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Physical Activity, Leisure-Time, Cognition and Academic Grades: Connections and Causal Effects in Chinese Students

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ABSTRACT

Academic achievement and positive leisure activities are traditionally considered significant determinants of economic growth and human capital accumulation. This paper estimates the impact of physical activity on academic outcome and time allocation to 25 different types of leisure activity by Chinese adolescents. We use structural equation models (SEM) to explore the channels of this transmission. Our results suggest that physical exercise not only exerts a positive direct effect on academic outcome but also increases (decreases) students' time devoted to activities that are positively (negatively) correlated with academic outcome. All the effects are statistically significant but modest at the individual level. Our findings are robust to different measures of exercise frequency and academic outcome indicators based on student's self-assessment, academic scores and cognitive tests.

Keywords: Structural equation models, leisure-time activities, academic performance, cognition, physical activity, instrumental variables.

Jel classification: I10, I20, Z20, C36, C38.

Highlights

- Physical activity exerts a significantly positive effect on academic outcomes both directly and indirectly by affecting time spent on leisure activities.
- This effect is robust to different academic outcomes such as self-assessed academic performance, scores in academic tests and cognitive tests.
- Physical activity exerts a significantly positive impact on Math and English but not on Chinese.
- Doing exercise 2 days per week is the optimal amount for academic improvement.

1. Introduction

Education plays an important role in human capital formation. A more educated society facilitates not only higher economic growth (Barro, 1991; Delgado, Henderson, & Parmeter, 2014) but also makes people more concerned about themselves and others, enhancing social values (Sanborn & Thyne, 2014). Among the different ways to improve educational achievement, promoting physical exercise is attracting increasing interest (Lipscomb, 2007; Pfeifer & Cornelißen, 2010) as it has the advantage of being relatively cheap and easy to implement and it could be applied at the school rather than the national level. However, the overall effect of physical exercise on educational outcome is still ambiguous. On the one hand, the medical literature generally finds a positive effect of physical exercise on cognitive ability by, among other advantages, improving long-term brain plasticity and even increasing individuals' capacity to resist disease (Fernandes, Arida, & Gomez-Pinilla, 2017). On the other hand, exercise may also decrease students' attention to school work or indirectly affect academic outcomes by increasing the allocation of time to leisure activities (Golsteyn, Jansen, Van Kann, & Verhagen, 2020; Pfeifer & Cornelißen, 2010).

This paper analyses the impact of physical activity on academic outcome and time allocation to different types of leisure activities by Chinese adolescents. The study uses data from the China Education Panel Survey (CEPS), a comprehensive longitudinal database which contains information of individual adolescents in 28 counties. We conduct the analysis by means of structural equation models (SEM henceforth). The use of this methodology serves two key purposes. First, it allows us to make the estimation problem more tractable by grouping a large and heterogeneous set of variables into a reduced number of latent variables with a more insightful interpretation that are jointly estimated with the model parameters. This is the case of information about 25 leisure activities, that are grouped into 4 main latent variables, and academic performance in three main subjects (Math, Chinese and English) that are explained by a single measure of academic performance. This facilitates a simple and intuitive estimation of the impact of physical activity on academic performance. A second advantage of using SEM in our particular context is that it allows us to explore the path through which exercise affects academic outcome by distinguishing between a direct impact and an indirect impact through affecting the time devoted to different activities. We estimate these effects by using instrumental variables that deal with the potential endogeneity of physical exercise.

The analysis of the impact of physical activity on academic outcome has already attracted the attention of academics in previous literature. See Barron, Ewing, and Waddell (2000) and Golsteyn et al. (2020) to cite just two examples. Our paper contributes to previous research in at least three ways. Earlier papers already discuss the different direct and indirect channels by which exercise influence academic achievements (Barron et al., 2000) and academic performance (Golsteyn et al., 2020; Pfeifer & Cornelißen, 2010). A novel aspect of this research is the use of SEM to explore channels by which exercise influence academic outcome through the time devoted to 25 different activities. This could be relevant for school managers and policy makers in order to get a complete picture of the effect of policies that incentivise physical activity. Moreover, estimating the effect of physical activity on many positive and negative habits is interesting in itself as they can affect the formation of human capital even if they do not affect academic outcome. A second contribution is the joint consideration of self-assessed and objective measures of academic performance in different subjects as well as cognitive test results. The use of this large range of response variables allows us to explore the robustness of the results and to identify the subjects where students' performance is more likely to be affected by physical exercise. A final contribution is our focus on Chinese students. To our knowledge, this is the first analysis of this type for a developing country. We consider this is relevant as, in order to increase economic growth, these countries require to close the gap with more developed economies in terms of school attainment (Hanushek, 2013) and their populations face greater obstacles to practicing exercise and other types of leisure activity (Reichert, Barros, Domingues, & Hallal, 2007). China is one of the most interesting cases to study as it is the most populous country and the second largest economy in the world, but has relatively low per capita income.

Our results suggest that physical exercise exerts a positive effect both on academic outcome and leisure-time activities that are positively correlated with academic outcomes such as studying and cultural activities. Moreover, exercise reduces students' time devoted to activities negatively correlated with academic outcome such as time spent on visual media and many different types of harmful habits that includes, for example, quarreling, bullying and truancy. We also find that our results are robust to different measures of academic outcome and to econometric considerations on the simultaneity between leisure-time activities and academic outcome in the SEM.

This paper proceeds as follows. Section 2 explores the related literature. Section 3 describes the theoretical framework employed in the paper. Section 4 describes our database and the variables considered in the paper. Empirical analysis and extended analysis are contained in Sections 5 and 6 respectively. Section 7 concludes.

2. Related literature

Research about the impact of sport participation and physical activity on academic outcome is very heterogeneous in many aspects such as subjects and countries included in the analysis, methodologies and variables employed. A detailed review of this literature can be found, for example, in Bradley and Conway (2016) and Muñoz-Bullón, Sanchez-Bueno, and Vos-Saz (2017). It is probably because of this that results are mixed and largely inconclusive. Therefore, while some papers have found a positive impact of physical activity on academic performance (Muñoz-Bullón et al., 2017; Pfeifer & Cornelißen, 2010) others find week positive evidence (Barron et al., 2000) or even a negative relationship (Golsteyn et al., 2020).

One important concern in this literature is the reverse-causality problem between physical activity and academic outcome. Thus, healthier students are more likely to engage in sport and perform better at school. This problem is overcome in Golsteyn et al. (2020) because they are able to exploit an exogenous shock, a political intervention in the Netherland aiming to incentivise physical activity during school hours, which allows a causal effect identification. Using a difference-in-difference analysis, they find that students affected by this policy did not improve their school performance compared to other groups. Although their analysis has important implications for policymakers and educators, the authors also suggest that their results cannot be generalised to physical activity in everyday life.

Where a longitudinal database is available, the use of individual fixed effects is an alternative method to control for unobserved heterogeneity, i.e. individual characteristics that do not change over time. Rees and Sabia (2010) and Lipscomb (2007) are two examples of this approach, finding in both cases a positive, but small, effect of sport participation on education outcomes. As discussed by Rees and Sabia (2010), although fixed effects allow to control for time-invariant unobservables, casual estimates could still be biased under this approach if individual motivations to demand education change through time.

Another approach to overcome the problem of endogeneity involves the use of instruments (Barron et al., 2000; Muñoz-Bullón et al., 2017; Pfeifer & Corneließen, 2010; Rees & Sabia, 2010). Instruments are expected to help predict the decision to practice sport but there should not be a direct relationship between the instrument and the response variable, educational outcome. While the former condition can be formally tested in a regression analysis, the latter is untestable and can only be justified based on logical arguments as the real error components are unobservable.

Thus, Barron et al. (2000) use as instruments the size of the school and characteristics of the geographical area where the school is located. Rees and Sabia (2010) use height as an instrument and Muñoz-Bullón et al. (2017) choose the number of sports clubs serving the population in the student's region of residence. These papers provide mixed evidence about the impact of sports participation on education. Thus, while Pfeifer and Cornelißen (2010) and Muñoz-Bullón et al. (2017) find that sports have a significant and positive effect on the attainment of educational goals, Rees and Sabia (2010) and Barron et al. (2000) only find evidence of a small but positive effect.

Felfe, Lechner, and Steinmayr (2016) and Cabane, Hille, and Lechner (2016) consider propensity score techniques to identify the causal effect of physical exercise on education. These two papers are closely related to our research as they explore the potential channels of transmission. In particular, Felfe et al. (2016) find that participation in sport clubs exert a positive effect on children's school performance in Germany by crowding out of passive leisure-time activities such as TV consumption. Cabane et al. (2016) compare the impact that physical exercise and an alternative leisure-time activity, playing music, exert on educational performance finding that playing music has a relatively bigger impact on the educational output of adolescents. We contribute to this literature by estimating the impact of physical exercise on academic outcome both directly and indirectly through more than 20 habits and leisure-time activities that we group into harmful activities, visual media exposure, study time and cultural activities.

3. Theoretical framework

Physical activity may affect academic outcome in a number of direct and indirect ways. Barron et al. (2000) employed the two-period model of time allocation proposed by Becker (1965). Under this framework, a student's utility depends on the time devoted to education, leisure-time and physical activities. The reward to time spent acquiring education is a higher stock of human capital, and therefore, a higher income in the future period. Although this assumption is subsequently relaxed in Barron et al. (2000), the model initially assumes that participation in physical activity makes no direct contribution to an individual's stock of human capital. According to this, if we abstract from the impact of physical activity on human capital, we can hypothesize that physical exercise may have a negative effect on academic outcome if it reduces the time that students devote to their education (H1). An alternative possibility is that participants in physical activity do not necessarily reduce the time devoted to study if they replace time devoted to physical activity with other leisure-time activities. If this is the case, the impact of physical activity on academic outcome is ambiguous. On the one hand, it could displace negative leisure-time activities that do not contribute, or have a lesser contribution than physical exercise, to educational attainment but, on the other hand, it could crowd out positive activities in terms of education, especially time devoted to study. In the former case, we would assume that physical activity would have a positive impact on academic output (H2) while the impact would be negative (H3) in the latter case.

Even if we do not consider the hypotheses discussed in the previous paragraph, and instead ignore any effect of participation in physical activity on time devoted to leisure-time activities and study time, physical exercise could still exert an influence on academic outcome. This would be the case if, as suggested by the medical literature, it exerts a positive effect on health, concentration and/or ability (H4).

A key point to note is that hypotheses H1 to H4 are not mutually exclusive. For example, physical activity could increase students' concentration, which is consistent with H4, but, at the same time, it could reduce the time devoted to study, H3. If this were the case, the two effects could be offset making the total impact close to zero. This suggests that, in order to have a complete picture of the mechanism through which physical activity influences academic outcome, it is necessary to estimate its impact on the time devoted to different types of leisure-time activity.

4. Data

The study uses data from the China Education Panel Survey (CEPS) conducted by the National Survey Research Center at Renmin University of China. The CEPS is a nationally representative and school-based survey which samples approximately 20,000 students' observations from 438 classrooms in 112 junior high schools in 28 counties in Mainland China. It provides information at different levels including individual, family and school. The CEPS includes demographic characteristics and education outcomes, as well as basic household and school information. Our analysis period contains seventh-year students in the 2013/14 academic year and subsequent observations of the same students in the 2014/15 academic year. As we will explain later, we restrict our analysis to the second wave given that our treatment variable is only observed in that period. However, the longitudinal nature of our database is relevant as it allows us to consider lagged instrumental variables of our treatment to control for potential simultaneity between physical exercise and response variables. Therefore, our final estimation sample consists of 7002 observations in the second wage after removing missing values. In a non-reported experiment, we also considered to tackle data irregularities with an EM algorithm, which increased the number of observations to 7987 (Graham, 2009). However, it did not produce any material change in the analysis reported in the subsequent sections.

Response variables represent students' academic outcome and cognition. Students' academic outcome is measured based on three sets of variables indicating: (1) their own self-assessment, (2) score in academic tests, and (3) score in cognitive tests. For simplicity, we denote these three sets of indicators as subjective academic assessment (SAA), objective academic performance (OAP) and cognition respectively. In turn, SAA is measured by three variables that indicate the difficulty of learning Mathematics, Chinese and English at present evaluated by students themselves that are denoted by Math, Chinese and English respectively. They are ordinal indicators taking discrete values from 1 to 4, ranging from greater to lesser difficulty for the student. Having a subjective student evaluation of academic outcome has the advantage that it offers more comprehensive information about this variable than the one obtained from exam results, which may depend on the type of questions and marking conventions. However, it has the disadvantage that as a subjective evaluation it could be affected by idiosyncratic shocks. Thus, in order to have a more complete measurement of academic performance, we further consider three OAP items including the mid-term marks of students' Mathematics, Chinese and English modules in the second wave, ranging from 0 to 150, that are denoted by Mathscore, Chinesescore and Englishscore respectively. Cognition measures students' basic logical thinking and problem-solving ability, rather than knowledge to be memorised or taught by the school curriculum. This variable takes values from 0 to 35 and it includes information on students' abilities such as language, space, as well as calculation and logic.

Our treatment variable is an integer measuring day(s) per week a student does physical exercise in general which takes values from 0 to 7 (Exercise). Our sample includes 25 different leisure-time activity variables that are classified into four main groups: harmful habits, visual media, study and culture activities. Detailed descriptions of all these variables are presented in Appendix 1.

We also consider different predisposing and enabling variables that, in principle, are main determinants of academic output. Our predisposing variables include the following individual characteristics: age, male and ethnicity. More specifically, the inclusion of age is because of the different brain maturation and lifestyle for different age groups (Lebel, Walker, Leemans, Phillips, & Beaulieu, 2008). Male is a binary variable which takes on the value 1 for male and is 0 otherwise. It is included to control for potential gender differences that could affect treatment allocation, evaluation of academic performance and cognition. For example, boys could be more active than girls (Trost et al., 2002) and are in general better equipped with electronic media devices (Mossle, Kleimann, Rehbein, & Pfeiffer, 2010). In addition, there might be gender inequalities in educational performance and attainment (Buchmann, DiPrete, & McDaniel, 2008) as female advantage in school marks is commonly found in previous research (Voyer & Voyer, 2014). Ethnicity takes the value 1 or 0 depending on whether an individual's ethnic nationality is Han. Non-Han people generally live in less developed provinces with less social resources including sports facilities, education resources, museums, entertainment venues, etc.

Enabling variables refer to the availability of educational resources and participation in specific activities. We include household registration type (hukou), income level and poor health in this variable list. Hukou is a dummy variable which takes value 1 or 0 depending on whether a student has an agriculture hukou or not. This variable is considered since individuals with the agriculture hukou typically come from rural China and could have more restricted access to social resources comparing to people with other types of hukou. Income level takes values 1 to 5, ranging from very poor up to very rich individuals. Children of rich families, in general, get better education and can participate in a wide variety of activities. Poor health takes values 1 or 0 depending on whether or not a student's self-rated health status is poor. Health measurements are included because fitness has a significant relationship with academic achievement (Chomitz et al., 2009). Additionally, it is also related to the ability to engage in specific activities.

[Table 1 near here]

Table 1 shows descriptive statistics of our variables. The sample used in the baseline analysis includes students whose age ranges in the interval 12 to 19 with an average age of 14 and a standard deviation of 0.85. The diversity in age for students in the same grade is due to grade retention. However, the number of these students is small (only 35 out of 7002 students are more than 16 years old). The other confounders show that, for example, the sample is roughly equally split between males and females and that, on average, individuals are in the average income level of 3. Interestingly, for our treatment variable, the mean of exercise frequency is 3.4 days a week with a standard deviation of 2, which indicates that the database contains information on basically all the possible exercise frequency. Figure 1 shows the distribution of our dependent variables. In general, with the only exception of Match and Chinesescore, they are asymmetric and left skewed. However, most ranges of values are represented in the sample.

[Figure 1 near here]

5. Empirical analysis

Three SEM models are specified and estimated for each of the three groups of response variables defined in the previous section: SAA, OAP and cognition. In each model, physical exercise can have a direct effect on self-reported academic performance as well as indirect effects by affecting different types of activities. In the first two cases, SAA and OAP report information on math, Chinese and English. We group these three variables into a single latent variable given that our focus is on total academic output. We report individual estimation for each subject in the next section. Moreover, for the 3 SEM specifications, the 25 leisure activities presented in the previous section are grouped into four latent variables, namely, harmful habits, visual media, study and culture activities. Detailed information about this estimation is reported in appendix Table 1. Harmful habits correspond to activities that can represent damage to the student's health or his/her relationship with the academic community such as, for example, being involved in a quarrel, fight, bullying, being violent or skipping classes. Culture activities involve visits to museums, zoos, science museums, etc. and time spent watching films, shows, sports games, etc., while visual media includes time spent watching tv and internet surfing, or playing video games. The impact of these latter two latent variables on academic outcome is uncertain as, on the one hand, they can incentivise students' academic curiosity but, on the other hand, they could also crowd out time devoted to study. The fourth latent variable, study, is composed of different measures of time devoted to doing homework or schoolwork by the students. The expected impact of this variable on academic outcome is positive.

As discussed in Section 3, the effect of exercise in each of the four mediators discussed above is uncertain. For example, it could change life habits by either increasing or decreasing time devoted, for example, to study or culture activities. Moreover, even if exercise does not affect the amount of time devoted to different activities, it still can affect the quality of this time by affecting the student's capacity for concentration.

Figure 2 describes how variables are connected in each of the three models under analysis. All of them have a similar structure. Exercise, together with other confounders in the model, already defined in the previous section, affects SAA, OAP or cognition. This effect could be direct or indirect through four latent groups of leisure-time activities already described. These latent variables are simultaneously estimated with the other parameters in the SEM models. Estimated loading factors for the different latent variables employed in the model are included in the appendix, Table A1.

[Figure 2 near here]

Note that in order to deal with the endogeneity of physical exercise, we consider the following four instruments: 1) On average, minutes per day an individual spent doing exercise during the previous weekend, measured at the first wave; 2) whether practicing physical exercise was a hobby for the student at the first wave; 3) whether a student' school had a swimming pool at the second wave; 4) the student's height, measured in centimeters, at the first wave. These are common instrumental variables in the literature. For example, lagged exercise variables are useful instruments to deal with the problem of simultaneity between exercise and academic outcome; see Reed (2015) for a discussion on this issue. The presence of a swimming pool is a good proxy for access to general sports facilities as its construction is generally more expensive than alternative facilities. Height is a common instrumental variable used in the literature as it is plausible to assume this variable is associated with the probability of doing exercise but not with academic outcome (Rees & Sabia, 2010).

Table 2 shows the estimated effect of confounders and IV on Exercise in each of the three SEM models. It can be observed that the four IVs are significant with the expected sign. Among the set of confounders, male, ethnicity, agricultural hukou and income significantly explain Exercise indicating that, other things equal, girls, Han students, students with non-agricultural hukou and students in high-income families practice more physical exercise on average.

[Table 2 near here]

Now we turn our attention to the main purpose of the analysis, the estimation of the direct and indirect effect of exercise on the different measures of academic achievement considering the different mediating effects of each activity. This information is shown in Table 3. The goodness of fit statistics (CFI>0.9; RMSEA<0.06) indicate that all of the three models fit well (Hu & Bentler, 1999; Huber, 2014). For the sake of brevity, path diagrams for three models are presented in Figures A1 to A3 in the Appendix.

Interestingly, exercise not only exerts a significantly positive direct effect on academic outcome which is consistent across the three measured of academic achievement considered in the analysis, but also contributes incentivise (reduce) positive (negative) habits in terms of academic achievement. Therefore, the total effect of increasing exercise by one hour per week obtained from the sum of direct effect and indirect effect is 0.33, 10.35 and 2.69 on SAA, OAP and cognition respectively. These estimates are of small magnitude in all cases, which logically suggests that increasing physical exercise by itself cannot turn a student with poor academic outcome into an optimal one. However, the fact that this causal effect is highly significant suggests that managerial policies promoting physical exercise can have a relevant effect on the aggregate student population in China by promoting healthy habits and improving student's academic achievement.

[Table 3 near here]

Table 4 presents the direct effect of exercise, different mediators and confounders on SAA, OAP and cognition. Other than physical exercise, devoting more time to study and culture activities can also exert a significantly positive effect on SAA, OAP and cognition of students. Moreover, other things equal, female students and those from richer families have significantly higher level of academic outcome. Age has a significantly negative effect on academic outcome. The most likely reason for this is that grade repeaters generally face more difficulty in learning.

[Table 4 near here]

Table 5 presents the effect of exercise on four groups of leisure-time activities (mediators). Under three models, exercise significantly decreases students' time spent on harmful habits and visual media, however, significantly increases students' time spent on studying and culture activities. This is interesting, as the results indicate that doing physical exercise does not crowd out studying time but guides students to allocate their time in a more efficient way.

[Table 5 near here]

6. Extended analysis

Results in the previous section assume that leisure-time activities are meditators through which physical exercise indirectly affects academic outcome. This is consistent with the hypothesis that human capital formation by investing time in acquiring education and other activities precedes the observation of academic outcome (Becker, 1965). However, it is also possible to adopt a more conservative approach by assuming that academic outcome and all the different leisure-time activities are simultaneously determined. In order to take this point into account, we modify the structure of the SEM models by allowing for correlated residuals between each of the different leisure-time activities and response variables. This is represented in Figure 3. Note that this model is conceptually different from the one defined in the previous section as the four activities are no longer mediators between exercise and academic output but additional response variables. In this framework we can only estimate the direct effect of Exercise on academic performance and also its effect on activities that are correlated with academic outcome.

We also run two experiments not explicitly reported here to deal with the potential endogeneity of leisure activities. First, we estimated SEM models similar to the ones discussed in the previous section using time lagged values, parents and peer information as instruments for each of the 25 leisure activities, However, models were very complex and gave us convergence problems. In a second experiment we followed a two-step approach. In the first step, instruments were used to estimated predicted values of leisure activities. Then, these predicted values were used to estimate SEM models in a second step finding robust results to those reported in the previous section.

[Figure 3 near here]

Estimation results of these models are almost identical to those reported above and, for conciseness are not shown here. However, the economic interpretation of these results is very different. More specifically, the total effect of increasing exercise by one hour per week obtained from the direct effect are all statistically significant and of magnitude 0.33, 10.35 and 2.69 on SAA, OAP and cognition respectively, which are the same as the total effects in the baseline model. Moreover, exercise still increases the amount of time devoted to study and culture activities while it decreases the time devoted to harmful habits and social media activities. Although we cannot infer causality in this case, the former two habits are positively correlated with academic output while this correlation is negative for the latter two ones.

A second extension regards the estimation of the specific effect of physical exercise on different academic subjects: Math, Chinese and English. This is relevant as different subjects could be related to students' different abilities. Figure 4 shows the path model for this analysis, which is similar to Figure 2 but replaces the response variable with each subject. Thus, we use the information reported by SAA and OAP in each of the three subjects to estimate three SEM models with the following structure

[Figure 4 near here]

Table 6 shows the results from this estimation. The total effect of increasing exercise by one hour per week, obtained from the sum of direct effect and indirect effect, is significant and positive for each of the three subjects under analysis. However, the direct impact of exercise is significant only for math and English, not for Chinese.

[Table 6 near here]

In our last experiment, we consider the impact of different exercise frequencies on academic performance and cognition. More specifically, we disaggregate the treatment variable in the baseline model (Exercise) into three different treatment variables. These variables indicate whether students participate in physical exercise two days or more, four days or more, or six days or more per week. Table 7 shows main estimation results. All levels of exercise exert both significantly positive direct and indirect effects on SAA and Cognition. However, participating in exercise more than 3 days per week has a significant direct effect on OAP only through different leisure activities. This might due to students who devote a lot of time to physical exercise lacking enthusiasm in study curriculums at school. A remarkable result is that the magnitude is bigger when students practice exercise two days or more per week compared to other frequencies. However, this result needs to be interpreted with caution as the models do not fit well.

[Table 7 near here]

7. Concluding remarks

Using comprehensive information from Chinese school students, this paper explores the channels through which physical exercise affects academic outcomes.

We find that our treatment exerts a significantly positive effect on academic outcomes both directly and indirectly by incentivising habits which positively correlate with academic outcomes while discouraging other habits where there is negative correlation. This result is robust to different measures of academic outcomes regarding subjective academic assessment, objective academic performance and cognition. Results are also general to different academic subjects with Chinese the only exception where exercise exerts only a positive indirect effect, by affecting leisure activities. We also found that the positive effect of physical activity on academic outcome is more evident when it is practiced with low frequency (2 days a week). This suggests that there is an optimal amount of physical activity and exceeding this optimal amount could distract students' attention making the improvement in academic outcome less evident.

Although the estimated individual impacts are of small magnitude, they can still have an important aggregate impact in a populous country like China. Policy decisions must confront total, rather than individual, costs and benefits of incentivising physical exercise in schools. Moreover, the contribution of physical exercise to promote positive leisure activities and reduce passive and harmful habits could be deemed as politically relevant. Thus, an accurate policy analysis should take into account the effect of exercise not only on academic outcomes but also on a big group of variables such as, for example, crime, mental health and life expectancy. A joint policy evaluation of all these impacts should be worthwhile to consider in a future research.

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APPENDIX

Table A1 Definition and factor loadings for observed items

Constructs	Variables	Definition	Factor loading		
			SAA	OAP	Cognition
SAA	Math	Difficulty of learning Mathematics	1		
	Chinese	Difficulty of learning Chinese	0.971***		
	English	Difficulty of learning English	1.925***		
OAP	Mathscore			1	
	Chinesescore			0.588***	
	Englishscore			1.022***	
Harmful habits	Curse	Frequency of cursing or saying swearwords	1	1	1
	Quarrel	Frequency of quarreling with others	0.969***	0.980***	0.984***

	Fight	Frequency of having a fight with others	0.997***	1.031***	1.033***
	Bully	Frequency of bullying the weak	0.580***	0.603***	0.607***
	Violent	Frequency of having a violent temper	0.934***	0.957***	0.964***
	Notconcentrate	Frequency of unable to concentrate on one thing	0.898***	0.880***	0.865***
	Skip	Frequency of skipping classes, being absent, or truanting	0.418***	0.438***	0.439***
	Copy	Frequency of copying homework from others, or cheating in exams	1.005***	1.031***	1.027***
	Smokeordrink	Frequency of smoking, or drinking alcohol	0.586***	0.609***	0.612***
	Netbar	Frequency of going to net bars or video arcade	0.760***	0.792***	0.793***
	Undersleep	Whether or not a student is under sleep, which is less than 8 hours, every night	0.038***	0.032**	0.032**
Visual media	Time_tv1	Time spent on watching TV on weekdays	1	1	1
	Time_net1	Time spent on surfing the Internet or playing video games on weekdays.	1.541***	1.451***	1.332***

	Time_tv7	Time spent on watching TV on weekends	0.512***	0.536***	0.559***
	Time_net7	Time spent on surfing the Internet or playing video games on weekends.	1.389***	1.238***	1.080***
Study	Time_teacher1	Amount of time doing homework assigned by teachers on weekdays	1	1	1
	Time_teacher7	Amount of time doing homework assigned by teachers on weekends	0.817***	0.820***	0.816***
	Time_pa1	Amount of time doing homework assigned by parents or cram school on weekdays	2.322***	2.301***	2.348***
	Time_pa7	Amount of time doing homework assigned by parents or cram school on weekends	1.614***	1.597***	1.613***
	Time_cram1	Amount of time taking schoolwork related cram school courses on weekdays	2.742***	2.725***	2.830***
	Time_cram7	Amount of time taking schoolwork related cram school courses on weekends	3.495***	3.504***	3.638***

Culture activities	Museum	Frequency of vising museums, zoos, science museums, etc. alone or with schoolmates	1	1	1
	Museum_family	Frequency of vising museums, zoos, science museums, etc. with family members	0.741***	0.722***	0.723***
	Film	Frequency of watching films, shows, sports games, etc. alone or with schoolmates	1.257***	1.260***	1.264***
	Film_family	Frequency of watching films, shows, sports games, etc. with family members	0.946***	0.941***	0.946***

* p<0.1 ** p<0.05 *** p<0.01

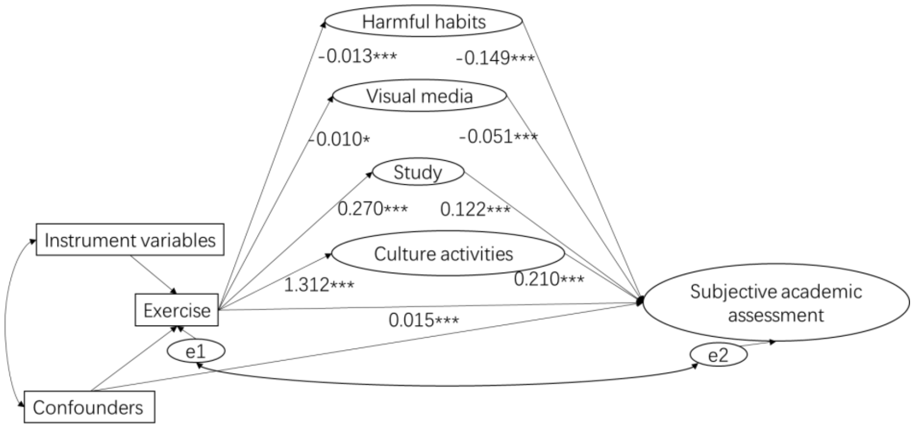

Figure A1 Estimated impact of exercise on SAA

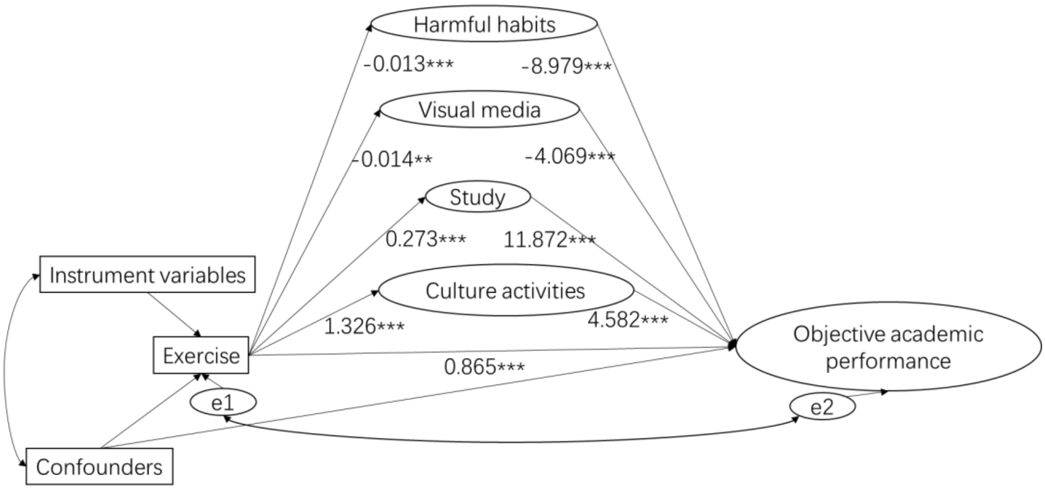

Figure A2 Estimated impact of exercise on OAP

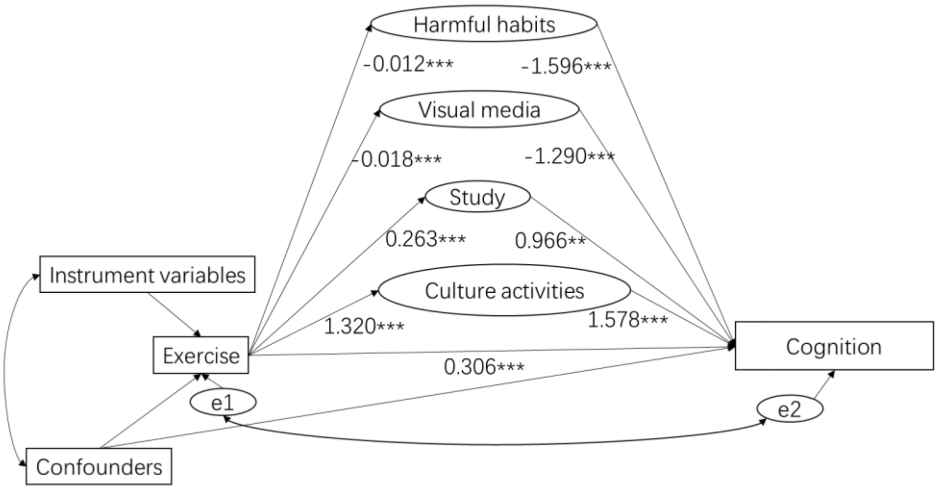

Figure A3 Estimated impact of exercise on cognition

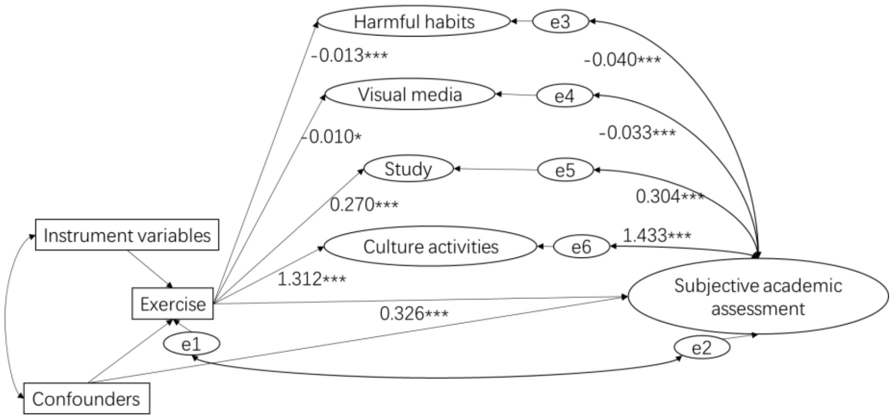

Figure A4 Estimated impact of exercise on SAA by considering the correlation between activities and SAA

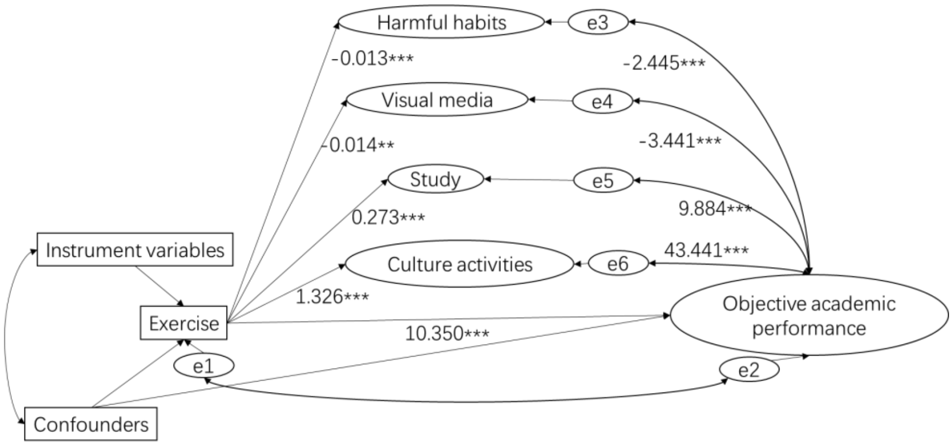

Figure A5 Estimated impact of exercise on OAP by considering the correlation between activities and OAP

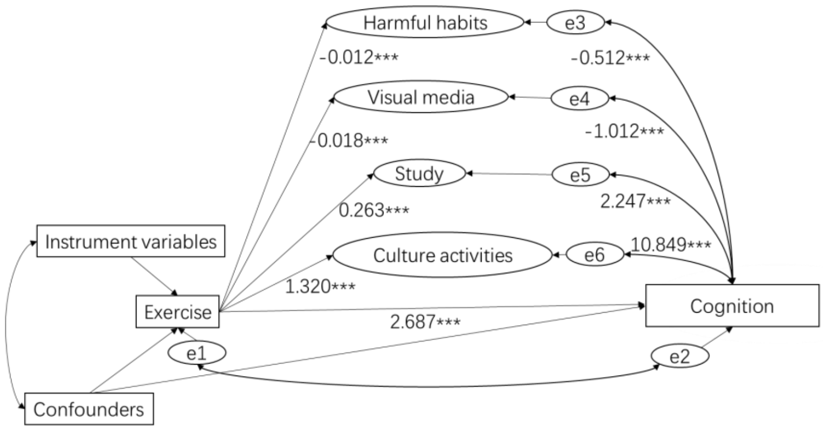

Figure A6 Estimated impact of exercise on cognition by considering the correlation between activities and cognition

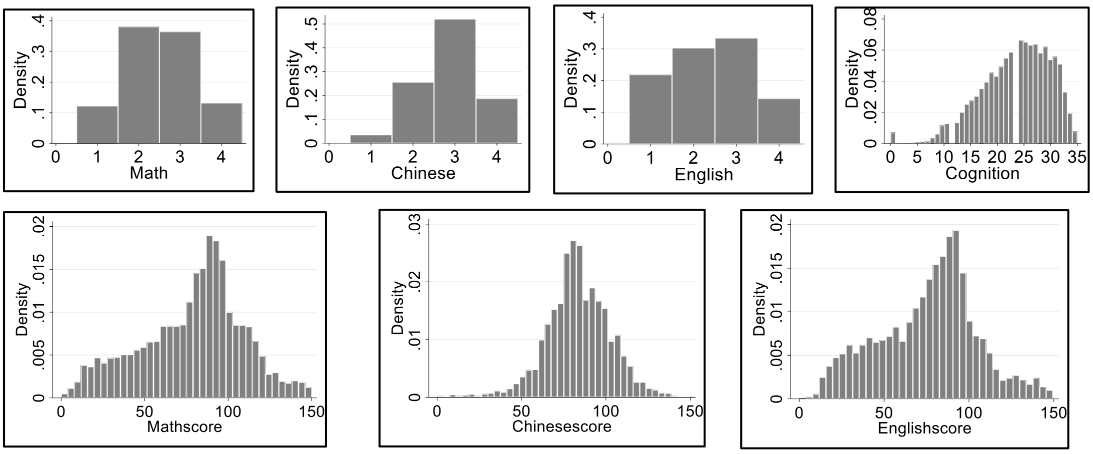

Figure 1 Distribution of the dependent variables

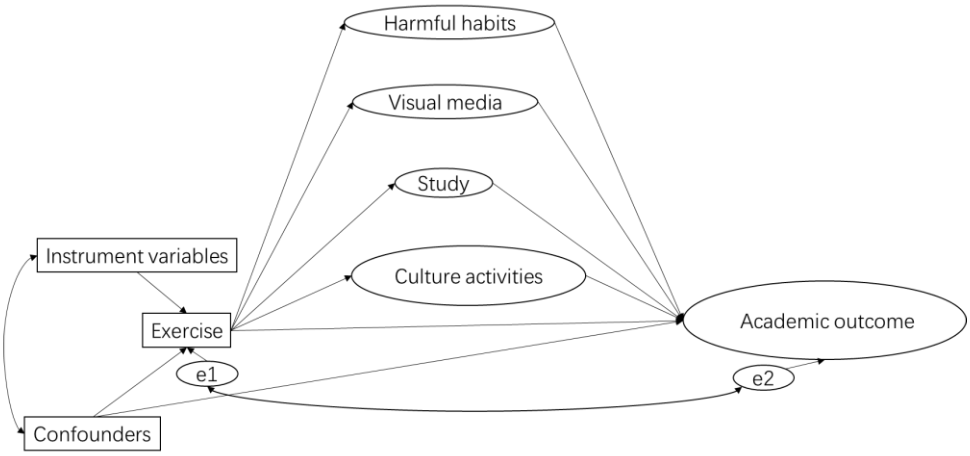

Figure 2 Path model for relationships between exercise and academic outcome.

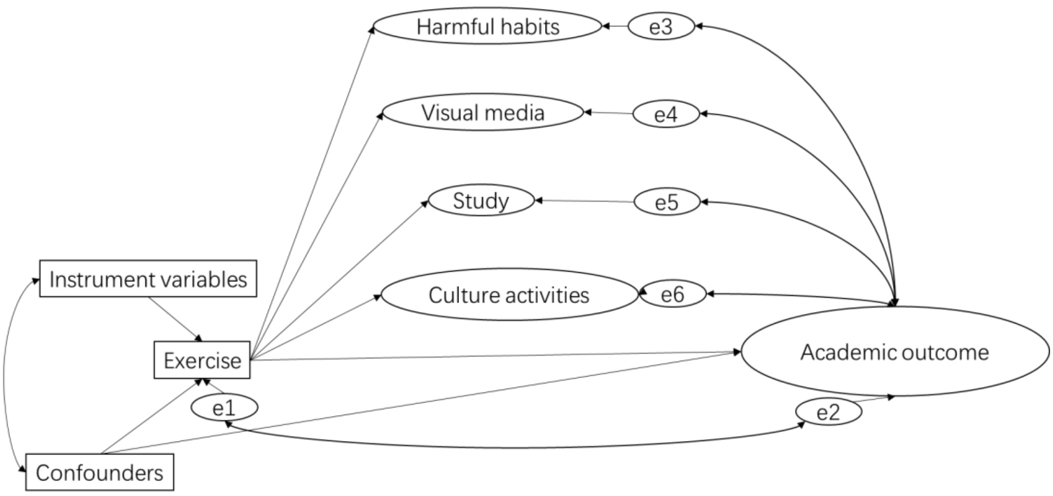

Figure 3 Path model for relationships between exercise and academic outcome considering the correlations between mediators and academic outcome

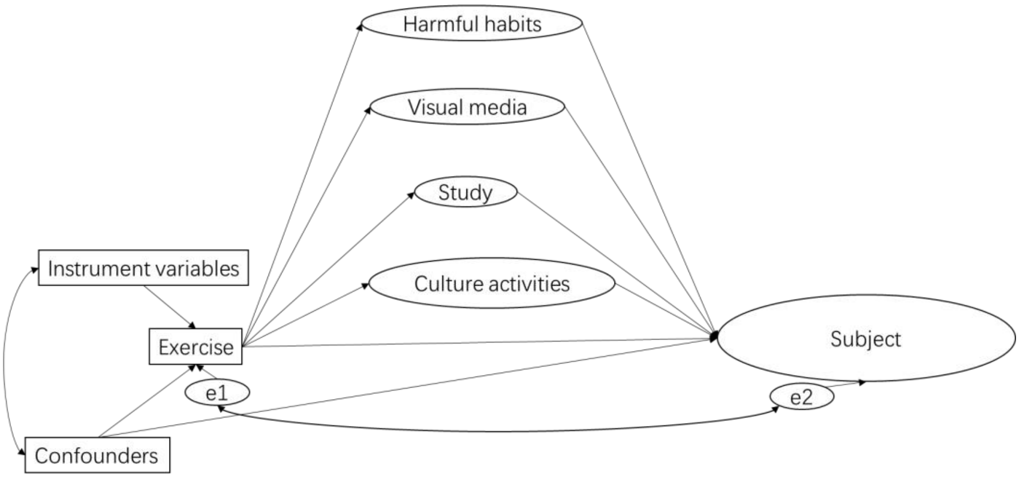

Figure 4 Path model for relationships between exercise and each subject considering the correlations between mediators and each subject

Table 1 Summary statistics (number of observations= 7002)

	(1)	(2)	(3)	(4)
Variable	Mean	Standard. Deviation.	Minimum	Maximum
SAA				
Math	2.507	0.871	1	4
Chinese	2.861	0.752	1	4
English	2.402	0.982	1	4
OAP				
Mathscore	78.49	30.64	0	150
Chinesescore	83.39	18.96	0	142.5
Englishscore	75.91	28.99	0	149.5
Cognition	23.63	6.453	0	35

Time allocation

Harmful habits				
Curse	2.210	0.978	1	5
Quarrel	1.820	0.866	1	5
Fight	1.322	0.680	1	5
Bully	1.132	0.477	1	5
Violent	1.856	0.974	1	5
Notconcentrate	2.213	1.020	1	5
Skip	1.074	0.380	1	5
Copy	1.470	0.766	1	5
Smokeordrink	1.094	0.445	1	5
Netbar	1.180	0.594	1	5
Undersleep	0.379	0.485	0	1
Visual media				
Time_tv1	2.419	1.371	1	6
Time_net1	2.200	1.395	1	6
Time_tv7	2.744	1.177	1	6
Time_net7	2.586	1.323	1	6
Study				
Time_teacher1	3.541	1.129	1	6
Time_pa1	1.772	1.024	1	6
Time_cram1	1.603	1.239	1	6
Time_teacher7	3.028	1.018	1	6

Time_pa7	1.616	0.830	1	6
Time_cram7	1.709	1.155	1	6
Culture activities				
Museum	2.156	1.281	1	6
Film	2.473	1.489	1	6
Museum_family	2.090	1.060	1	6
Film_family	2.133	1.181	1	6
Treatment variable				
Exercise	3.421	1.938	0	7
Predisposing variables				
Age	13.89	0.852	12	19
Male	0.501	0.500	0	1
Ethnicity	0.920	0.272	0	1
Enabling variables				
Agricultura hukou	0.516	0.500	0	1
Income	2.956	0.597	1	5
Poor health	0.060	0.237	0	1

Table 2 Determinants of Exercise

	SAA	OAP	Cognition
Lag exercise in weekend	0.001***	0.001***	0.001***
	(7.57)	(7.53)	(7.34)

Lag exercise hobby	0.059***	0.060***	0.057***
	(3.76)	(3.76)	(3.58)
Swimming pool	0.209***	0.188***	0.219***
	(4.59)	(3.96)	(4.73)
Lag height	0.014***	0.014***	0.014***
	(10.52)	(10.48)	(10.59)
Age	-0.014	-0.013	-0.013
	(-1.58)	(-1.45)	(-1.43)
Male	-0.148***	-0.147***	-0.145***
	(-8.35)	(-8.35)	(-8.27)
Ethnicity	0.049*	0.050*	0.051*
	(1.79)	(1.82)	(1.84)
Agriculture hukou	-0.374***	-0.374***	-0.375***
	(-13.58)	(-13.52)	(-13.61)
Income	0.270***	0.269***	0.271***
	(12.83)	(12.78)	(12.88)
Poor health	-0.016	-0.016	-0.016
	(-0.53)	(-0.53)	(-0.54)
Constant	0.772***	0.757***	0.726***
	(2.97)	(2.91)	(2.78)
#Obs.	7002	7002	7002

t statistics in parentheses

* p<0.1 ** p<0.05 *** p<0.01

Table 3 Effect of exercise on SAA, OAP and cognition

	SAA	OAP	Cognition
Exercise			
Direct effect	0.015***	0.865***	0.306***
	(5.03)	(5.26)	(7.32)
Indirect effect	0.311***	9.485***	2.381***
	(7.00)	(4.13)	(4.27)
Total effect	0.326***	10.350***	2.687***
	(7.32)	(4.49)	(4.80)
CFI[a]	0.905	0.914	0.910
RMSEA[b]	0.038	0.038	0.038
#Obs.	7002	7002	7002

t statistics in parentheses

* p<0.1 ** p<0.05 *** p<0.01

[a] CFI indicates comparative fit index

[b] RMSEA indicates root mean squared error of approximation

Table 4 Direct effect of exercise and mediators on SAA, OAP and cognition

	SAA	OAP	Cognition

Exercise	0.015***	0.865***	0.306***
	(5.03)	(5.26)	(7.32)
Harmful habits	-0.149***	-8.979***	-1.596***
	(-9.24)	(-9.68)	(-7.02)
Visual media	-0.051***	-4.069***	-1.290***
	(-5.76)	(-8.00)	(-10.06)
Study	0.122***	11.872***	0.966**
	(4.01)	(6.97)	(2.31)
Culture activities	0.210***	4.582***	1.578***
	(7.99)	(3.14)	(4.38)
Age	-0.054***	-3.798***	-0.691***
	(-7.79)	(-10.24)	(-7.42)
Male	-0.116***	-8.042***	0.689***
	(-10.24)	(-12.64)	(4.33)
Ethnicity	0.031	-4.264***	-0.369
	(1.49)	(-3.68)	(-1.26)
Agriculture hukou	-0.008	-3.164***	-0.087
	(-0.44)	(-2.87)	(-0.32)
Income	0.058***	0.844	0.424**
	(3.94)	(1.01)	(2.04)
Poor health	-0.060***	0.177	0.042
	(-2.70)	(0.14)	(0.13)

#Obs.	7002	7002	7002

t statistics in parentheses

* p<0.1 ** p<0.05 *** p<0.01

Table 5 Effect of exercise on time allocation of different groups of activities

	SAA	OAP	Cognition
Harmful habits			
Exercise	-0.013***	-0.013***	-0.012***
	(-4.01)	(-3.95)	(-3.92)
Visual media			
Exercise	-0.010*	-0.014**	-0.018***
	(-1.95)	(-2.41)	(-2.95)
Study			
Exercise	0.270***	0.273***	0.263***
	(10.27)	(10.16)	(10.10)
Culture activities			
Exercise	1.312***	1.326***	1.320***
	(13.83)	(13.74)	(13.83)
#Obs.	7002	7002	7002

t statistics in parentheses

* p<0.1 ** p<0.05 *** p<0.01

Table 6 Effect of exercise on each subject

	Math†	Chinese†	English†
Exercise			
Direct effect	0.035***	0.005	0.031***
	(6.99)	(1.61)	(5.92)
Indirect effect	0.241 ***	0.221***	0.527***
	(3.65)	(4.11)	(6.86)
Total effect	0.276***	0.226***	0.558***
	(4.15)	(4.19)	(7.26)
CFI(a)	0.907	0.910	0.911
RMSEA(b)	0.038	0.037	0.038
#Obs.	7002	7002	7002

t statistics in parentheses

* p<0.1 ** p<0.05 *** p<0.01

† A latent variable generated by subjective and objective measurements for each subject.

(a) CFI indicates comparative fit index

(b) RMSEA indicates root mean squared error of approximation

Table 7 Effect of different frequencies of exercise on SAA, OAP and cognition

	SAA	OAP	Cognition

Exercise two days or more per week			
Direct effect	0.645***	13.408*	6.602***
	(4.69)	(1.66)	(3.33)
Indirect effect	0.074***	3.090***	0.646***
	(10.77)	(9.30)	(8.44)
Total effect	0.719***	16.500**	7.248***
	(5.23)	(2.06)	(3.67)
CFI[(a)]	1	1	1
RMSEA[(b)]	NA	NA	NA
Exercise four days or more per week			
Direct effect	0.338***	0.606	4.204***
	(5.07)	(0.16)	(4.47)
Indirect effect	0.042***	1.425***	0.300***
	(8.54)	(5.79)	(5.39)
Total effect	0.380***	2.031	4.503***
	(5.71)	(0.53)	(4.82)
CFI[(a)]	0.878	0.889	0.881
RMSEA[(b)]	0.043	0.043	0.044

Exercise six days or more per week			
Direct effect	0.425***	2.826	4.200***
	(4.71)	(0.54)	(3.23)
Indirect effect	0.045***	1.238***	0.216***
	(6.61)	(3.57)	(2.78)
Total effect	0.470***	4.064	4.417***
	(5.22)	(0.79)	(3.42)
CFI[(a)]	1	1	1
RMSEA[(b)]	NA	NA	NA
#Obs.	7002	7002	7002

t statistics in parentheses

* $p<0.1$ ** $p<0.05$ *** $p<0.01$

[(a)] CFI indicates comparative fit index

[(b)] RMSEA indicates root mean squared error of approximation