grissom (2005) pointed out that the factor of social-economic background was highly associated with children's academic achievement scores and their fitness performance. Additionally, Donnelly et al. (2016) mentioned that other potential factors, such as peer and teacher influence, and students' individual attitude towards academic learning and fitness exercise, may confound the results of the research findings.

1.2 The Significance and Purpose of the Study

Although numerous studies have been conducted among K-12 school-aged children in the context of different educational settings around the world, few studies have implemented in the Chinese educational context focusing on adolescents in the middle school period. It is necessary to pay more attention to this group of students, who are going through considerable body shape changes in the most important developmental stage of puberty. In addition, this group of adolescents aged from 13 to 15 years not only encounter these significant physical changes, but also experience enormous challenges from the first high-stakes standardized tests – the senior high school entrance examination (Zhong Kao). The results of Zhong Kao will influence the destination of future academic study and can even impact on their future life trajectory.

It is necessary and meaningful to conduct research which aims to explore the longitudinal relationship and the degree of effects between each type of physical fitness and academic achievement in the context of Chinese middle school educational settings in urban areas. By contrast with the fitness test standards utilized in many other countries around the world, such as FitnessGram in the USA, this study will apply the Chinese National Student Physical Fitness Standard (CNSPFS) as an instrument to extend knowledge in this research field. The research findings of the present study may be useful for addressing the fitness crisis among adolescents in the urban areas of China and may also provide suggestions for educational curriculum reform, for developing an effective strategy for optimising academic learning in a healthy educational environment.

1.3 Research Questions

Three research questions are proposed in the present study:

RQ1: Is there any relationship between physical fitness and academic achievement in terms of Chinese, Mathematics and English among middle school students from Year 7 to Year 9?

RQ2: If a correlation exists, how well do one or more components of physical fitness predict the academic achievements of boys and girls in the three core subjects and do results vary between boys and girls?

RQ3: Does the physical performance of the most effective component at a prior time-point predict academic performance in one or more specific subjects at a subsequent time-point?

1.4 Definition of Terms

Chinese Nati*onal Student Physical Fitness Standard (CNSPFS)* is a series of fitness test standards for Chinese school-aged students, which covers five components of physical fitness tests: BMI, muscular strength, aerobic endurance, agility, and flexibility. The latest version was released by the National Physical Health Management Center (NPHMC) in 2014 (Ministry of Education of the People's Republic of China, 2014).

BMI is the abbreviation of Body Mass Index, which is commonly used to evaluate the level of body fat composition though measuring the ratio of height to weight (kg/m^2). In CNSPFS, the BMI level is grouped into three categories: normal weight, less than normal (under/overweight) and obese (Ministry of Education of the People's Republic of China, 2014).

Agility fitness is the ability of moving swiftly and changing the position of the body in a short time (Roy et al., 2010). In CNSPFS, this type of fitness is measured by a 50m sprint for the purpose of testing the ability of speed and quick response (Ministry of Education of the People's Republic of China, 2014).

Aerobic endurance fitness (also called cardiorespiratory endurance fitness), which is the capacity of the cardiorespiratory system to produce sufficient oxygen to support physical activity over a long period of time (Roy et al., 2010). In CNSPFS, this component of fitness is tested by a 1,000m endurance run for boys and an 800m endurance run for girls (Ministry of Education of the People's Republic of China, 2014).

Muscular strength fitness is the capability of muscular performance to generate force and power (Roy et al., 2010). In CNSPFS, the component of muscular strength is measured by standing long jump. Students are instructed to stand with their feet apart on the starting line and to take-off vigorously, jumping forward as far as possible. The jumping distance (cm) is measured from the starting line to the landing point of the back of the heels (Ministry of Education of the People's Republic of China, 2014).

1.5 Structure of the Dissertation

This dissertation consists of five chapters. Chapter 1 has mainly aimed to introduce the background of this study and the significance and purpose of conducting this research in the context of Chinese educational settings. In addition, it has listed the three research questions of the present study, and some useful definitions have been provided for the purpose of interpreting the meanings of some fitness tests and their fitness test events. In Chapter 2, the researcher will present the literature on the scientific evidence from laboratory studies in the neuroscience field and other empirical and non-empirical research findings regarding the relationship between physical fitness and academic achievement among school-aged students around the world. Furthermore, more details regarding the researched school's characteristics will be presented at the end of this chapter. In Chapter 3, the researcher will report the research method and design applied in this study. This chapter will cover the process of data collection, the approaches to data analysis and how the issue of missing data was dealt with. Furthermore, more details about the instruments utilised and the statistical techniques employed for the purpose of establishing the longitudinal model will also be reported. Following that, Chapter 4 will show the research findings. The findings will be concluded in each section based on the research questions in turn. Finally, Chapter 5 will discuss the key findings and limitations of the present study. In addition, the researcher will also provide some suggestions regarding the improvement of educational practice and offer recommendations for future research at the end of the chapter.

Chapter 2 Literature Review

In this chapter, firstly, the review of literature will focus on the research evidence based on neuroscience mechanisms regarding the effect of physical exercise/fitness on sparking the brain's cognitive performance. Secondly, the literature review will emphasise the relationship between physical fitness and academic achievement among school-aged students in the context of different countries. Thirdly, according to the previous research findings, the researcher will also discuss the possible confounding factors which may impact on the results in this research area and will present the details of the educational background and settings in the current study.

2.1 The Effect of Physical Exercise/Fitness on the Performance of the Brain

Ratey and Hagerman (2008) stated that moderate-to-vigorous intensity physical exercise can not only improve the level of physical fitness but also optimise the brain's performance in terms of readiness to learn new things. To explain this in terms of neuroscience mechanisms, neuroscientists have shown that physical exercise can increase the level of neurotransmitters such as dopamine, serotonin and noradrenaline, thus improving concentration and positive emotional states for learning (Ratey & Hagerman, 2008; Suzuki, 2015). Dopamine, for example, is associated with curiosity, concentration and a willingness to try new things, while serotonin can relieve negative emotions such as depression and stress (Hansen, 2017). In addition, Hansen (2017) noted that some substances secreted by muscles could enter the brain through the blood stream to stimulate the release of more BDNF, a vital brain nutrient for (1) improving the function of neurons and protecting the brain from damage, (2) helping new brain cells proliferate and survive in the early stages of their development, (3) strengthening the connection of new neurological pathways effectively and (4) increasing the plasticity of the brain.

An increasing body of literature in the field of neuroscience has documented the effectiveness of physical exercise/fitness on enhancing the capacity of the brain's cognitive functions (e.g., Chaddock 2010; Hansen, 2017; Hillman et al., 2008). As reported by Hillman et al, (2008), neuroscientists have examined the functional neuroanatomy of reading comprehension- and mathematical ability-related brain parts (the prefrontal cortex – known as the brain's 'boss' control for superior cognitive functions) in school-aged children. The results revealed that physical fitness training can active relevant neural networks and revitalize the brain cells in this area, and this affects children's cognitive performance in Reading and Mathematics. Later, this finding was confirmed by American scientists through testing 250 primary school children across Year 3 to Year 5. The children's physical fitness level was measured by their overall performance in three components of fitness: aerobic endurance, muscle strength, and agility. The results showed that physically active children did better than unfit children at Mathematics and reading comprehension (Hansen, 2017). These research findings also imply the importance of physical exercise/fitness for optimising the brain's readiness for learning Mathematics and Reading.

Additionally, the neuroscientists found out that the hippocampus produced the most BDNF compared to other part of the brain (Hansen, 2017). This discovery may account for why physical exercise has the largest effect on memory compared to other cognitive functions. In the last few decades, a large number of studies (e.g., Chaddock 2010; Erickson et al., 2011) using animal and human subjects has started to focus exclusively on the effects of aerobic training on the hippocampus (a vital brain part for memory-dealing with the memory processes of encoding, storage, and recall). A laboratory study on mice has documented that voluntarily wheel-running mice showed better performance in spatial memory and were faster at getting out of a maze than those mice without wheel-running exercise (Van Praag, et al., 2005). This animal study demonstrates that physical exercise can increase the size of the hippocampus and generate more BDNF for new brain cell survival and for the effective connection of neurological pathways (Raine, 2013). However, another animal-based study shows that ultra-runner mice spent longer than other regular-running mice to learn a new maze (Hansen, 2017). This result suggests that when the intensity of exercise reaches a certain extent, memory capability may get worse (Hansen, 2017). Thus, exhaustive physical exercise may not produce benefits for the memory.

Later, Erickson et al., (2011) implemented a study on human subjects for the purpose of exploring the changes of hippocampus volume and BDNF level produced by aerobic fitness intervention. One hundred and twenty older adults were recruited in this study and randomly assigned to two groups: an aerobic exercise group and a stretching control group. Data was collected by magnetic resonance images (MRI) and serum tests. After one year of the program completed, the participants in the aerobic group achieved higher aerobic fitness levels and showed an increase of hippocampal volume in both hemispheres. This demonstrates that aerobic fitness training can not only mitigate aged-related degeneracy, but can also improve the memory function of the brain. Furthermore, this study also indicates the importance of the intensity of physical exercise. Lower heat-rate physical activity, such as flexibility training, may not increase the level of BDNF in the brain, due to insufficient blood flow and brain neurotransmitters (Hansen, 2017).

Chaddock (2010) extended this reseach area by investigating pre-adolescents. The target participants in this study were children aged 9 to 10 years old in east-central Illinois, USA. These children were asked to complete an aerobic fitness assessment (running on a motor-driven treadmill) and an IQ test (the Kaufman Brief Intelligence Test) at the begaining of the study. After that, participants were screened using magnetic resonace imaging (MRI). The results revealed that children with higher levels of aerobic fitness showed a larger size of bilateral hippocampal volume compared to less fit children ($F_{(146)} = 6.63$, $p = .013$). In addition, these physically fit children performed better than unfit children on relational memory tasks: they were more effective at using the strategy of encoding and recall.

These studies indicate that aerobic fitness training may contribute to the improvement of the memory function of the brain. These biological changes, such as the volume of the hippocampus and BDNF level increases, may lead to better performance in language learning.

2.2 The Relationship between Physical Fitness and Academic Achievement

2.2.1 The positive relationship between physical fitness and academic achievement

A growing number of studies have shown that a positive association exists between the overall level of physical fitness, or some specific fitness, among K-12 school-aged students (Donnelly et al., 2016). To be more precise, multiple studies have found that there was an association between fit students and a higher level of Mathematics performance (Chomitz et al., 2008; Laura, et al., 2015). In addition, many studies using correlational design have also found a similar association to exist with Reading (e.g., Bass et al., 2013; Castelli et al., 2007; Chomitz et al., 2008) and Language (e.g., García-Hermoso et al., 2017; Sasayama et al., 2019). However, the assessment tools for measuring physical fitness level and academic achievment varied from state to state in the USA and from country to country. The instument used in most such studies was the FitnessGram(e.g., Bass et al., 2013; Chomitz et al., 2008; Coe, et al., 2012), which was designed for assessing four components of fitness, namely body composition, aerobic capacity, muscular strength fitness and flexiblity (Meredith & Welk, 2009). Some research applied the PACER (Progressive Aerobic Cardiovascular Endurance Run) test for measuring the level of aerobic endurance fitness (e.g., Castelli et al., 2007; Wittberg et al., 2012). For the assessment of academic achievement, many studies took advantage of national standarised tests adminstrated by the states or countries (e.g., Bass et al., 2013; Eveland-Sayers et al., 2009; London & Castrechini, 2010). Further details of some key studies in relation to this research topic are provided below.

Chomitz et al.(2008) conducted a cross-sectional study in an urban pbulic school in the north-eastern USA. This study recruited over 1,000 students ranging from Year 4 to Year 8. The instruments used in this study for evaluating students' fitness level and academic attainment were the FitnessGram test and the Massachusetts Comprehensive Assessment System (MCAS). The results of this research indicate that there was a significant relationship between the passing rate of overall physical fitness and academic attainment in Mathematics and English. Controlling for ethnicity, SES, gender, and grade year, the findings from multivariate logistic regression analysis showed that, as the physical fitness passing rate increased, the rates of passing Mathematics and English standarized tests increased simultaneously ($p < .01$ and p

< .05 respectively in Mathematics and English). Later, a longittudianl study was conducted in California for the purpose of investigating the disparities in Mathematics and English performance between persistently fit students and unfit students (London & Castrechini, 2010). Data was collected from two cohorts among middle school students (1,325 and 1,410 respectively in two cohorts) in two school districts in California. Secondary data was selected from the records from 2002-2003 to 2007-2008 of participants' BMI level in the Fitness Gram test. The results in this study indicated that the students who consistenly maintained a standard level of BMI were more likely to pass the California standarised test in both Mathemetics and English. Furthermore, the findings also report that the improvement of BMI level was associated with the enhancement of academic performance among the two cohorts' of middle school students.

In contrast to Chomitz et al. (2008) and London & Castrechini (2010)'s studies, Bass et al. (2013) not only investigated the overall level of physical fitness and BMI, but also further explored the relationship between each component of physical fitness and academic performance. This study used the same measurement tool, the FitnessGram fitness test, to examine the corrlation between overall fitness and each type of fitness to academic attainment in Reading and Mathematics. The target participants in this study were middle school students in Year 6 to Year 8 from Illinois. By using the statistical techniques of logistic regression and Person correlation, the results indicated that there was a small but positive correlation between the fitness level of cardiorespiratory endurance and muscular strengh to achievment in Illinois standarized tests for both boys and girls (ranging from 0.12 to 0.27, all $p < .05$). However, in terms of the BMI level and flexibility fitness, no significant correlation was found.

Following on from these research findings which indicate the positive correlation between cardiorespiratory endurance fitness and acadmic achievment, Castelli et al. (2007) also demonstrated that the academic tests scores in Reading and Mathematics were highly correlated to aerobic endurance fitness ($r = .43$, $p < .01$). This study utilized PACER (a 20-metre shuttle run item) for measuring the aerobic capacity fitness level of the children. Many confounding factors were considered in the correlation and regression analysis, such as the academic ranking of schools, gender, age, and family economic status. The results confirmed the findings of previous relevant research: that aerobic endurance fitness may contribute to academic performance.

Interestingly, some slightly different results were reported with regard to gender when Eveland-Sayers et al. (2009) conducted a similar study in Tennessee, USA. Data was collected from primary school students from Year 3 to Year 5. The same instrument as that employed Castelli et al. (2007) was used for evaluating the capability of aerobic endurance, but a different academic test was used: TerraNova achievement, which is another national standarized test designed for USA students. A positive correlation between aerobic fitness levels and academic attainment was found to occur, but only for the girls in the study.

Beyond the USA, similar studies have been replicated by an increasing number of researchers from different countries in the world. A study carried out by García-Hermoso et al. (2017) revealed a correlation between aerobic endurance fitness, as measured by the PACER test (20m shuttle run), and academic achievement in Language and Mathematics among middle school students in Chile. This study was conducted with a large sample size of 36,870 (55.2% boys and 44.8% girls). The findings show that adolescents who have reached at good level of aerobic endurance fitness are more likely to achieve high performance in both subjects ($p < .01$). Furthermore, this study also found out that, compared to adolescents who were in the obese level band of BMI, those adolescents who belongs to normal and under weight groups had significantly higher odds for achieving higher academic test scores in both Language and Mathematics (all $p< .05$).

Another cohort study report from Australia carried out by Dwyer et al. (2001) extended knowledge in this field by examing three components of fitness level: agility, muscular strength and aerobic endurance, measured respectively by a 50-metre sprint, sit-ups and pull-ups, and a 1.6 kilometre run. Furthermore, questionnaires were employed for meauring the frequency, time and intensity of participants' daily physical excercise. This large-scale study recruited 7,961 school-age students ranging from 7 to 15 years old across different school district and grades. The results inidcate that a significant correlation exists not only exist for aerobic endurance fitness but also for the component of muscular strength fitness. Dwyer et al. (2001) also noted that their results reveal an association between the frequency and intensity of regular daily physical activity and school academic performance.

In Asia, Sasayama et al. (2019) also investigated the relationship between physical fitness and academic achievement among Japanese adolescents (N= 1189) by taking advantage of cross-sectional sequential design. Each cohort was followed up over two years in order to track their academic performance in three core subjects: Japanese, Mathematics and English (as a foreign language). In this study, some of the fitness test events are similar to those in the Chinese National Student Physical Fitness test, such as the 50-metre sprint and the standing long jump. The results show that, for boys, a higher fitness level for all test events, apart from handball throwing, indicates a higher academic attainment level in all three subjects. However, for girls, only two types of fitness: muscular strength fitness (sit and reach) and cardiorespiratory endurance fitness (a 20-metre shuttle run) were found have a positive longitudinal correlation to a higher level of academic performance in Japanese, Mathematics and/or English (Sasayama et al., 2019).

In China, the discussion of the relationship between physical fitness/activity and academic achievement has received attention in recent years. The positive findings documented from many other countries convey the message to Chinese school administrators that physical activities may improve the outcomes of academic learning among school-age students. To determine whether the same findings would appear in the context of Chinese students, Yu (2016) initially conducted a study among 640 year 8 middle-school students in Nanjing, China. Using the instrument of the Chinese National Student Physical Fitness Standard (CNSPFS), she compared the average level of academic scores in students' main subjects to their overall physical fitness level. The results showed that there was a significant positive correlation between a good average level in academic attainments and the pass level in overall physical fitness tests ($r = .689$, $p < .05$).

Li and Ji (2016) systematically reviewed literature based on Chinese research projects in this topic area and point out that only a limited number of studies had addressed the longitudinal effects of physical fitness on academic attainment. They also suggest that it is necessary to conduct a longitudinal design study for the purpose of tracking the impact of each component of physical fitness on academic performance over a longer-term period of schooling stages.

Based on the findings of previous research and suggestions from Li and Ji (2016), this research proposes to explore further the relationship between physical fitness and academic achievement among adolescents in Shanghai, China, by employing a longitudinal design. The aim of this study is to ascertain whether similar positive findings will emerge in the Chinese educational context. Furthermore, this research also aims to examine the longitudinal effects of each component of fitness on each specific Chinese core subject in the middle-school stage of education. The instrument for fitness tests will be as the same as that used by Yu (2016) by adopting CNSPFS as a criterion-referenced standard.

2.2.2 The Inconsistency of the Relationship and Confounding Factors

Although large numbers of studies have reported that a positive relationship was found between physical fitness and academic achievement in one or more specific subjects across various stages of school-age students, this research topic is still under debate due to some inconsistent findings. For example, compared to the findings from Castelli et al. (2007), which revealed the positive correlation between aerobic endurance fitness and Mathematics achievment for all students, Eveland-Sayers et al. (2009)'s study, which used the same fitness assessment tool as Castelli et al. (2007), produced somewhat slightly different results: the relationship only occurred for girls. Donnelly et al. (2016) systematically reviewed 27 studies in relation to this research topic and stated that the inconsistent results may be due to the limitations of the research design, which fails to control for confounding factors.

One of the possible confounding factors could be parents' social-economic background. A large body of literature has documented that the strata of parents' social-economic background could predict a child's academic achievement (e.g., Reardon, 2011; Sirin, 2005) and physical fitness level (Coe et al., 2013; Grissom, 2005). For example, in Grissom's 2005 study, he investigated 884,715 students in California public schools across Year 5, Year 7 and Year 9. Although a positive relationship was found between the overall fitness level and children's performance in terms of Reading and Mathematics on the Sandford Achievement Test, he also found that the relationship appeared to be stronger for students who came from a higher social-economic family background.

Apart from the factor of family social-economic background, gender and ethnicity may be another factor which could influence the findings. In Backer's (2014) research, he tested 5,256 middle-school students in Delaware, USA and found that significant different existed among different ethnic groups and genders. Compared to the African American students with higher fitness levels, Asian students with high fitness levels achieved significantly higher test scores in both Reading and Mathematics. Additionally, the research paper also mentioned that female students outperformed male students in Reading attainment across three academic years.

One of the impressive interventions in response to the research findings on the effect of physical fitness training on academic improvement was the Zero Hour PE programme. This interventional programme was initially implemented in Naperville Central High School, Illinois, USA (Ratey & Hagerman, 2008). The students in this school were required to do a moderate-to-vigorous level of physical training, such as an endurance run, in the morning, before having their first academic class. Before the commencement of this programme, neither the academic performance in core subjects of these children nor their physical fitness level was above the average standard in the state. However, the situation changed after the PE intervention, and in their final graduating year, these students not only scored above the state average of 20.1 points in ACT test (the American University entrance examination), but also achieved the first place in Science and the sixth in Mathematics on the TIMSS tests (one form of international test for comparing the academic level of different countries in Science and Mathematics). This inspiring evidence attracted attention from around the world. Ratey & Hagerman (2008) had described the background of Naperville Central High School in detail. This school is located in a rich suburban district, with 83% white children and only 2.6 % students living in a low-income family background. These factors may well have affected the children's high academic achievement, rather than any unique contribution from physical fitness training.

2.3 The Educational Background and Settings of the Present Research

In order to know more details about the educational background and settings of the target researched school, the researcher had a meeting with schoolteachers and obtained some anecdotes regarding the students' individual characteristics, family background, the implementation of physical education, and the teaching quality in related core subjects. According to the introduction from the school academic administrator, this researched school is located in an urban area. All the students are Chinese and living in the same neighborhood district as the school. The majority of enrolled students had been randomly selected from this school district by a computer. The proportion of male and female students is roughly equal. Students' academic performance and their family economic background may vary from each cohort and between individuals. The teaching quality is generally ahead of other public schools in Shanghai and students from the school had consecutively achieved first place in the total average test stores in Zhongkao (senior high school entrance exams designed for Year 9 middle school students in Shanghai) among all the schools in the district. In terms of physical education, the target school operates in line with the 'Sunshine Sports' policy, a physical health provision policy released by The Chinese Ministry of Education and General Administration of Sport of China (Ministry of Education of the People's Republic of China, 2011). Students have three compulsory PE classes per week and 20 minutes morning physical exercise every day. The school offers an additional 40 minutes of physical activity class for students who do not have a PE class on any given day, for the purpose of guaranteeing that every student can have one hour of physical activity every day.

Considering the possible effect of confounding factors, although researcher cannot be able to obtain data in relation to the family social-economic background of the students, The researcher proposed to investigate the relationship between each component of physical fitness and each core subject separately by gender, and by controlling for cohorts for the purpose of minimizing confounding effect on the research findings. In the next chapter, more details about the research design and method will be reported.

Chapter 3 Methodology

3.1 Rationale for the Research Methods

The present study utilised quantitative research methodology and took advantage of a longitudinal cohort sequential design. Many previous studies employed a single-cohort cross-sectional design (e.g., Bass et al., 2013; Chomitz et al., 2008) by selecting different samples of students, ranging from primary school students to middle school students. However, this type of research design has limitations for investigating developmental processes and could be confounded with the sampling variability among different age cohorts (Little, 2013). Thus, in order to minimise the effect of confounding age cohorts and with the aim of attempting to investigate longitudinal processes during puberty, this study employed two cohorts with adjacent classes of students (Class 2015 and Class 2016), which both started at Year 7 and were followed for three academic years up to the first semester of Year 9.

Furthermore, this study took advantage of secondary data instead of collecting primary data for the following two reasons: first, the advantages of using secondary data are the low cost and fast speed, because the data already exist for research purposes and are quicker to collect (Gorard, 2001); and secondly, secondary data is assumed to guarantee high quality due to the requirements of collecting data for official datasets (Gorard, 2001). The datasets applied in this study were used to test the academic attainment of students in related subjects and to monitor the physical fitness levels of school-age students. In the case of this dissertation, which aims to investigate the relationship between physical fitness and performance in three core subjects among urban middle school-aged students in Shanghai, these secondary data fulfil the purpose of addressing new research inquires for the present study. Each research question will be addressed by separating by gender as (1) some of the test items for measuring fitness performance are slightly different between boys and girls, (2) the transformation to standardized fitness scores in each test item varies by gender, and (3) pre-existing literature reports gender difference in some components of fitness between boys and girls. Thus, the approach of separating by gender may be more rigorous and also necessary for making comparisons with previous research findings.

3.2 Research Questions

Three research questions are proposed in this study, which are listed below.

RQ1: Is there any relationship between physical fitness and academic achievement in terms of Chinese, Mathematics and English among middle school students from Year 7 to Year 9?

RQ2: If a correlation exists, how well do one or more components of physical fitness predict the academic achievements of boys and girls in the three core subjects and do results vary between boys and girls?

RQ3: Does the physical performance of the most effective component at a prior time-point predict academic performance in one or more specific subjects at a subsequent time-point?

3.3 Data Collection Procedure and Ethics

Prior to the commencement of the study, the researcher received ethical approval from the Departmental Research Ethics Committee (DREC) (see details in Appendix A). A consent form and an information sheet were translated into Chinese (see details in Appendix B & C) for the purpose of asking permission to collect data from the target school; this request was directed to the headteachers. The researcher obtained consent and received consecutive archival data of the two cohorts (Class 2015 and Class 2016) over three years from the urban public middle school in Shanghai, China.

In order to address issues of confidentiality and anonymity, each student was by the school given a unique, anonymous ID number. In addition, students' names were deleted by the school's academic administrator and PE teachers before being transferred through the OneDrive of the Oxford University account. All data were password-protected and stored securely, based on the requirements of the General Data Protection Regulations (GDPR) and the Data Protection Act 2018.

3.4 Researched Samples and Missing Data

The target participants of this study were adolescents aged 12 to 15 years old attending an urban middle school in Shanghai, China. The dataset included total three-year standardised tests scores for Chinese, Mathematics and English at five time-points (two times in Year 7 and Year 8, and one time in Year 9), individual basic information (such as date of birth, height and weight) and each component of physical fitness according to the test scores from Year 7 to Year 9 in the two cohorts. Students who left school in Year 8 and Year 9 (n = 74) were excluded from the dataset. Figure 1 illustrates the attrition flow of the two cohorts across three academic years. In addition, through normality checking in SPSS version 27, the univariate outliers (more than +/- 3 standard deviations (SD) beyond the mean (Kline, 2011) found for each variable were excluded from the dataset.

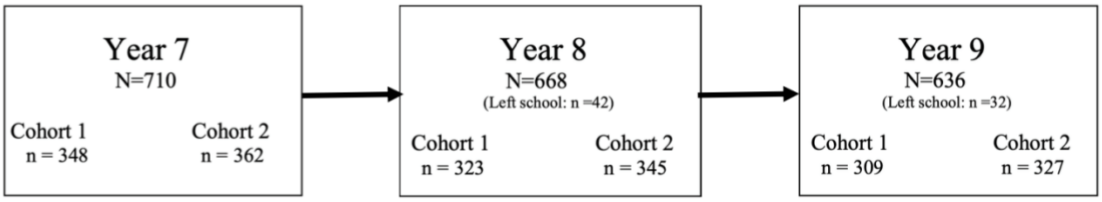

Figure 1. Attrition Flow in the Two Cohorts from Year 7 to Year 9.

Furthermore, in longitudinal studies, missing data are inevitable. This is not only due to student attrition, but to the uncertainty arising from incomplete data. In this study, the overall proportion of missing data points was 0.02 (Boys: SD = 7.5, Min = 0, Max = 19; Girls: SD = 3.8, Min = 0, Max = 11). The missing data was found to be missing at random (MAR) by using Little's MCAR test in SPSS version 27. Although deleting incomplete data records via listwise deletion is the most convenient method for dealing with missing data (Enders, 2010), it is unacceptable for MAR data and may reduce statistical power (Field, 2018). Alternatively, there are several traditional single imputation approaches for dealing with MAR. The best choice could be Stochastic regression imputation, which could give unbiased parameter estimates (Enders, 2010). Therefore, to address the issue of missing data, Stochastic regression imputation was applied through using AMOS version 23. All data analyses were based on the full analytic sample of 557 participants (boys n = 312 and girls n = 245) from Year 7 to Year 9 in the two cohorts (Cohort 1: n = 287, Cohort 2: n = 270; 52% vs 48%).

3.5 Instruments

3.5.1 Physical Fitness

In contrast to many previous studies that utilised the FitnessGram physical fitness test (e.g., Bass, et al., 2013; Chomitz, et al., 2008) to measure physical fitness among middle-school students, in this study the researcher applied the Chinese National Student Physical Fitness Standard (CNSPFS), the same instrument as Yu (2016), to assess BMI (Body Mass Index) and three components of physical fitness (agility, muscular strength and aerobic endurance fitness) among Chinese middle school students from Year 7 to Year 9 (aged 12 to 15 years old). Students' BMIs were measured using height and weight (kg/m^2), and each student was grouped into three categories (normal, under/overweight and obese) according to the criterion-referenced standards. Furthermore, in the CNSPFS test battery, the components of agility, muscular strength and aerobic endurance fitness were measured through a 50-metre sprint, standing long jump and 800m (girls)/1,000m (boys) endurance run, respectively. This method was developed by the National Physical Health Management Centre (NPHMC) in 2014 (Ministry of Education of the People's Republic of China, 2014). Therefore, the reliability and validity of the CNSPFS fitness tests have been confirmed by PE specialists over the years.

All the physical fitness test items were administrated by professional PE teachers and completed by the end of December of each academic year. The results of each fitness component were converted into a score ranging from 0 to 100 per cent based on CNSPFS fitness criterion-referenced standards for age and gender. Higher scores in each test item indicated higher capability in each related component of fitness.

3.5.2 Academic Achievement

Academic achievement was measured using the standardised tests of three core subjects: Chinese, Mathematics and English. The variables of each subject were recorded at five time-points (7A, 7B, 8A, 8B and 9A) from Year 7 to Year 9. Two exams took place in each year; 'A' was taken in the middle of January at the end of the first semester and 'B' was taken in the middle of June at the end of second semester. The exams were valid and administered by qualified schoolteachers. The difficulty of the exams was progressive and met the requirements of the curriculum for evaluating the academic performance of middle school students in the designated subjects within each year. According to the criterion-reference, the mark of each subject ranged from 0 to 100 per cent. Higher scores represent higher levels of academic achievement in the designated subjects.

3.6 Statistical Approaches of Data Analysis

3.6.1 Pearson Correlation Coefficient and Spearman Correlation Coefficient

The Pearson product-moment correlation coefficient (r) is designed to analyse the relationship between two continuous variables. The Spearman rank-order correlation (rho) is more suitable for other types of variables which violate the assumptions of Pearson's r (Pallent, 2020). Thus, in this study, Spearman's rho was employed to analyse the relationship between BMI and performance in each academic subject. Meanwhile, Pearson's r was applied to explore the correlation between each type of physical fitness to the three core subjects separately.

The results of both correlation techniques can determine the strength and direction of the linear relationship between two variables, which are identified by the r value, ranging from -1 to 1 (Field, 2018). The sign indicates the direction of correlation, either positive (+) or negative (-). An r value close to +/- 1 indicates a strong linear relationship (Field, 2018). In this study, the researcher employed the criteria of Cohen's r value threshold to determine the strength of the relationship between two variables: weak = 0.1, medium = 0.3 and strong = 0.5 (Cohen, 1998, p. 79-81).

3.6.2 Structural Equation Modelling (SEM)

For the purpose of addressing the research questions, the researcher took advantage of the techniques of SEM to analyse the multivariate longitudinal data. SEM is a multivariate statistical tool that enables researchers to specify multivariate models (Kline, 2011). There are many forms of SEM: in this study, the researcher applied observed variables in longitudinal SEM with a path autoregressive model to investigate longitudinal multivariate relationships between one specific component of physical fitness and one core subject over time. There are many advantages of using SEM over multiple linear regression for data analysis. For example, multiple regression can only be used to explore the relationship with one single continuous dependent variable (Pallent, 2020), whereas SEM allows for more than one dependent variable in more complicated relationships in the model and takes the effect of ‘chains’ into consideration (Streiner, 2005, p. 115). Additionally, SEM can obtain parameter estimates of measurement errors, disturbance covariances or disturbance correlations from the model, and can evaluate whether the model fits the data (Kline, 2011). There are two approaches to SEM: recursive and non-recursive models (Kline, 2011). The present study applied the most straightforward recursive model, which means that all effects are unidirectional and disturbances are uncorrelated in the longitudinal models (Kline, 2011).

The statistical technique of SEM is an extension of multiple linear regression; thus, it shares many similar assumptions (Streiner, 2005). The data of the present study meet these assumptions: first, all the exogenous (independent) variable and endogenous (dependent) variables are continuous; second, although the sample size in SEM is required to be larger than for other regression techniques (e.g., Streiner (2005) recommends at least 10 cases per variable), the sample size in this study is large enough to accurately estimate the values in the model. Furthermore, the distances between adjacent time-points are equal in the autoregressive paths. For example, the time between physical fitness tests is one year with repeated test measures, and there are six months between each academic test across three years.

3.6.3 Covariates

According to Pallent (2020, p. 315), a ‘covariate is a variable that you suspect may be influencing scores on the dependent variable’. Considering the probability of finding disproportionate levels of physical fitness and academic performance among the target samples, an independent-samples t-test was used to detect the mean difference of all the test scores separated by gender. The results show that not all test results are equivalent within the two cohorts (for some, $p < 0.05$, see details in Appendix D). Thus, in order to ensure the results of the present study were not affected by the initial disproportion of test performance, the researcher controlled for cohorts in the models by including a dummy-coded predictor (0 = cohort 1, 1 = cohort 2).

In addition, previous studies have found that there is positive correlation between BMI and physical fitness among Chinese adolescents, especially between aerobic endurance and muscular strength (Yi et al., 2019). The physical fitness test performances among students in the normal weight group are significantly different than those of students in the underweight, overweight and obese groups for both boys and girls (Zhang et al., 2019). Therefore, the researcher treated BMI as a covariate due to its possible impact on performance in each component of physical fitness.

3.7 Goodness-of-Fit (GOF) Indices

As mentioned above, SEM enables a researcher to evaluate whether the model fits the data according to statistical rationale and modelling rationale (Little, 2013). Generally, three dominant goodness-of-fit (GOF) indices can be applied and reported: the model χ^2, the root mean square error of approximation (RMSEA), and the comparative fit index (CFI).

3.7.1 Statistical Rationale – Chi-Squared (χ^2)

The approach to evaluating statistical fit is the χ^2 test (Little, 2013). The χ^2 statistical test has certain degrees of freedom and an associated p-value, which rely on a null model to gauge model fit (Little, 2013). The central χ^2 distribution is used as the reference to determine whether the model fits the data (i.e., $p > 0.05$). However, the χ^2 test is overly sensitive to large sample sizes when attempting to balance Type I and Type II errors (Little, 2013, p. 107). For example, when the sample size is moderately large, the p-value is often significant. Despite this sensitivity issue, the χ^2 statistic is the commonly used GOF index for SEM evaluation (Blunch, 2008). However, χ^2 is very sensitive to model complexity and sample size, thus, other GOFs are also relied on.

3.7.2 Modelling Rationale – RMSEA and CFI

The other approaches for evaluating model fits based on modelling rational are RMSEA and CFI (Little, 2013). RMSEA is classified as absolute fit indices, which provides an index of "badness-of-fit" (Kline, 2011). The value closer to 0 indicates the better model fit. Browne and Cudeck (1992) provide the threshold value for interpreting acceptable model fit, which is the RMSEA value <.08 can be considered as acceptable model fit.

Some methodologists agree that the value < .06 could be determined as good model fit (Hu & Bentler, 1999). In addition, another alternative GOF indice, CFI is commonly used for measuring the incremental improvement of the specified model. Compared to χ^2 statistic, CFI is less sensitive to the large sample size (Bryne, 2009). The good model fit value for CFI is determined to be over 0.95 and above 0.90 for acceptable fit (Blunch, 2008). Thus, in contrast to the RMSEA index, the value of CFI being closer to 1 indicates a stronger model fit.

Although there are various GOF indices that could be taken into account and the cut-off values for model fit are not firm, in this study, the researcher chose to use the most common references and general approaches for evaluating SEM. The GOF indices for each model will be reported in the next chapter.

Chapter 4 Results

4.1 Introduction

This chapter will mainly present the results for the three research questions by using the statistical techniques of correlation and longitudinal SEM, which have been discussed in the previous chapter. In addition, as has been mentioned in the Methodology chapter, BMI will not only serve as one component of physical fitness, but will be treated as covariate in the longitudinal models. In this chapter, the researcher will firstly provide some basic information regarding the BMI level of participants, with particular focus on obesity among participants across three academic years. After that, the results relating to the research questions will be presented in turn. Firstly, the researcher will report the correlation results regarding the research question of the relationship between each component of physical fitness and the three core subjects: Chinese, Mathematics and English. Secondly, based on the correlation results, the researcher will then specify appropriate longitudinal path models for addressing research questions 2 and 3, which aim to explore further the longitudinal effect of one or more components of physical fitness on each academic subject among middle-school students. The findings will be reported separately by gender and will be summarized at the end of each section.

4.2 Basic Information regarding BMI levels among Boys and Girls across Three years of Middle School

Table 1. Descriptive Statistics for the BMI Levels of Boys and Girls across Three Years

	Normal		Under/ Overweight		Obese	
	Boys	Girls	Boys	Girls	Boys	Girls
Year 7	64.4%	80.9%	28.8%	12.2%	6.7%	6.5%
Year 8	69.6%	77.6%	20.2%	13.4%	10.3%	8.5%
Year 9	71.5%	78.1%	19.2%	12.2%	9.3%	9.3%

Notes: Total (N=557) in two Cohorts (Boys n=312 and Girls n=245). BMI (kg/m^2) reference index: see details in Appendix E.

In order to obtain fundamental knowledge about the BMI levels of participants, Table 1 reports the basic descriptive statistics for the percentage of each BMI level among boys and girls in the two cohorts, with 312 boys and 245 girls in total. The level of BMI was evaluated according to the criteria of the Chinese National Student Physical Fitness Standard (CNSPFS), which is categorised into the three levels: normal, under/overweight, and obese (See details in Appendix E). The average age of participants on the testing day was 12.7, 13.7, and 14.7 years old respectively across Year 7 to Year 9. The figures reveal that the proportion of obese level adolescents increased for both boys and girls, especially from Year 7 to Year 8 (with a 3.6 % increase for boys and 2 % for girls). The proportion of obesity for boys is slightly higher than for girls in Year 8, with 10.3 % vs 8.5 %. Additionally, in Year 9, the proportion of obesity for girls continues to rise, reaching the same level (9.3 %) as for boys. In short, the figures indicate the tendency that, the percentage of obese adolescents increased from Year 7 to Year 8. For girls, it continued to rise to Year 9, whereas, for boys the obesity rate dropped off slightly between Year 8 and Year 9.

4.3 Research Question 1: Is there any relationship between physical fitness and academic achievement in terms of Chinese, Mathematics and English among middle school students from Year 7 to Year 9?

4.3.1 The Correlation between BMI and Academic Achievement

Table 2. The Correlation between BMI and Academic Achievement in terms of Chinese, Mathematics and English from Year 7 to Year 9

	Year 7 BMI		Year 8 BMI		Year 9 BMI	
	Boys	Girls	Boys	Girls	Boys	Girls
Chinese						
Year 7A	.062	.095				
Year 7B	.069	.116				
Year 8A	.026	.105	.077	.132*		
Year 8B	.026	.006	-.058	-.006		
Year 9A	.043	.078	.04	.086	.074	.084
Mathematics						
Year 7A	.060	.087				
Year 7B	.070	.058				
Year 8A	.059	.096	.024	.071		
Year 8B	.049	.049	.062	.038		
Year 9A	.090	.091	.06	.112	.119*	.118
English						
Year 7A	.057	-.001				
Year 7B	.091	.039				
Year 8A	.029	.052	.044	.054		
Year 8B	.067	.078	.066	.124		
Year 9A	.042	.054	.024	.085	.069	.098

Notes: Two-tailed test. The analysis was carried out in SPSS 27. * P < .05. Total N=557 in two cohorts (Boys n=312 and Girls n=245). A= the exam taken in the first semester of each academic year; B= the exam taken in the second semester of each academic year. BMI was coded 1= obese; 2= under/overweigh; 3= normal weight.

Table 2 shows the correlation between BMI and the academic achievement in three core subjects respectively from Year 7 to Year 9. For girls, a positive correlation was found in the first semester of Year 8 Chinese (r = .132, p < .05). In contrast, for boys, a significant correlation exists in the first semester of Year 9 Mathematics (r = .119, p < .05). Although weak relationships found in Year 8 and Year 9, there were no correlations found generally at most time-points over the three years.

4.3.2 The Correlation between Agility Fitness and Academic Achievement

Table 3. The Correlation between Agility Fitness (50m run) and Academic Achievement in terms of Chinese, Mathematics and English from Year 7 to Year 9

	Year 7 50m		Year 8 50m		Year 9 50m	
	Boys	Girls	Boys	Girls	Boys	Girls
Chinese						
Year 7A	-.002	.110				
Year 7B	.161**	.036				
Year 8A	-.106	.048	.015	.088		
Year 8B	.152**	.088	.125*	.116		
Year 9A	.092	.121	.089	.121	.088	.138*
Mathematics						
Year 7A	.111	.063				
Year 7B	.050	.021				
Year 8A	.056	.102	.100	.035		
Year 8B	.108	.051	.107	.040		
Year 9A	.096	.074	.142*	.086	.107	-.002
English						
Year 7A	.248**	.082				
Year 7B	.272**	.064				
Year 8A	.169**	.015	.139*	.066		
Year 8B	.131*	.080	.109	.112		
Year 9A	.208**	.108	.176**	.123	.091	-.020

Notes: Two-tailed test. The analysis was carried out in SPSS 27. * P < .05; ** P < .01. Total N=557 in two cohorts (Boys n=312 and Girls n=245). A= the exam taken in the first semester of each academic year; B= the exam taken in the second semester of each academic year.

Table 3 displays the results of the correlation between agility fitness (measured by a 50-metre run) to three academic subjects. There are significant positive correlations at some time-points with specific subjects. For example, for girls, a weak but positive correlation was found at Year 9 Chinese ($r = .138, p < .05$). It is worth mentioning that the most frequent correlation was found between boys' agility fitness and their academic performance in English ($r = .248$ and $r = .272$ in Year 7AB, both $p < .01$; $r = .139$ in Year 8A, $p < .05$). The results also indicate that a relationship between agility fitness and academic achievement exists more often for boys than girls over the three academic years in middle school.

4.3.3 The Correlation between Muscular strength Fitness and Academic achievement

Table 4. The Correlation between Muscular Strength Fitness (Standing long jump) and Academic Achievement in terms of Chinese, Mathematics and English from Year 7 to Year 9

	Year 7 Standing long jump		Year 8 Standing long jump		Year 9 Standing long jump	
	Boys	Girls	Boys	Girls	Boys	Girls
Chinese						
Year 7A	.089	-.009				
Year 7B	.132*	-.004				
Year 8A	.010	.011	.011	-.066		
Year 8B	.098	.090	.072	.092		
Year 9A	.079	.135*	.008	.053	.023	.048
Mathematics						
Year 7A	.136*	.109				
Year 7B	.076	.015				
Year 8A	.063	.160*	.117*	.056		
Year 8B	.106	.057	.170**	-.009		
Year 9A	.146**	.191**	.149**	.123	.135*	.140*

English						
Year 7A	.220**	.061				
Year 7B	.203**	.046				
Year 8A	.102	.067	.061	.012		
Year 8B	.099	.013	.038	-.044		
Year 9A	.142*	.165**	.068	.083	.077	.055

Notes: Two-tailed test. The analysis was carried out in SPSS 27. * P < .05; ** P < .01, *** P < .001. Total N=557 in two cohorts (Boys n=312 and Girls n=245). A= the exam taken in the first semester of each academic year; B= the exam taken in the second semester of each academic year.

Table 4 reports the results of the correlation between muscular strength fitness measured by standing long jump (lower limb strength) and academic performance in Chinese, Mathematics and English respectively. Compared to boys, apart from the positive association that was found in Year 9A Mathematics ($r = .140$, $p < .05$), few correlations exist for girls. However, the figures indicate that many positive correlations exist for boys, especial between muscular strength fitness and Mathematics across the three academic years ($r = .136$, $r = .117$, $r = .135$, respectively in Year 7, Year 8 and Year 9, all $p < .05$). In addition, this relationship was also found with the subject of English in Year 7 AB ($r = .220$, $r =.203$, all $p < .01$).

4.3.4 The Correlation between Aerobic Endurance Fitness and Academic Achievement

Table 5. The Correlation between Aerobic Endurance Fitness (1000m/800m run) and Academic Achievement in terms of Chinese, Mathematics and English from Year 7 to Year 9

	Year 7		**Year 8**		**Year 9**	
	1000m	800m	1000m	800m	1000m	800m
	Boys	Girls	Boys	Girls	Boys	Girls
Chinese						
Year 7A	.130*	-.100				
Year 7B	.237**	.030				
Year 8A	.007	.128	.161**	.224**		
Year 8B	.194**	.136*	.123*	.102		
Year 9A	.115*	.066	.145*	.134*	.173**	.005

Mathematics						
Year 7A	.221**	.105				
Year 7B	.194**	-.072				
Year 8A	.170**	.143*	.192**	.100		
Year 8B	.172**	.108	.209**	.138*		
Year 9A	.180**	.168**	.202**	.168**	.233**	.118
English						
Year 7A	.275**	.109				
Year 7B	.287**	.096				
Year 8A	.243**	-.009	.201**	.061		
Year 8B	.206**	-.070	.190**	.090		
Year 9A	.220**	.109	.128*	.021	.259**	.177**

Notes: Two-tailed test. The analysis was carried out in SPSS 27. * $P < .05$; ** $P < .01$. Total N=557 in two cohorts (Boys n=312 and Girls n=245). A= the exam taken in the first semester of each academic year; B= the exam taken in the second semester of each academic year.

The findings in Table 5 report the results of the correlation between aerobic endurance fitness and three core subjects' test performance over three years in middle school. In the CNSPFS fitness test, the fitness level of aerobic endurance was measured through a 1000m endurance run for boys and 800m for girls. For boys, many significant correlations were found across the three academic years to all three subjects (most $p < .01$). Furthermore, there are also lots of significant positive correlations found for girls, starting from Year 8 onwards (most $p < .01$). It is notable that the relationship between boys 1000m endurance run and academic achievement in Mathematics and English exists throughout the whole period of middle school years.

4.3.5 Summary of Research Question 1

In response to the first research question, which refers to the relationship between physical fitness and academic achievement in the three core subjects among middle school students from Year 7 to Year 9, the correlation results show that there were some weak but positive relationships between physical fitness and academic achievement in all three subjects: Chinese, Mathematics and English. Interestingly, the relationships were generally found more frequently among boys than girls. In terms of each component of physical fitness, the findings from the correlation results indicate that, in contrast to the other three components of physical fitness, fewer associations were found between BMI and academic achievement. Furthermore, in terms of agility fitness, more correlations were found with the subject of English for boys. Compared to agility fitness, muscular strength fitness was associated for both boys and girls with Mathematics. It is also worth of mentioning that there were significant relationships between aerobic endurance fitness and all the three subjects for both boys and girls.

4.4 Research Question 2: If a correlation exists, how well do one or more components of physical fitness predict the academic achievements of boys and girls in the three core subjects and do results vary between boys and girls?

The key statistical technique, SEM, was applied to address the follow-up research questions, which aim to investigate the within-time point effects of each type of physical fitness on academic achievement in each core subject. Although the research will not examine the direct longitudinal effect between BMI and each academic subject due to the correlation results (fewer correlations exist across three years compared to other types of physical fitness), the variables of BMI would be treated as covariate in the longitudinal path models. Previous literature (e.g., Yi et al., 2019; Zhang et al., 2019) has documented that the individual BMI level was highly correlated to physical fitness performance. Furthermore, the cohorts were controlled in the models as well.

4.4.1 Boys Longitudinal Path Models for the Prediction of Physical Fitness and Academic Achievements over Three Academic Years

Based on the correlation results, for the boys' models, the researcher proposed to explore the longitudinal effect of the relationship between agility fitness (50m sprint) on English, muscular strength fitness (standing long jump) on Mathematics and English, and aerobic endurance fitness (1000m endurance run) on all three subjects. The longitudinal path-model includes autoregressive paths, which is the concurrent physical fitness regressed on previous time-point fitness performance and concurrent academic achievement regressed on previous time-point academic performance in the relevant subject. In addition, the directional paths in the longitudinal model for examining the effects of each type of physical fitness on academic performance of three core subjects regressed academic performance in the first term of each year on physical fitness (testing in the first term), controlling for the covariates of cohorts and BMI level.

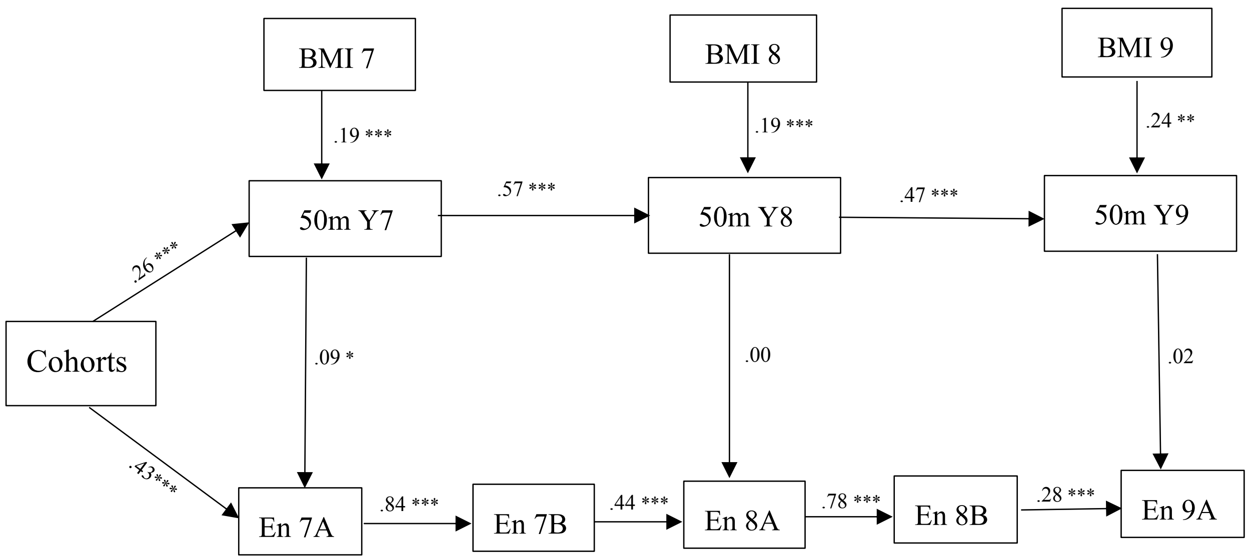

Figure 2. Longitudinal Path Model for Boys 50m Performance and the Achievements in English Standardized Tests over Time from Year 7 to Year 9, Controlling for the Covariates of Cohorts and BMI Level.

Notes: standardized estimates from AMOS 23 version. * P < .05; ** P < .01; *** P < .001.

As presented in Figure 2, The model fits the data well ($\chi^2_{(37)}$ = 37.124; p > .05; RMSEA= .003; CFI = 1.000). The results from multivariate path analysis show that boys' 50m performance in Year 7 predicted academic achievement in English at the same time-point (β= .09, p < .05). However, the effects were not significant in the following two years. Figure 2 also shows that the academic performance in English was relatively stable within years (β= .84 within Year 7 and β= .78 within Year 8), but not stable in the transition from Year 7B to Year 8A and from Year 8B to Year 9A (β= .44 and β= .28, all p < .001).

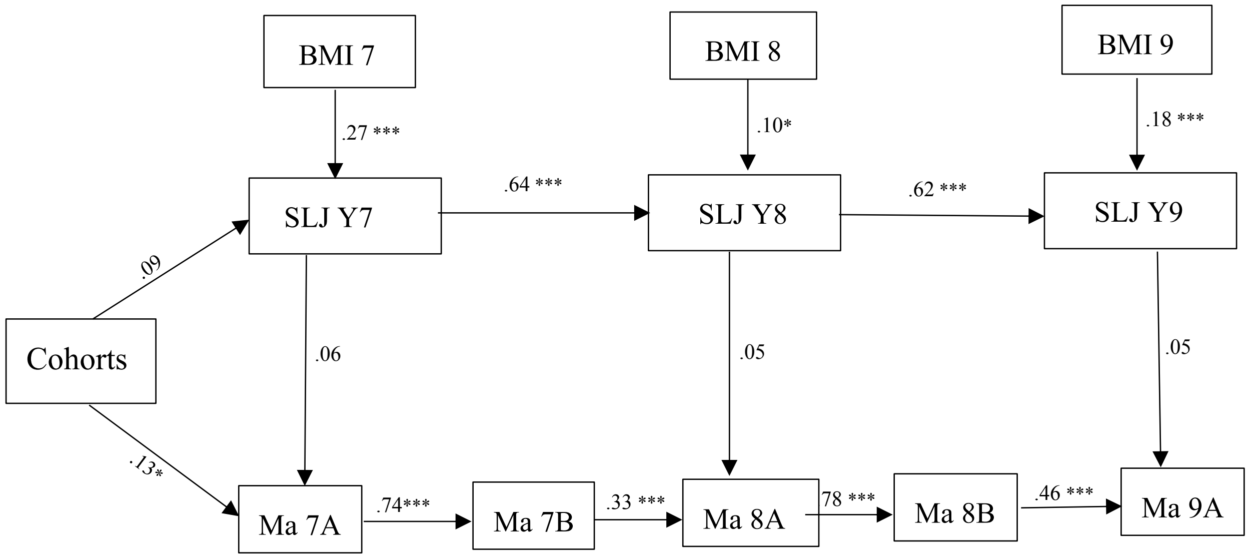

Figure 3. Longitudinal Path Model for Boys Standing Long Jump (SLJ) Performance and the Achievements in Mathematics Standardized Tests over Time from Year 7 to Year 9, Controlling for the Covariates of Cohorts and BMI Level.

Notes: standardized estimates from AMOS 23 version. * P < .05; ** P < .01; *** P < .001.

Figure 3 reports the results of the longitudinal relationship between Muscular strength fitness measured by standing long jump to Mathematics test performance. The model fits the data well ($\chi^2_{(37)}$ = 43.259; p > .05; RMSEA= .023; CFI = .997). Although, according to the correlation results, there are weak but significant consecutive relationships existing between the variables of standing long jump and Mathematics performance in the first time-point of each year, the significant effect of muscular strength fitness on Mathematics was not found across three academic years (all p > .05). Similar to English performance, the academic performance in Mathematics was stable within years (β= .74 within Year 7 and β= .78 within Year 8, all p < .001), but not stable in the transition from Year 7B to Year 8A and from Year 8B to Year 9A (β= .33 and β= .46, all p < .001).

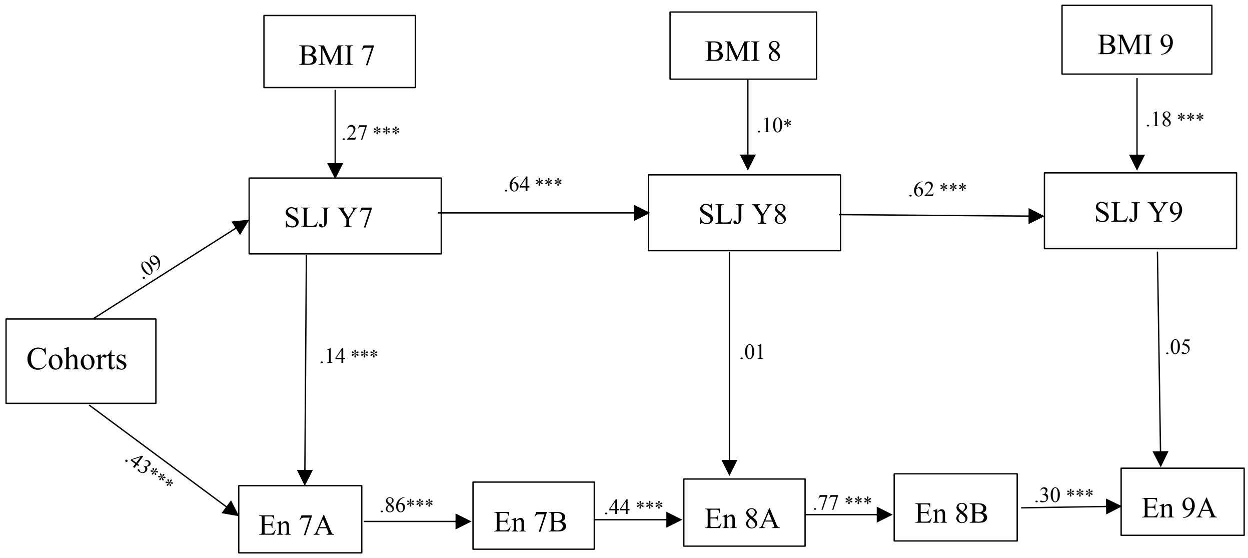

Figure 4. Longitudinal Path Model for Boys Standing Long Jump (SLJ) Performance and the Achievements in English Standardized Tests over Time from Year 7 to Year 9, Controlling for the Covariates of Cohorts and BMI Level.

Notes: standardized estimates from AMOS 23 version. * $P < .05$; ** $P < .01$; *** $P < .001$.

In contrast to the results for Mathematics, Figure 4 displays the results with regard to the prediction of muscular strength fitness for academic achievement in English. The results show a good model fit ($\chi^2_{(40)} = 52.343$; $p > .05$; RMSEA= .031; CFI = .996). The results from this model report that in Year 7, muscular strength fitness has a significant effect on English test performance ($\beta = .14$, $p < .001$). However, the effects were diminished and not significant in the following two years ($\beta = .01$ and $\beta = .05$ in Year 8 and Year 9 respectively, $p > .05$). As presented in Figure 2, the tendency of English performance was unstable in the transition from 7B to 8A and from 8B to 9A.

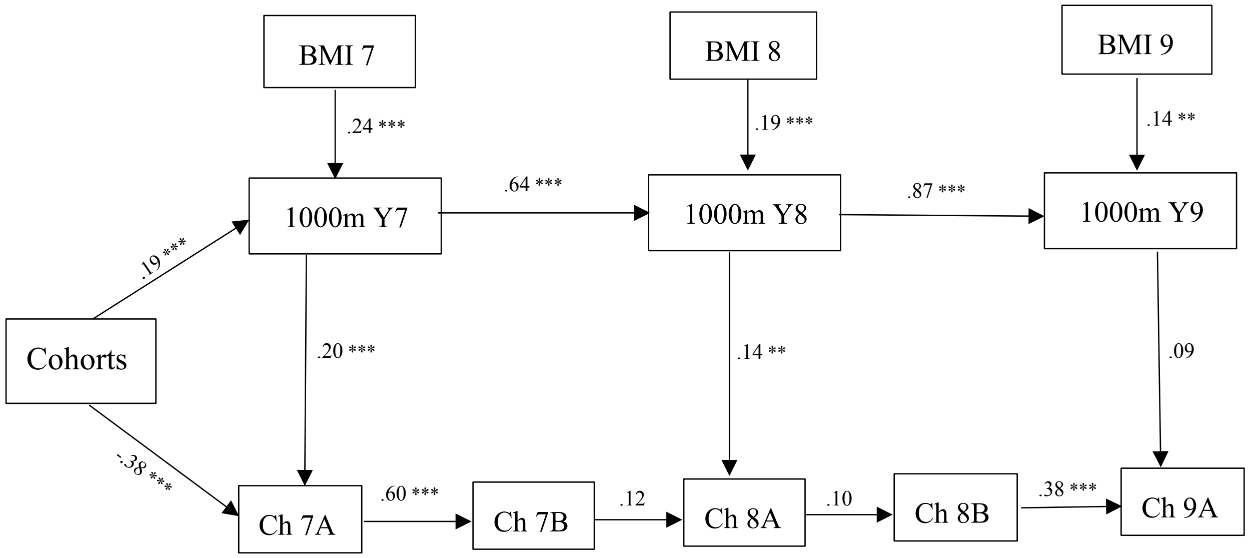

Figure 5. Longitudinal Path Model for Boys 1000m Performance and the Achievements in Chinese Standardized Tests over Time from Year 7 to Year 9, Controlling for the Covariates of Cohorts and BMI Level.

Notes: standardized estimates from AMOS 23 version. * P < .05; ** P < .01; *** P < .001.

Figure 5 shows the longitudinal relationship between aerobic endurance fitness measured by 1000m and Chinese standardized test performance over three time-points in the first semesters of academic years. This model shows a good model fit ($\chi^2_{(31)}$ = 37.605; p > .05; RMSEA= .026; CFI = .996). The results demonstrate that the higher level of 1000m endurance run for boys has a significant effect on Chinese test performance in both Year 7 and Year 8 (β= .20, p < .001 and β= .14, p < .01, respectively). Although there was a weak effect in Year 9A, it was not found to be significant (β= .09, p > .05). Furthermore, this model also presents the unstable academic performance in Chinese among boys during the whole period of middle school stage (β= .60, β= .12, β= .10, and β= .38 in each time-point from 7A to 9A).

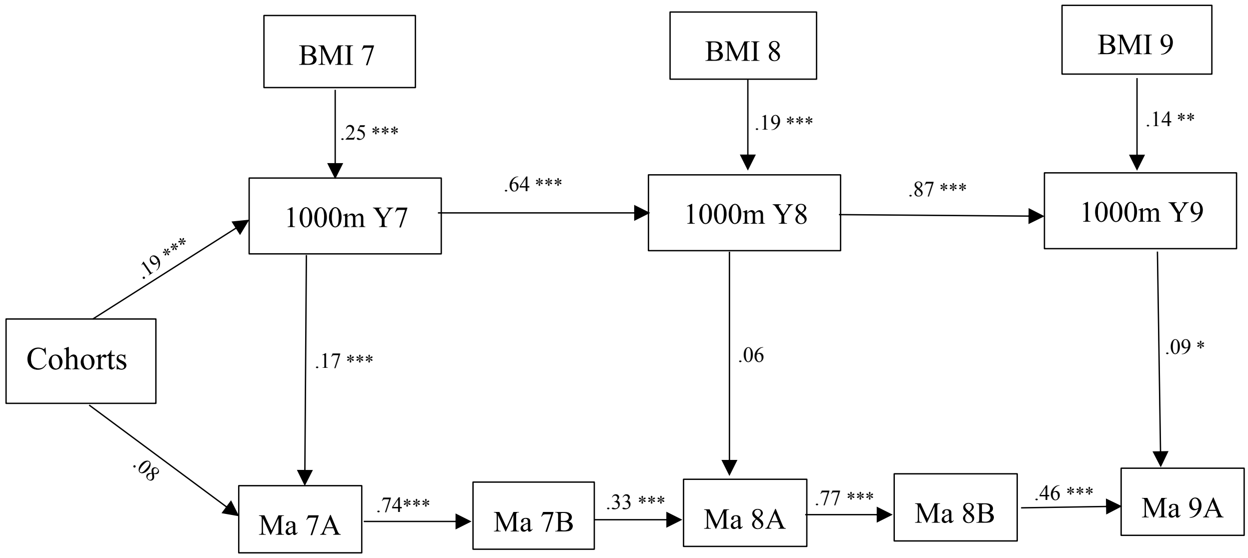

Figure 6. Longitudinal Path Model for Boys 1000m Performance and the Achievements in Mathematics Standardized Tests over Time from Year 7 to Year 9, Controlling for the Covariates of Cohorts and BMI Level.

Notes: standardized estimates from AMOS 23 version. * P < .05; ** P < .01; *** P < .001.

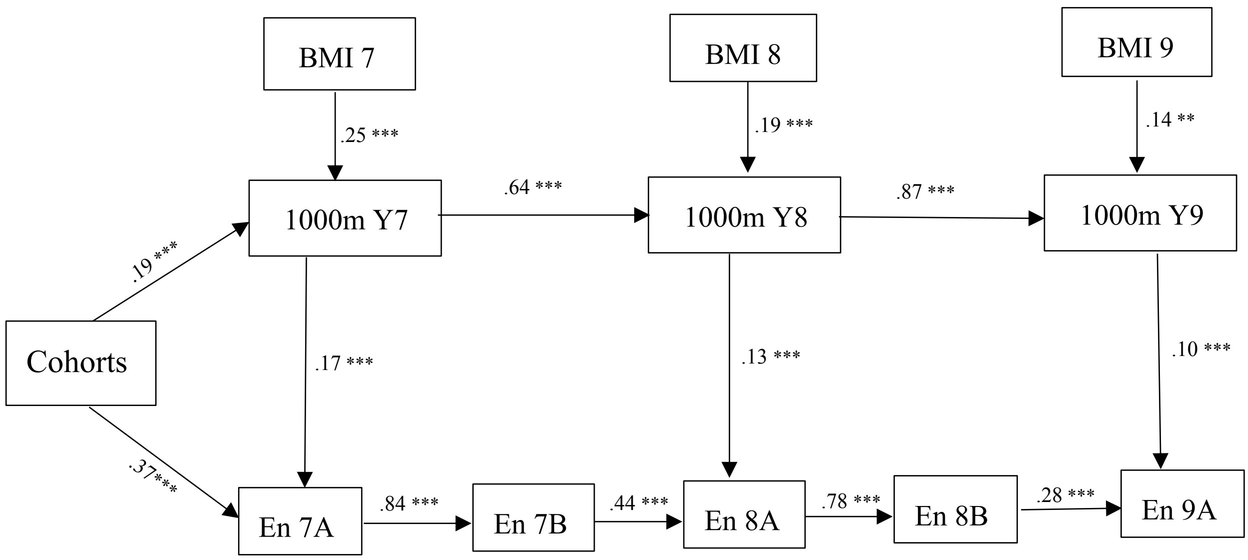

Figure 7. Longitudinal Path Model for Boys 1000m Performance and the Achievements in English Standardized Tests over Time from Year 7 to Year 9, Controlling for the Covariates of Cohorts and BMI Level.

Notes: standardized estimates from AMOS 23 version. * P < .05; ** P < .01; *** P < .001.

Similarly, the models in Figure 6 and Figure 7 report that the fitness of aerobic endurance could predict academic performance. These model meets the criteria for good model fit ($\chi^2_{(33)}$ = 38.228; p > .05; RMSEA= .023; CFI = .998; and $\chi^2_{(33)}$ = 38.530; p > .05; RMSEA= .023; CFI = .998, respectively). In terms of Mathematics, boys' 1000m level could predict the academic performance in Year 7 (β= .17, p < .001) and Year 9 (β= .09, p < .05). Surprisingly, the findings from the Figure 7 model indicate that there were significant continuing effects in English over years (β= .17 p < .001; β= .13, p < .001; β= .10, p < .001, respectively in Year 7, Year 8 and Year 9), even under the impacts of erratic academic performance in the transition from year to year.

Table 6. Summary Table for the Predication of Each Component of Physical Fitness and Academic Achievements in terms of Chinese, Mathematics and English according to the Results from Boys Longitudinal Path Models

	Chinese (β)			Mathematics (β)			English (β)		
	Y7	Y8	Y9	Y7	Y8	Y9	Y7	Y8	Y9
Boys									
Agility (50m)							.09*		
Muscular strength (Standing long jump)							.14***		
Aerobic endurance (1000m)	.20***	.14**		.17***		.09 *	.17***	.13***	.10***

Notes: The analysis was carried out in AMOS 23. * P < .05; ** P < .01. Total N=312 (Boys) in two cohorts. The physical fitness tests and academic exam taken in the first semester of each academic year.

Table 6 summarizes the findings from the boys' longitudinal path models in order to address the question: how well do one or more components of physical fitness predict the academic achievement in one or more specific subjects. This table shows that all three types of fitness can predict English performance in Year 7 (β= .09, p < .05; β= .14, p < .001; and β= .17, p < .001, predicted by Agility, Muscular strength, and Aerobic endurance respectively). The fitness of aerobic endurance could predict the academic performance in all three core subjects in one or more academic years in the middle school stage (β range from .09 to .20). It is worth mentioning that aerobic endurance fitness could consecutively predict boys' English performance across Year 7 to Year 9 (β range from .10 to .17, all P < .001).

4.4.2 Girls Longitudinal Path Models for the Prediction of Physical Fitness and Academic Achievements over Three Academic Years

Additionally, the girls' longitudinal path model was employed the same statistical techniques and approaches as in the boys' model. In order to investigate the directional effects, the academic performance in related core subject of each year regressed on the fitness level in one specific component (both of them tested in the first semester of each year). In addition, the longitudinal path model control for the variables of BMI and cohort for the purpose of minimizing the influence on the results. Based on the correlation results for girls, the researcher mainly focuses on exploring the longitudinal effects of muscular strength fitness (standing long jump) on Mathematics, and the degree of contribution of aerobic endurance fitness (800m run) to all three subjects.

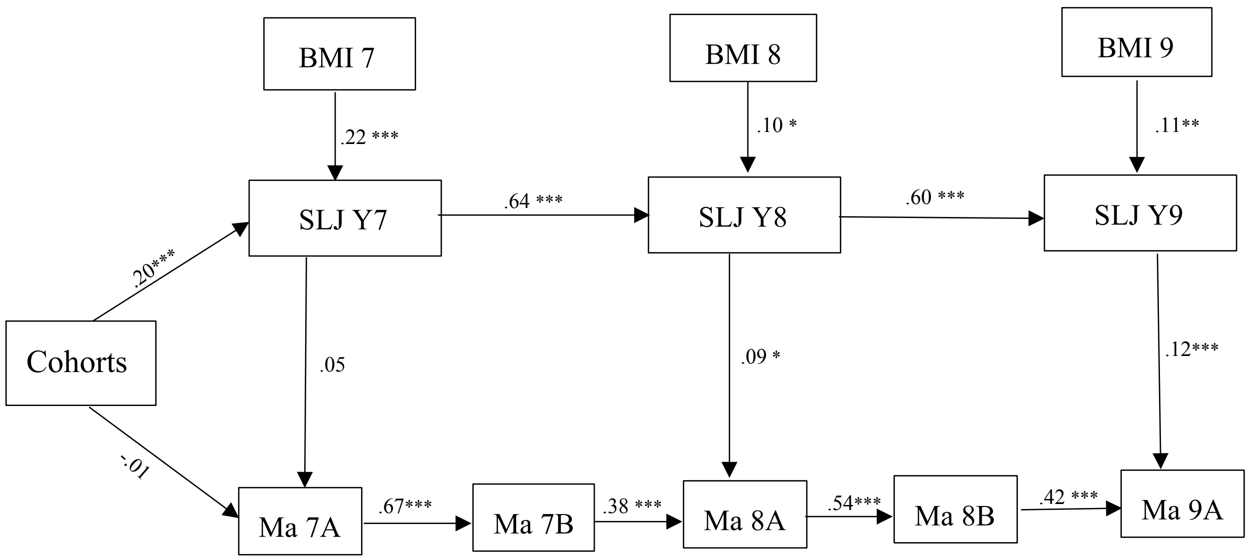

Figure 8. Longitudinal Path Model for Girls Standing Long Jump (SLJ) Performance and the Achievements in Mathematics Standardized Tests over Time from Year 7 to Year 9, Controlling for the Covariates of Cohorts and BMI Level.

Notes: standardized estimates from AMOS 23 version. * P < .05; ** P < .01; *** P < .001.

Figure 8 illustrates how well the component of Muscular strength fitness measured by standing long jump could predict the test performance in Mathematics across three academic years. This model exhibits a good model fit ($\chi^2_{(30)}$ = 42.354; p > 0.05; RMSEA= .041; CFI = .993). The results from multivariate path analysis report that there were significant impacts of muscular strength fitness on the Mathematics test achievement starting from Year 8 (β= .09, p < .05) and with a slight increase in Year 9 (β= .12, p < .001). The Mathematics test performance was relatively stable from Year 8A to Year 9A (β= .54 and β= .42, all p < .001), compared to the performance from Year 7A to Year 8A (β= .67 and β= .38, all p < .001).

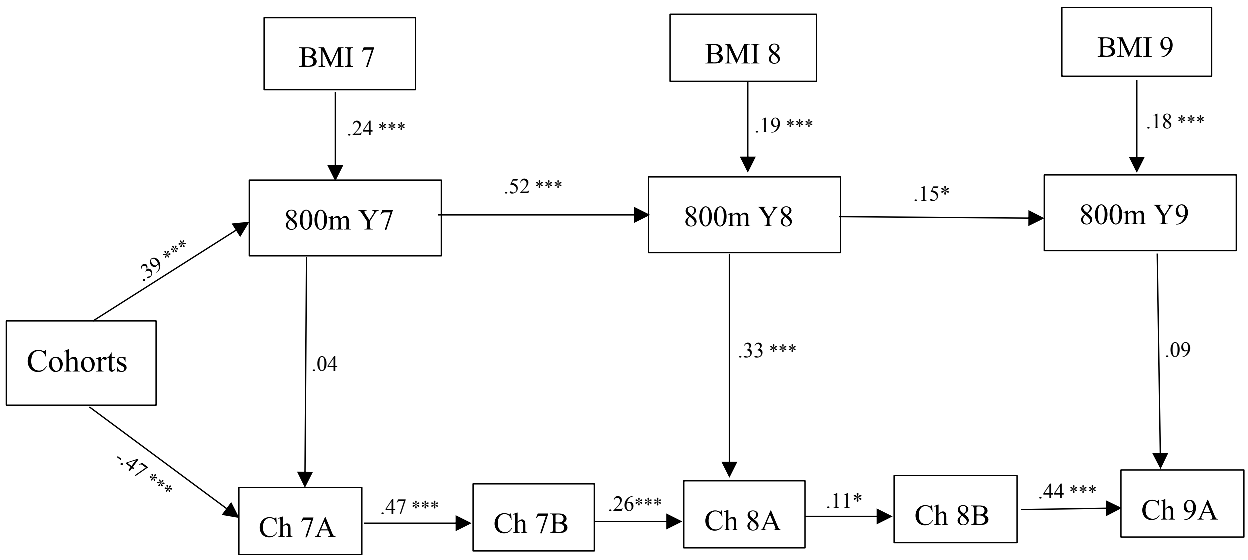

Figure 9. Longitudinal Path Model for Girls 800m Performance and the Achievements in Chinese Standardized Tests over Time from Year 7 to Year 9, Controlling for the Covariates of Cohorts and BMI Level.

Notes: standardized estimates from AMOS 23 version. * P < .05; ** P < .01; *** P < .001.

Slightly different from the boy's fitness test item, an 800-metre endurance run was utilized for measuring girls' aerobic endurance fitness level. Figure 9 displays the prediction of aerobic endurance fitness for Chinese academic performance in the first semesters over three years. The model fits the data well ($\chi^2_{(32)}$ = 42.914; p > .05; RMSEA= .037; CFI = .993). The results from this model show that the fitness level of aerobic endurance could significantly predict the academic performance in Year 8A

Chinese (β= .33, p < .001), but not significantly in Year 7A and Year 9A (all p > .05). Similar to boys' academic performance in Chinese, this model also elaborates the erratic Chinese performance among girls in the whole period of middle school (β= .47, β= .26, β= .11, and β= .44 across five time-points from Year 7 to Year 9).

Additionally, Figure 10 and Figure 11 models exhibit the results in terms of the academic achievement in another two subjects: Mathematics and English. Both models achieve a good model fit ($\chi^2_{(30)}$ = 41.001; p > 0.05; RMSEA= .039; CFI = .994 and $\chi^2_{(30)}$ = 40.759; p > 0.05; RMSEA= .038; CFI = .995, respectively). The findings in the Figure 10 model indicate that there was a significant impact of aerobic endurance fitness on Mathematics standardized test performance in Year 9 (β= .09, p < .05). In addition, the findings in the Figure 11 model report that the component of aerobic endurance could significantly predict the academic achievement in English tests, not only in Year 8 but also in Year 9 (β= .10, p < .05 and β= .25, p < .001, respectively). Similar to boys' academic performance in Mathematics and English, girl's performance in Mathematics from Year 7A to Year 8A was less predicted to the adjacent time-point performance (β= .68 and β= .35, all p < .001) compared to the period from Year 8A to Year 9A (β= .54 and β= .42, all p < .001). In English, the transition period from 7B to 8A (β= .49, p < .001) and from 8B to 9A (β= .45, p < .001) were less predicted to the following time-points' academic performance compared to the within-year period (β= .79 in Year 7 and β= .72 in Year 8, all p < .001).

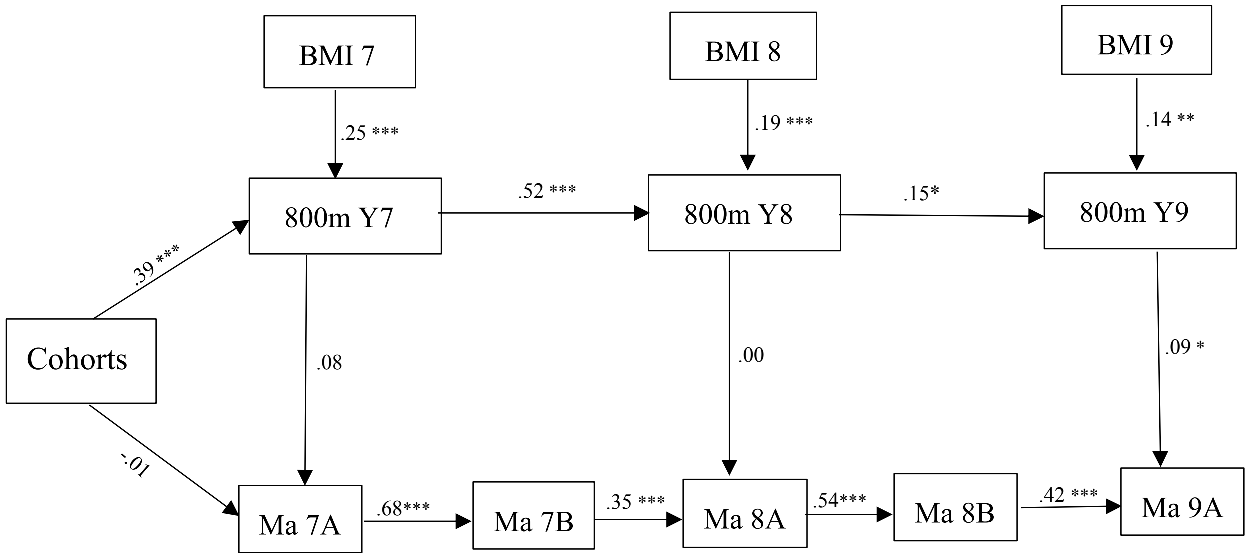

Figure 10. Longitudinal Path Model for Girls 800m Performance and the Achievements in Mathematics Standardized Tests over Time from Year 7 to Year 9, Controlling for the Covariates of Cohorts and BMI Level.

Notes: standardized estimates from AMOS 23 version. * P < .05; ** P < .01; *** P < .001.

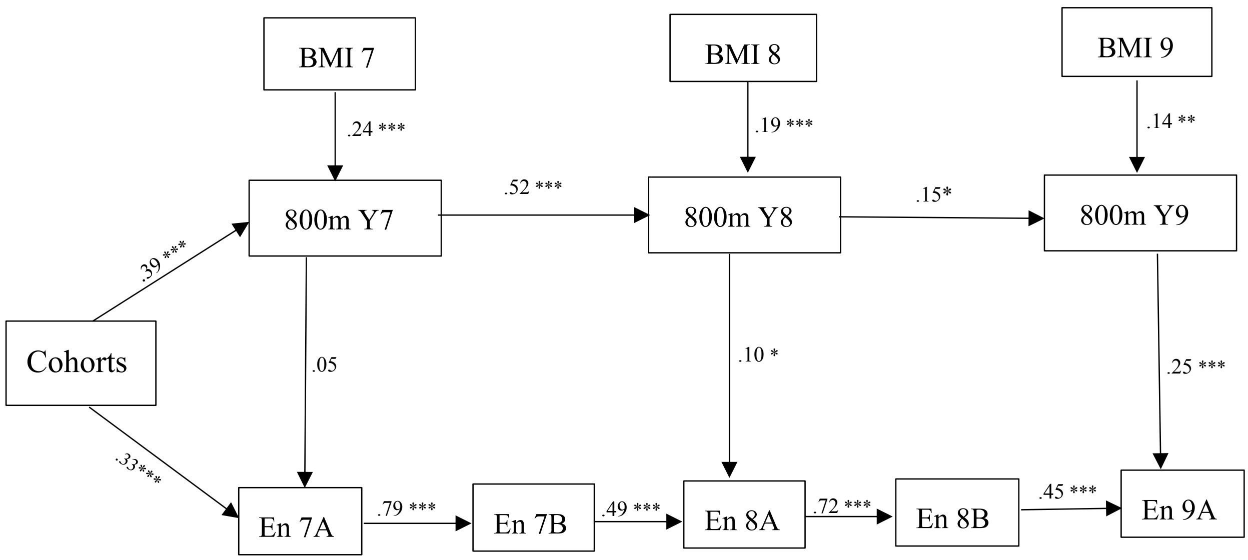

Figure 11. Longitudinal Path Model for Girls 800m Performance and the Achievements in English Standardized Tests over Time from Year 7 to Year 9, Controlling for the Covariates of Cohorts and BMI Level.

Notes: standardized estimates from AMOS 23 version. * P < .05; ** P < .01; *** P < .001.

Table 7. Summary Table for the Predication of Each Component of Physical Fitness and Academic Achievements in Chinese, Mathematics and English according to the Results from Girls' Longitudinal Path Models

	Chinese (β)			Mathematics (β)			English (β)		
	Y7	Y8	Y9	Y7	Y8	Y9	Y7	Y8	Y9
Girls									
Agility (50m)									
Muscular strength (Standing long jump)					.09*	.12**			
Aerobic endurance (800m)		.33***				.09 *		.10*	.25***

Notes: The analysis was carried out in AMOS 23. * P < .05; ** P < .01. Total N= 245 (Girls) in two cohorts. The physical fitness tests and academic exam taken in the first semester of each academic year.

Table 7 summarizes the findings from girls' longitudinal path models regarding how well one or more types of physical fitness predict the academic achievement in one or more specific subjects. The table indicates that two components of physical fitness could predict academic achievement for girls: muscular strength and aerobic endurance. However, compared to the muscular strength fitness, which could only predict Mathematics performance in Year 8 (β= .09, p < .05) and Year 9 (β= .12, p < .01), the aerobic endurance fitness could predict all three core subjects (β= .33 in Year 8 for Chinese; β= .09 in Year 9 for Mathematics; β= .10 and β= .25 in Year 8 and Year 9 respectively for English).

4.4.3 Summary of the Research Question 2

The second research question was: how well do one or more components of physical fitness predict the academic achievements of boys and girls in the three core subjects and do results vary between boys and girls? As has been reported above, according to the results from the longitudinal path models, there was more than one component of physical fitness which could significantly predict academic achievements to some degree at one or more time-points in the first semester over three academic years (β range from .09 to .33). However, the results vary slightly between boys and girls.

Compared to girls, the effect of each component of physical fitness on three subjects were found more frequently among boys during the period of middle school years. However, the aerobic endurance fitness could predict the academic achievement in all three subjects for both boys and girls, especially in English performance.

4.5 Research Question 3: Does the physical performance of the most effective component at a prior time-point predict academic performance in one or more subjects at a subsequent time-point?

Based on the summary findings in table 6 and 7, aerobic endurance fitness shows the most contribution to the academic performance in English. Therefore, two additional models were established to further investigate whether the component of aerobic endurance fitness at a prior half-year time-point could predict progress in English performance at a subsequent time-point in the second semester of each year. Figure 12 displays the boys gain model with a good model fit ($\chi^2_{(29)}$ = 38.285; p >.05; RMSEA= .032; CFI = .997). The results in this model demonstrate that the effect of aerobic endurance fitness was diminished at a subsequent half-year time-point and did not show significance in Year 7B (β=.02, p > .05).

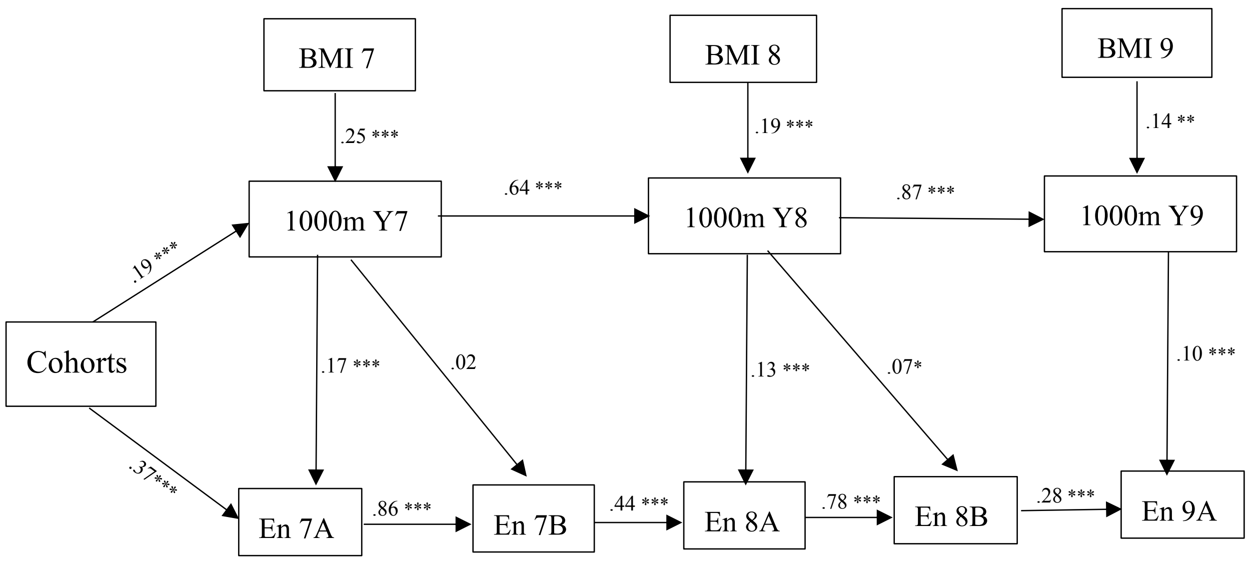

Figure 12. Longitudinal Cross-lagged Path Model for Boys 1000m Performance and the Achievements in English Standardized Tests over Time from Year 7 to Year 9, Controlling for the Covariates of Cohorts and BMI Level.

Notes: standardized estimates from AMOS 23 version. * P < .05; ** P < .01; *** P < .001.

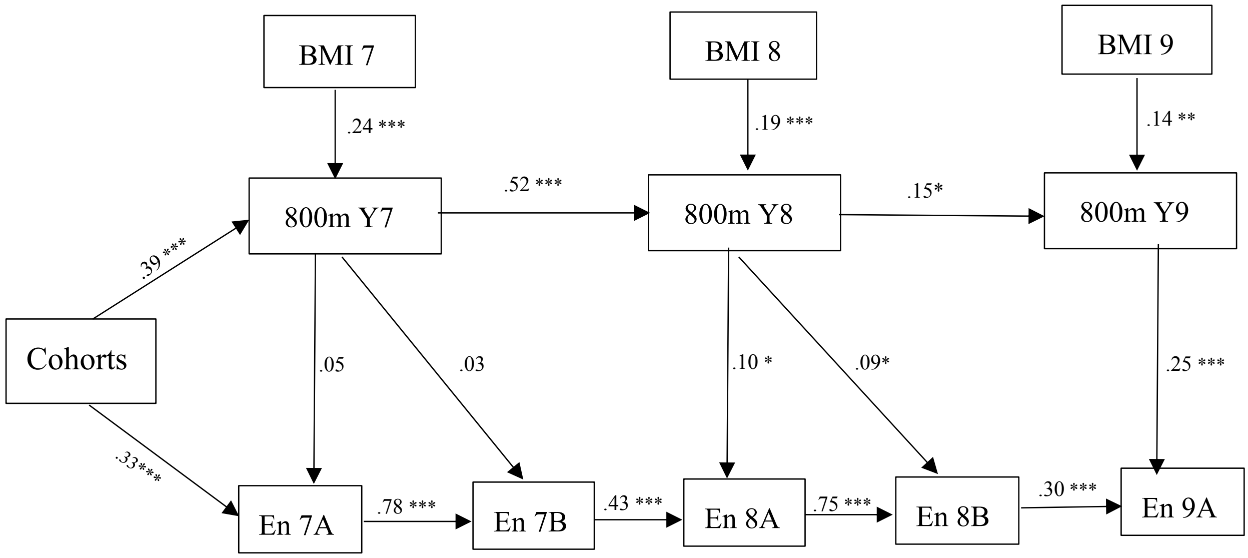

Figure 13. Longitudinal Cross-lagged Path Model for Girls 800 m Performance and the Achievements of English Standardized Tests over Time from Year 7 to Year 9, Controlling for the Covariates of Cohorts and BMI Level.

Notes: standardized estimates from AMOS 23 version. * P < .05; ** P < .01; *** P < .001.

Figure 13 exhibits the model results for girls in order to explore the gain effects of aerobic endurance fitness at a subsequent time-point. This model fits the data well ($\chi^2_{(28)}$ = 37.237; p > .05; RMSEA= .037; CFI = .996). Similar to the results from the boys' model, even though measured by a different test item, the higher level of endurance run performance could significantly contribute to the higher level of English test achievement in Year 8B (β=.09, p < .05).

In summary, regarding the fourth research question, the findings from Figure 12 and Figure 13 models indicate that the aerobic endurance fitness, as the most effective component, has a relatively stable effect on English achievement among both boys and girls across each time-point over three academic years. Especially starting from Year 8, a higher level of aerobic endurance shows long-term effects on the academic achievement in English, regardless of the erratic tendency of academic performance in the transition period from 7B to 8A and from 8B to 9A.

Chapter 5 Discussion

In this chapter, the key research findings will be discussed in relation to the results from the previous relevant studies. In addition, the limitations of the present study will be reported. Finally, according to the key findings, the researcher will provide some recommendations for educational practice in terms of suggestions for interventional PE programs and curriculum reform. Furthermore, recommendations for future research will be discussed in the final section.

5.1 Conclusion and Discussion of the Key Research Findings

5.1.1 The Relationship between BMI and Academic Achievement

London & Castrechini (2010) reported the association between BMI normal level and passing academic standarised tests among middle school students. In contrast, the results from Bass et al. (2013) show that no relationship was found between BMI level and higher academic performance in core subjects. Both of these studies were conducted in the context of American urban public schools. In this study, the researcher investigated this topic by examing the correlations over the whole three-year period of middle school in the context of a Chinese urban public school, using CNSPFS standard to rank order the BMI into three levels (obese, under/overweight and normal). A difference with the method of London & Castrechini (2010), who identified academic achievment as passing the standarized test, was that the current study took as its measure of academic achievement higher academic scores in the core subjects. The results in this study show that weak relationships occur between BMI and higher academic performance of Year 8A Chinese students ($r = .132, p < .05$) among girls, and Year 9 Mathematics ($r = .119, p < .05$) among boys. This finding may support the interpretation that there was a correlation between BMI level and academic standardized test performance regardless of gender, but the correlation was too weak, and the association may have been influenced by many confounding factors which makes the relationship found to be not consistently significant. Likewise, the uncorrelated findings from Bass et al. (2013) may be due to disturbance by some dominant condunding factors, such as family economic background and the children's attitude towards learning in the different stages. Furthermore, the findings of this study also indicate that, compared to the physical performance-related fitness in terms of agility, muscular strength and aerobic endurance fitness, fewer associations exist between normal BMI level and higher academic performance, even though the BMI level affected the fitness performance in these three components to some extent.

5.1.2 The Relationship between Physical Performance-related Fitness and Academic Achievement

According to the results from the correlation analysis, many positive relationships were found between the three components of fitness performance and academic achievements in three core subjects. The results in this study not only confirm most of the previous research findings (e.g., Castelli et al., 2007; Dwyer et al., 2001; Hermoso et al., 2017; Sasayama et al., 2019), but extend the knowledge by adding the subjects of Chinese (native languge) and English (as a foreign language) into consideration. Other innovations in this study provide further evidence by using Chinese Fitness standarized tests in the context of an urban area in China. However, slightly different from the results obtained by Eveland-Sayers et al. (2009), which shows that the association only occurred for girls, the results in this study demonstrate that the correlations were more frequently and generally found among boys. This interesting finding was quite similar to Sasayama et al.'s (2019) findings in Japan, which revealed that only two types of fitness (muscular strength and aerobic endurance) correlated to girls' higher academic performance in three core subjects (Japanese, Mathematics and English), compared to boys, where all types of fitness were associated with academic attainment in the perspective of a longitudinal relationship in the middle school stage of education. It is worth mentioning that, even though different fitness instruments and standardized criteria were used, the relationship between aerobic endurance fitness was found for both boys and girls in all three subjects. This finding supports a majority of prior studies from different countries in the world (e.g., Bass et al., 2013; Castelli et al., 2007; Dwyer et al., 2001; Hermoso et al., 2017; Sasayama et al., 2019), which show that this type of fitness was associated with attainment in a varity of subjects such as Mathematics, Reading and Language learning. Thus, this dominant finding may indicate that there are possible links between a higher level of aerobic endurance fitness and higher academic performance in all three core subjects, although the direct causality cannot be determined by a correlational research design.

5.1.3 The Effects of Physical Fitness on Academic Achievement

The results from the longitudinal path models show the directional within time-point effect of physical fitness on academic achievement in specific subjects, based on the findings from correlational analysis. Although the fitness of agility and muscular strength are able to predict academic test performance at one or more time-points across middle school years, the effects are not stable and differ slightly between the genders. For boys, the fitness level of agility and muscular strength could predict English test performance in Year 7 (β= .09, $p < .05$ and = β= .14, $p < .001$). In contrast, the findings for girls indicate that a positive effect was found between muscular strength fitness and mathematics performance in Year 8 and Year 9 (β= .09, $p < .05$ and = β= .12, $p < .01$). It is possible that the results are influenced by many other confounding factors, even though controlling for BMI and cohorts. The results from the longitudinal path models indicate erratic academic performance between adjacent time-points, especially in the transition period from one academic year to the next. The reason for this phenomenon may be the shifting of related subject teachers, and the increasing difficulty in the content for each subject; this erratic trajectory may also be due to the changes in students' attitudes towards academic learning. However, even though influenced by many potential confounding factors, aerobic endurance fitness displays a small but significant effect on all three core subjects, regardless of gender (β range from .09 to .33). In addition, the further exploration in this study found that, compared to Chinese (native language) and Mathematics, the aerobic endurance fitness had a markedly greater effect on second language learning (English). It might be argued that, by contrast with Chinese as a native language, English as a second language learning may rely more heavily on the performance of memory to remember large amounts of vocabulary and the pronunciation of new words in the foreign language.

Prior experimental studies based on neuroscientific mechanisms may account for the reasons behind these findings of the present study. On the one hand, physical exercise can improve the cognitive function for better readiness for learning, by activating the growth of new brain cells and neurological pathways in the related cognitive brain area and stimulating BDNF release for neurotrophic supply (Ratey & Hagerman 2008; Hansen, 2017). Hillman et al, (2008) reported the effect of physical fitness training on the prefrontal cortex (control for superior cognitive functions), which impacts on the performance of reasoning, spatial orientation, logical analysis and other mathematical-related abilities. The development of these brain functions may give rise to the better performance in Mathematics and reading comprehension in Chinese. On the other hand, regular physical exercise can optimise good brain conditions in terms of concentration and positive emotion for learning new things, due to the increasing levels of neurotransmitters such as dopamine, serotonin, and noradrenaline (Ratey & Hagerman; Suzuki, 2015). Thus, in terms of non-cognitive aspects, compared to unfit students, physically active students may be more likely concentrate on studying and to sustain a positive mood and mindset when encountering challenges in learning new things.

Furthermore, this study also resulted in the impressive findings that, compared to the effect of the other two components of fitness, the aerobic endurance fitness is shown to be the most effective predictor of attainment in all three subjects among middle school students, especially contributing to the second language learning (English). Previous laboratory studies on animals and humans have documented the largest effect of aerobic training on the cognitive function of memory through exploring the biological changes in the hippocampus (Chaddock, 2010; Erickson et al., 2011; Van Praag, et al., 2005). For example, the wheel running mice study suggests that regular running training can increase the size of the hippocampus, which leads to the better performance in memory. Additionally, neuroscientists have discovered that the hippocampus (the brain's memory center) produced the most BDNF when doing aerobic fitness training, such as endurance running, compared to other parts of the brain (Hansen, 2017). The higher BDNF level produced, the more the likelihood of improving the performance of memory through stimulating the proliferation of new brain cells and the growth of new neurological pathway connections in the hippocampus that effectively facilitates the memory processes of encoding, storage, and recall (Hansen, 2017). Therefore, this scientific evidence may explain why aerobic endurance fitness level could contribute most to academic performance in foreign language learning, compared to the other two core subjects.

In conclusion, although the BMI level may affect the fitness performance of agility, muscular strength and aerobic endurance fitness to some extent, compared to these physical performance-related fitness measures, fewer associations were found with the academic performance in three core subjects in the context of Chinese urban middle school settings. There are two possible reasons based on neuroscience mechanisms which may account for the key findings of this study. From the perspective of cognitive improvement, physical fitness training may activate vital brain area control for the performance of cognitive functions and stimulate more BDNF for the readiness for academic learning. In addition to the cognitive aspect, doing physical activity could also benefit non-cognitive factors, such as the attention and good emotional orientation to encounter the difficulties of learning. The key findings of this study also show that, although the fitness of agility and muscular strength could contribute to the academic achievement in one or more subjects among middle school students, the most effective component of fitness was aerobic endurance fitness, especially as this could affect performance in second language learning. One reasonable explanation may be the greater production of BDNF released in the hippocampus after doing physical exercise, which improves the function of memory processes. In short, the endurance aerobic fitness training may contribute more to anaerobic activity, by facilitating both cognitive and non-cognitive factors for achieving a high level of academic performance among middle school students.

5.2 Limitations of the Study

Firstly, although the sample size in this study is large enough to draw robust evidence for addressing the research questions, the findings may not generalise to the population among middle school students in different educational settings. For example, the data for the present study was collected in one urban public school in Shanghai, which operates in accordance with the guidance of the 'Sunshine Sports' policy for guaranteeing one-hour physical activity time for each student in the school. Therefore, the findings of this study may be only valid for the schools in a similar educational context where there is a robust school policy to promote the children's physical fitness.

Secondly, the physical fitness tests are only recorded in the first semester of each academic year, whereas the academic tests were taken twice a year. Therefore, it is uncertain whether the gain in the subsequent academic test performance in the second semester would be influenced by the changes of physical fitness level among participants. Therefore, it would be better if one more assessment of physical fitness test could be added in the second semester of each year for the purpose of accurately evaluating the effects on academic performance in the second semester.

Thirdly, in the longitudinal path model, the researcher found that the academic performances were unstable across the five time-points during the middle school years. The reasons for this phenomenon may be due to many confounding factors, such as family social economic background, teachers and parents' impacts or students' attitudinal change towards academic learning. Unfortunately, in this study, the researcher was unable to obtain data in relation to these potential confounding factors and therefore unable to control for these potential confounding factors.

Fourthly, the single quantitative method design is limited in forming comprehensive evidence knowledge (Creswell & Plano Clark, 2017). For example, the findings in this study show that the correlation between physical fitness level and academic performance differs slightly between gender and exists more frequently among boys. However, the single quantitative method design may not be able to provide comprehensive knowledge for explaining the reasons behind this findings. Thus, it is necessary to take advantage of mixed methods, adding qualitative data, in order to minimize the weakness of a single quantitative method design.

Fifthly, neither the results from correlation nor from SEM can prove causality in this research topic. Although the researcher knows that each student had one-hour of physical activity in school, some other important information, such as the intensity of the physical exercise, the types of physical activity, and the intensity and time for academic learning after doing fitness exercise, was unknown. Thus, interventional studies may be necessary for explaining the cause-and-effect relationship between physical fitness and academic achievement more precisely.

5.3 Recommendations for Educational Practice

The research findings in the present study imply that physical fitness exercise may not only contribute to bodily health, but may also facilitate cognitive functions of the brain and good emotional preparation for improving academic performance among middle school students. Adolescents in the vital stage of puberty are more likely to experience changes of body-shape and challenges to their physical fitness level. In addition, with the increase of academic difficulty and the pressure from the important standardized tests, it is necessary to support students' mental wellbeing and to provide healthier and more effective ways of studying. The researcher recommends that the school principals and administrators should keep in line with the policy guidance of guaranteeing at least one-hour moderate physical activity for students for the purpose of both enhancing student's physical wellbeing and optimising better conditions for academic learning.

Furthermore, the researcher also recommends that some interventional actions should be taken for the improvement of curriculum reform. The curriculum may take advantage of physical fitness training for specific subject learning. For example, the interventional programme may emphasise the effect of aerobic endurance fitness training on academic learning, especially for second language learning. Adding aerobic endurance activities before language lessons or using the strategy of restructuring the timetable for PE lessons may contribute to the better performance of learning in concerned subjects. Therefore, the educational policy makers could utilize the findings of the present study for revising the national curriculum in order to improve the physical fitness level of adolescents and to enhance the effectiveness of academic learning in the middle school stage.

5.4 Recommendations for Future Research

1. The target samples of this study was middle school students aged from 12 to 15 years old from urban public school in Shanghai, China, which may not generalize to the whole population. It is recommended that future studies could replicate this study by selecting samples from different educational settings in order to generalize the research findings.

2. For the longitudinal design study, it would be better to track the changes of individual physical fitness level followed by the simultaneous time-points of the academic standardized tests taken. In addition, it is recommended to control for some potential factors which may confound the results, such as family economic background, teachers' qualifications and teaching level, and students' attitudes towards academic learning and physical fitness.

3. An interventional design study, such as randomised control trial, may be necessary for exploring the cause-and-effect relationship between the improvement of physical fitness level and the increase of academic performance by adding one specific PE interventional program to the academic learning. Future studies should focus on the intensity of physical fitness training and the combination effect of one particular type of fitness on one concerned subject.

4. In order to minimize the inconsistent findings and obtain comprehensive knowledge for the results, apart from the suggestions listed above, it is highly recommended to take advantage of mixed methods for exploring the reasons behind the research findings and avoiding the limitations of a single quantitative method design.

5. This research topic involves theories and scientific knowledge from multiple disciplinary fields. Therefore, it is recommended that opportunities to conduct an interdisciplinary project be explored by cooperating multiple-disciplinary field experts in order to establish the optimisation of the educational regime in middle school.

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Appendix A:

DREC Confirmation of Ethical Approval

ED-CIA-21-106 - Approval

Laura Molway <laura.molway@sant.ox.ac.uk>
周五 2021/2/12 21:44

收件人： [redacted]@education.ox.ac.uk>
抄送： Lars-Erik Malmberg <lars-erik.malmberg@education.ox.ac.uk>; Student CUREC <student.curec@education.ox.ac.uk>

Dear [redacted]

Title: The relationship between physical fitness and academic achievement in middle school students in Shanghai
Ref: ED-CIA-21-106

The above application has been considered on behalf of the Departmental Research Ethics Committee (DREC) in accordance with the procedures laid down by the University for ethical approval of all research involving human participants.

I am pleased to inform you that, on the basis of the information provided to DREC, the proposed research has been judged as meeting appropriate ethical standards, and accordingly, approval has been granted.

Please continue to follow all current guidance issued by CUREC during the pandemic, notably COVID-19: CUREC guidance on research involving human participants, https://researchsupport.admin.ox.ac.uk/governance/ethics/coronavirus. The best practice guidance for internet-based research may also prove useful:
https://researchsupport.admin.ox.ac.uk/governance/ethics/resources/bpg

Should there be any subsequent changes to the project which raise ethical issues not covered in the original application you should submit details to student.curec@education.ox.ac.uk for consideration.

Good luck with your research study.

With best wishes,
Laura Molway
Member of DREC

Laura Molway (she/her)
Departmental Lecturer in Modern Languages Education
Lead Tutor for the ML PGCE
St Antony's College
@OxfordDeptofEd

Recent work:
Measuring effective teaching: Student perceptions of their modern languages lessons in England
What do languages teachers in England say they want to develop?

Appendix B:

PARTICIPANT CONSENT FORM

参与者知情同意书

Central University Research Ethics Committee (CUREC) Approval Reference: ED-CIA-21-106

CUREC 批准序列号: ED-CIA-21-106

The Relationship Between Physical Fitness and Academic Achievement in Middle School Students in Shanghai

上海市中学生体质健康与学业成绩相关性分析

The purpose of this study is to explore the relationship between physical fitness and academic achievement in middle school students in Shanghai. 本项研究目的是探究上海中学生体质健康与学业成绩的相关性。The findings of this study may provide suggestions for enhancing the quality of education and improving students' performance both academically and physically.研究结果或许可以为提升教育质量（学生学业成绩以及身体素质双方面表现）提出建议。

Please initial each box

1	I confirm that I have read and understand the information sheet for the above study. 我确认已阅读并且理解信息告知书上的关于该项研究的内容。I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.我有自主权去考虑信息告知书上的内容，提出疑问并获得满意的答复。	√
2	I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, and without any adverse consequences or penalty. 我了解到我的参与是自愿性的并且不需任何理由可以在任何时候选择推出（不会产生任何不利后果或处罚）。	√
3	I understand that research data collected during the study may be looked at by authorised people outside the research team. 我了解到在研究过程中采集到的数据可能会给研究团队以外的获授权人读取。I give permission for these individuals	√

to access my data. 我给予这些个人（获授权人）允许查看我提供的数据。

4	I understand that this project has been reviewed by, and received ethics clearance through, the University of Oxford Central University Research Ethics Committee. 我了解到该项目已经被牛津大学大学科研伦理委员会（CUREC）审批通过。	√
5	I understand who will have access to personal data provided, how the data will be stored and what will happen to the data at the end of the project. 我了解到谁会查看到我提供的数据，数据将如何存储以及项目结束后数据将如果处理。	√
6	I understand how this research will be written up and published. 我了解到该项研究将会以什么形式书写完成及发表。	√
7	I understand how to raise a concern or make a complaint. 我了解到可以通过何种途径提出疑虑或提出投诉。	√

[redacted]

Name of Participant 参与者姓名 Date 日期 Signature 签名

[redacted]

Name of researcher 研究者姓名 Date 日期 Signature 签名

Appendix C:

PARTICIPANT INFORMATION SHEET

参与者信息告知书

Central University Research Ethics Committee (CUREC) Approval Reference: ED-CIA-21-106

CUREC 批准序列号: ED-CIA-21-106

The Relationship Between Physical Fitness and Academic Achievement in Middle School Students in Shanghai

上海市中学生体质健康与学业成绩相关性分析

Dear School Principal/teachers 敬爱的校长/老师们

This research aims to investigate the relationship between physical fitness and academic achievement in middle school students in Shanghai. 该项研究目的是为了探究上海市中学生体质健康与学业成绩的相关性。The findings of this study may provide suggestions for enhancing the quality of education and improving of students' performance both academically and physically. 研究结果或许可以为提升教育质量（学生学业成绩以及身体素质双方面表现）提出建议。

The researcher, [redacted], suppose to collect data from middle school students (from year 7 to year 9), which includes students' ID number, physical fitness scores and three core subjects' scores in terms of Chinese, English and Mathematics. 研究者计划采集已毕业中学生（7年级至9年级期间）体质健康数据（一年一次）以及语文、数学、英语三门主学科成绩（一年两次期末成绩）作为研究数据（无要求提供学生姓名，可以用校方独立给每位学生编录的ID码替代）。I would like to ask for your permission in order to obtain archival data of previous graduated students in your school. 我希望获得您的批准并能获得该校已毕业学生的这些档案数据。You will be free to take part in or rejected my invitation without any pressure. 您可以自愿选择参加或拒绝邀请，不受任何压力。 Before you sign the informed consent sheet, please carefully read the information below. 在您签署参与者知情同意书之前，请仔

细阅读以下这些相关信息。

This study has been reviewed by, and received ethics clearance through the University of Oxford Central University Research Ethics Committee. 该项目已经被牛津大学大学科研伦理委员会（CUREC）审批通过。 The results of this study will only be published as a post-graduate dissertation for MSc Education programme in Oxford University.该项研究成果仅用于为牛津大学教育硕士专业毕业论文发表。The purpose of this study is to explore the relationship between physical fitness and academic achievement. 该项研究目的是为了探究中学生体质健康与学业成绩的相关性。The findings of this research may benefit to students' academic performance in middle school as well as their development of physical fitness. 研究结果可能有助于中学生学业表现以及提升他们的体质水平。Furthermore, there will be no potential risks and negative impact on your school students physically and mentally. 此外，该项研究不会对该校学生产生身体及心理等方面负面的潜在影响和风险。You can provide archival data without students' name and any identified information.您所提供的档案数据可以不包含学生姓名等任何身份信息。 If the data you provided with the identified information of students, a unique anonymous code will be given to every participant in order to guarantee the issues of confidentiality and anonymity. 如果您提供的数据中包含学生姓名等可能识别学生身份的信息，为保证保密性和匿名等原则，我将会给每一位学生编录一个匿名代码。

All the data will be password protected and stored on the University storage service securely based on the requirements of the General Data Protection Regulation (GDPR) and the Data Protection Act 2018.依照 GDPR 和 2018 年版数据保护法要求，所有的数据将会被加密保护并安全存储在所在大学的存储服务器中。These electronic copies of the data will be destroyed immediately after the dissertation submission (in August 2021). 这些电子版数据副本将会在论文提交后立即删除销毁（2021 年 8 月）。The researcher and her supervisor may access to these data during the study. 研究者和她的导师将会在研究过程中读取这些数据。 You also can withdraw from the study at any time through sending me an email, without penalty of any kinds. 您还可以在任何时候选择撤销参与（通过邮件形式告知我，不会涉及到任何处罚）。I will delete all the data as soon as I can. 我将会尽快将您提供的所有数据删除。The consent form will be retained three years after dissertation submission. 知情同意书将会在该论文提交后保留三年时间。

If you have any questions, concerns or complaint regarding this research, please contact me via email. 如有任何有关该项研究的问题、疑虑或投诉抱怨等问题可通过邮件形式与我沟通联系。

Researcher: [redacted] (MSc Education student, the University of Oxford)
研究者：[redacted] （牛津大学，教育学专业学生）
University email 邮箱: [redacted]

Appendix D:

Cohort Difference (T-test)

Cohort Difference in Academic Scores for Boys

Boys	Cohort (2016) n=159		Cohort (2017) n=153				
	M	SD	M	SD	t	df	P
Year 7							
Chinese A	82.04	5.1	77.98	5.65	6.673	310	.000
Chinese B	77.52	5.4	77.92	7.02	-0.571	310	.569
Mathematics A	84.09	9.08	85.99	11.25	-1.637	310	.103
Mathematics B	85.50	8.31	83.37	12.45	1.766	310	.079
English A	81.21	9.33	89.70	7.54	-8.859	310	.000
English B	80.15	10.26	88.02	6.46	-8.139	310	.000
Year 8							
Chinese A	79.55	5.83	73.24	5.54	9.782	310	.000
Chinese B	75.47	5.42	80.07	4.63	-8.041	310	.000
Mathematics A	76.64	11.85	80.71	10.50	-3.218	310	.001
Mathematics B	88.29	8.44	89.04	9.09	-0.752	310	.453
English A	80.70	8.61	84.96	9.51	-4.147	310	.000
English B	86.21	6.95	86.47	8.73	-0.287	310	.775
Year 9							
Chinese A	78.85	4.50	78.87	4.82	-0.047	310	.963
Mathematics A	80.59	10.27	83.69	10.64	-2.622	310	.009
English A	79.31	8.56	85.46	7.54	-6.731	310	.000

Cohort Difference in Academic Scores for Girls

Girls	Cohort (2016) n=128		Cohort (2017) n=117				
	M	SD	M	SD	t	df	P
Year 7							
Chinese A	85.61	4.49	79.9	5.65	8.701	243	.000
Chinese B	80.39	5.32	78.34	6.25	2.771	243	.006
Mathematics A	83.44	9.14	83.32	11.59	.09	243	.928
Mathematics B	84.81	7.89	80.79	11.86	3.098	243	.002
English A	86.36	6.82	90.92	6.06	-5.517	243	.000
English B	85.91	6.43	89.54	5.09	-4.923	243	.000
Year 8							
Chinese A	83.85	4.66	75.64	5.52	12.516	243	.000
Chinese B	79.26	4.93	81.39	4.42	-3.557	243	.000
Mathematics A	76.17	11.26	77.82	9.51	-1.232	243	.219
Mathematics B	88.75	7.85	87.53	7.49	1.238	243	.217
English A	86.02	6.50	85.37	8.59	.669	243	.504
English B	89.98	5.22	87.32	7.82	3.101	243	.002
Year 9							
Chinese A	81.71	3.90	81.42	4.66	.515	243	.607
Mathematics A	78.45	10.05	80.98	9.66	-2.002	243	.046
English A	82.83	7.07	86.40	6.63	-4.073	243	.000

Cohort Difference in Physical Fitness Scores

Cohort Difference in Physical Fitness Scores for Boys

Boys	Cohort (2016) n=159		Cohort (2017) n=153				
	M	SD	M	SD	t	df	P
Year 7							
50m	67.83	22.74	77.41	16.33	-4.286	310	.000
Standing long jump	70.06	18.58	72.85	12.50	-1.560	310	.120
1000m	61.81	21.07	69.31	19.08	-3.289	310	.001
Year 8							
50m	80.42	14.58	83.41	13.11	-1.902	310	.058
Standing long jump	74.64	14.58	74.82	14.52	-.107	310	.915
1000m	77.07	14.82	74.75	15.93	1.331	310	.184
Year 9							
50m	88.29	10.94	87.01	11.46	1.012	310	.312
Standing long jump	74.18	16.24	73.14	14.86	.592	310	.554
1000m	77.21	11.15	81.44	15.03	-2.818	310	.005

Cohort Difference in Physical Fitness Scores for Girls

Girls	Cohort (2016) n=128		Cohort (2017) n=117				
	M	SD	M	SD	t	df	P
Year 7							
50m	76.63	8.22	76.52	8.39	.098	243	.922
Standing long jump	68.73	13.19	74.05	15.89	-2.863	243	.005
800m	68.48	16.13	81.10	15.38	-6.258	243	.000
Year 8							
50m	81.45	7.54	80.96	8.96	.459	243	.647
Standing long jump	73.76	12.56	80.03	11.25	-4.106	243	.000
800m	83.65	9.70	78.95	10.54	3.634	243	.000
Year 9							
50m	80.36	9.93	79.48	8.59	.739	243	.461
Standing long jump	77.31	12.59	77.90	13.52	- .351	243	.726
800m	74.05	9.04	85.56	9.39	-9.779	243	.000

Appendix E:

Chinese National Student Physical Fitness Standard (CNSPFS)

BMI standards for Boys from Year 7 to Year 9

		Year 7	Year 8	Year 9
Normal (coded 3)		15.5-22.1	15.7-22.5	15.8-22.8
Less than Normal (coded 2)	Under weight	≤15.4	≤15.6	≤15.7
	Overweight	22.2-24.9	22.6-25.2	22.9-26.0
Obese (coded 1)		≥25.0	≥25.3	≥26.1

BMI standards for Girls from Year 7 to Year 9

		Year 7	Year 8	Year 9
Normal (coded 3)		14.8-21.7	15.322.2	16.0-22.6
Less than Normal (coded 2)	Under weight	≤14.7	≤15.2	≤15.9
	Overweight	21.8-24.4	22.3-24.8	22.7-25.1
Obese (coded 1)		≥24.5	≥24.9	≥25.2

More details regarding CNSPFS in terms of each component of fitness available from http://www.csh.moe.gov.cn