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Fitness Change and Subsequent Academic Performance in Adolescents

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ABSTRACT

BACKGROUND: This study examined the association between fitness change and subsequent academic performance in Taiwanese schoolchildren from 7th grade to 9th grade.

METHODS: The 7th graders from 1 junior high school district participated in this study (N = 669). Academic performance was extracted from school records at the end of each grade. Cardiovascular (CV) fitness, sit-and-reach flexibility, bent-leg curl-ups, and height and weight for calculating body mass index (BMI) were assessed at the start of each grade.

RESULTS: The results showed that improvement in CV fitness, but not muscular endurance or flexibility, is significantly related to greater academic performance. A weak and nonsignificant academic-BMI relationship was seen.

CONCLUSION: CV fitness exhibits stronger longitudinal associations with academic performance than other forms of fitness or BMI for adolescents.

Keywords: physical fitness; cardiovascular fitness; academic achievement; school performance; school achievement.

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There is a possibility that maintaining a high level of physical fitness might be helpful for improving academic performance in schoolchildren. This belief is supported by a meta-analysis demonstrating a significant positive relationship between physical activity and cognitive functioning in children (effect size = .32).[1] This fitness-academic performance relationship is especially interesting as students spend large amounts of their time at school working in the cognitive domain. Although several studies have found a positive link between physical fitness and academic performance,[2-5] the focus has mainly been on cardiovascular (CV) fitness.[6] Results for the association among other forms of fitness (muscular strength, flexibility, and body composition) and academic performance have been inconsistent,[7-9] suggesting a need for further exploration.

Additionally, there is little longitudinal work on the fitness-academic performance relationship, with 1 review showing that all studies were cross sectional and correlational in design.[6] These cross-sectional studies are unable to establish the causal direction of the relationship between physical fitness and academic performance. Longitudinal data controlling potential confounders (eg, sex and socioeconomic status [SES]) only appear in 1 published prospective study.[10] London and Castrechini[10] examined the association between academic performance and overall physical fitness from 4th to 7th (N = 1325) and 6th to 9th grades (N = 1410) in the United States. The results indicated that a combination of fitness tests was more predictive of academic performance than any one test. Students who were persistently fit had higher academic scores than those who were persistently unfit, suggesting improved fitness is associated with increased academic performance over time. There is also 1 longitudinal study focusing on the association of CV fitness with cognitive function.[11] The findings

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showed that those with increased CV fitness between 15 and 18 years of age had higher intelligence scores than those with decreased fitness. This suggests that CV fitness change is positively related to cognitive function for schoolchildren.

During adolescence, physical fitness may change with age or physical maturation. Changes in fitness may be systematically related to time and this may confound relationships with academic performance. Advanced analytical techniques are available for assessing change that is systematically related to the passage of time.[12] For instance, latent growth curve (LGC) analysis can provide growth curve interpretations and individual trajectories over time.[13-15]

Furthermore, previous reviews have shown that no study was conducted on Asian children.[6] The cultural differences might affect this fitness-academic performance relationship. For example, there is a strong tradition and emphasis on education and attending additional academic sessions for Asian schoolchildren often at the expense of participation in active pursuits and sports.[16,17] These academic-related behaviors, requiring sitting down, may restrict time available for physical activity and effect children's fitness levels. Examining the association of physical fitness on academic development would provide information for educational policies on school curriculum to promote learning among schoolchildren.

To address these concerns, this study was designed to explore the longitudinal associations of different forms of fitness on academic performance among adolescents. Specifically, this study applied regression and LGC analyses with 3-wave data on adolescent fitness and academic performance to fill the gap in the relationship between changes of fitness and subsequent academic performance.

METHODS

Participants

This study was conducted in 1 high school district in Taichung City, the third largest city in Taiwan. All students who enrolled in the school at 7th grade (N = 723) were invited to take part in this study. Before collecting the data, the research team had meetings and discussions with the Principal, Director of Student Affairs, and Chairman of Parents' Association of the school. Any student who moved out of the district, students with disability, or students who did not return the consent form were excluded from the study. The final sample was 669 with 352 boys and 317 girls (mean age grade = 14.6). Data were collected on 6 occasions across 3 school years. The 6 occasions were Fall of 2008 (beginning of 7th grade: baseline demographic data and fitness data), Summer of 2009 (end of 7th grade: academic data), Fall of 2009 (beginning of 8th grade: fitness data), Summer of 2010 (end of 8th grade: academic data), Fall of 2010 (beginning of 9th grade: fitness data), and Summer of 2011 (end of 9th grade: academic data).

Measures

Academic performance. Academic performance was the outcome variable, which was measured as the mean score of Language, Mathematics, Science, and Social Studies. All students took exactly the same tests in school and the scores which ranged from 0 to 100 were extracted from the school records at the end of each grade.

Fitness. The fitness tests were completed during physical education (PE) classes in fall each year, and administered by the Chief of PE to ensure consistency from 7th grade to 9th grade. The fitness tests included 4 measures: (1) 1600(boys)/800(girls)-meter run was used to assess CV endurance. It is one of the most widely used measures for determining aerobic capacity in children.[2,5,10,18] Acceptable validity and reliability have been established in previous research;[9] (2) The standardized sit-and-reach test was used to measure the lower back and hip joint flexibility; (3) The number of bent-leg curl-ups attained in 1 minute was used to test abdominal muscle strength and endurance; and (4) Body mass index (BMI) was obtained through measured height and weight by the school nurse.

The raw scores of the 1600(boys)/800(girls)-meter run, sit-and-reach test, and bent-leg curl-ups were converted into a percentile rank (PR) based on normative data at each age and for each sex in Taiwan. Then, the above fitness results were grouped into 2 levels: "pass" and "fail." Those who had fitness PR less than the 25th were classified as "fail," which was suggested by the Taiwan Ministry of Education as "needs improvement." Changes in fitness levels were created based on the difference between each child's scores in 7th grade and 9th grade. Four groups were categorized: "pass-pass" (pass at 7th grade and 9th grade), "pass-fail" (pass at 7th grade but fail at 9th grade), "fail-pass" (fail at 7th grade but pass at 9th grade), "fail-fail" (fail at 7th grade and 9th grade).

Weight and height were converted to BMI and children were categorized as underweight, normal weight, overweight, and obese using age and gender-specific criteria suggested by the Taiwan Ministry of Education.[19] Both the overweight and obesity figures were combined for analyses and subsequently referred to as "overweight/obesity." Then, a weight change variable was created based on an individual's weight status difference between 7th grade and 9th grade. Six groups were categorized as "always normal" (normal weight at 7th grade and 9th grade), "always underweight" (underweight at 7th grade and 9th grade), "always overweight/obese" (overweight/obese at 7th grade and 9th grade), ''became normal'' (not normal weight at 7th grade but was normal weight at 9th grade), ''became overweight/obese'' (not overweight/obese at 7th grade but was overweight/obese at 9th grade), and ''became underweight'' (not underweight at 7th grade but was underweight at 9th grade).

Demographic characteristics. Demographic variables collected in this study were based on previous literature. Variables included in most studies were age,[2,8,9] sex,[2,8-10,20] SES/parents' education/meal price status,[2,10,18,20] and ethnicity.[2,10] In this study, sex and parents' SES were collected at 7th grade. These factors have been shown to be associated with children's academic performance.[21,22] SES was assessed by parents' occupation and education based on Hollingshead's ''Two Factor Index of Social Position,'' modified to fit Taiwanese society by Lin.[23] Parents' occupation and education were both divided into 5 levels and scored from 5 to 1. The SES score was obtained with occupational score $\times$ 7 + educational score $\times$ 4.[24] Scores were then grouped into tertiles (low, moderate, and high). The child's age was not considered since all participants were 7th graders in 2008-2009 school year and 9th graders in 2010-2011 school year and grade in Taiwan is solely determined by birthdate. As for the ethnicity, the majority of junior high school students in Taiwan were Chinese (aborigines 2.9%, new immigrants 1.1%, and Chinese 96.0% during 2008-2009 school year; Department of Statistics, Taiwan Ministry of Education, www.edu.tw/statistics/). Thus, ''ethnicity'' was not included in the demographic variables.

Statistical Analysis

Descriptive statistics. Variable means and percentages were calculated for sex and academic performance at 7th grade. The differences were tested using χ^2, *t* test, or analysis of variance (ANOVA).

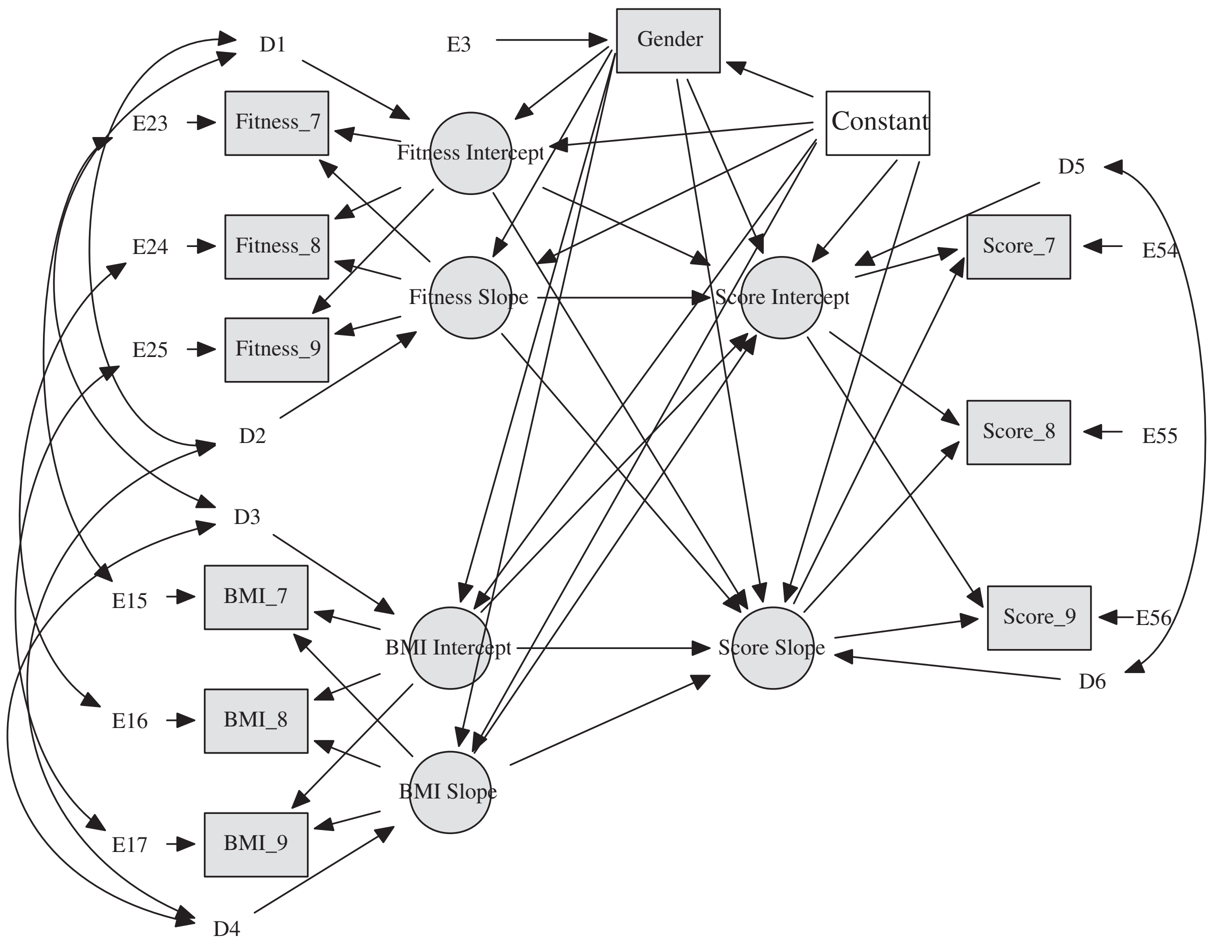
Univariate and multivariate linear regressions. To estimate the relationship between change in fitness levels and academic performance, univariate and multivariate linear regressions were conducted. The dependent variable was academic performance at 9th grade. The independent variables, recorded as dummy variables, were changes of fitness levels and weight status (2 waves: 7th and 9th grade data) controlling for sex and SES. Variables showing significant relationships with academic performance in the univariate model were then entered into a multivariate model simultaneously. The above analyses were performed with SPSS 16.0 for Windows (IBM, Armonk, NY).

LGC analysis. LGC, a powerful technique for longitudinal analyses, can reduce error by estimating growth parameters and their effects in one model.[25] It permits straightforward examination of individual change over time and variability in intraindividual change.[26] A model of the LGC is a 2-stage process. The first stage is viewed as a ''within-person'' model (level 1 or called a measurement model) representing individual change over time. This level modeling intraindividual change comprises 2 growth parameters: (1) an intercept parameter representing an individual's score on the variable of interest at time 1; (2) a slope parameter reflecting the individual's rate of change over time. Second, the level 2 model is regarded as a ''between-person model'' (or called a structural model) estimating inter-individual differences in change. This level is limited to the regression paths linking the constant to the intercept and slope factors and their related residuals.[14,15,27] Chi-square test statistics, the normed fit index (NFI $>$ .95), the comparative fit index (CFI $>$ .95), and the root mean square error of approximation (RMSEA $<$. 08) with 90% confidence interval are the indices of model fit.[13,15,28]

For this study, the first step of LGC is to analyze the pattern of changes in fitness and in academic performance across time. The second step is to examine the association between changes in fitness and changes in academic performance. Fitness was viewed as a time-varying predictor of change to control for adolescent concurrent status of fitness and academic performance in the 3 waves. After regression analyses, only 2 forms of physical fitness (CV fitness and weight status) were found to be related to academic performance. Thus, a conditional model of LGC was employed to further explore the direct effects of initial status and change factors for CV fitness and weight status on initial status and change factors for academic scores (3 waves) controlling for sex. Changes in CV fitness and weight status were examined as continuous variables with fitness PR and BMI in the LGC model.

Figure 1 presents the model for the initial status and slope in CV fitness and BMI on academic performance. The left side of the figure indicates the individual growth model for CV fitness and BMI. Each variable has 2 latent growth parameters, intercept and slope. The right side of the figure denotes the individual growth model for academic performance. The between-person model examines the relationship of changes in CV fitness and BMI on changes in academic performance. The coefficients of regression paths in this article are presented as standardized parameter estimates as these values can be interpreted easily.[29] Univariate normality was checked. The values of skewness and kurtosis did not exceed the criteria of extreme skewness ($>$3) or kurtosis ($>$8).[28] The analyses were conducted using EQS 6.1 with full-information maximum likelihood estimation, which is suggested to be an optimal method for the treatment of missing data.[29]

Figure 1. **Latent Growth Model of CV Fitness and BMI on Academic Performance From 7th Grade to 9th Grade**



RESULTS

Descriptive Statistics

Table 1 provides descriptive statistics by sex and academic performance at grade 9 for SES and all fitness components. About one third of boys and one half of girls remained normal weight. More than one fourth of boys and 18% of girls persisted as overweight or obese. Less than 4% of boys and girls became overweight or obese. The prevalence of becoming underweight was 4% for girls and 7% for boys. No significant sex difference was found in SES, or changes in CV fitness, flexibility, and muscular strength ($p = .072$, .209, .831, and .061, respectively). Significant associations were found in sex, SES, changes in weight status, and cardiovascular fitness with academic performance ($p < .001$, $< .001$, .003, and .001, respectively).

Univariate and Multivariate Linear Regressions

The association of fitness change between 7th and 9th grade and academic performance at 9th grade are shown in Table 2. Results from the univariate regression model showed no significant relationship between changes in flexibility and muscular strength and academic scores ($p = .488$ and .158, respectively). Sex, SES, weight status change, and CV fitness change were significantly associated with academic performance ($p < .001$, $< .001$, .003, and .001, respectively). These 4 variables were, therefore, entered into the simultaneous multiple regression model to explore predictors of academic performance and determine the proportion of variance explained by these variables. Similar results were found between univariate and multivariate models among these variables (Table 2). Those who persisted in being underweight or who became underweight showed worse academic scores than those who were consistently normal weight ($p = .027$ and .018, respectively). Those who passed both CV fitness tests and those who failed in the first test but passed in the second had higher academic scores than those who went on to fail both tests ($p = .006$ and .017, respectively). However, only a modest total amount of variance in academic performance (17.3%) was explained by these variables.

Table 1. **Descriptive Statistics by Sex and Academic Performance**

Variables	Sex			Academic Score (9th Grade)	
	Boys	Girls	p	Mean (SD)[†]	p
Sex (%)					<.001
Boys (N = 352)	52.6			68.2 (14.6)	
Girls (N = 317)		47.4		74.4 (12.4)	
SES (%)			.072		<.001
Low	45.5	54.4		70.3 (13.0)	
Moderate	40.4	32.1		71.9 (13.3)	
High	14.0	13.6		80.2 (11.4)	
Weight status change (%)			.004		.003
Always normal	34.9	50.0		73.7 (13.6)	
Always underweight	16.8	11.7		63.3 (12.7)	
Always overweight/obese	26.3	18.2		71.7 (14.0)	
Became normal	11.1	12.4		72.8 (13.7)	
Became overweight/obese	3.5	3.3		69.8 (15.3)	
Became underweight	7.3	4.4		65.7 (13.7)	
1600/800-m run (%)			.209		.001
Pass-Pass	54.5	59.4		72.3 (13.8)	
Pass-Fail	17.8	18.8		67.8 (14.0)	
Fail-Pass	10.3	10.7		74.2 (14.9)	
Fail-Fail	17.5	11.1		67.4 (14.0)	
Sit-and-reach (%)			.831		.488
Pass-Pass	78.7	78.1		71.0 (14.1)	
Pass-Fail	7.0	8.9		69.2 (14.0)	
Fail-Pass	6.7	5.9		73.6 (15.0)	
Fail-Fail	8.0	7.1		69.4 (13.9)	
Bent-leg Curl-ups (%)			.061		.158
Pass-Pass	69.3	65.0		71.6 (13.5)	
Pass-Fail	7.0	13.9		68.4 (14.7)	
Fail-Pass	12.3	10.9		71.6 (13.6)	
Fail-Fail	11.3	10.2		68.1 (17.1)	

[†]SD: standard deviation.

As some previous studies separated school subjects (mainly mathematics and language) to examine the relationship of fitness with academic performance, additional regression models were used with mathematics and language as the dependent variables. The results (not shown) revealed that in both univariate and multivariate regressions, no significant association was seen between any fitness component and school subject areas separately (all $p > .05$).

Latent Growth Curve (LGC)

The results from the LGC demonstrated acceptable model fit to the data ($\chi^2(19) = 59.10$, $p < .001$; NFI = .99; CFI = .99; RMSEA = .07, 90% CI: .05 to .09). Findings related to the intercept revealed the average score for CV fitness was 51.29 ($z = 32.35$). Overall, CV fitness changed significantly from 7th grade to 9th grade (slope = −5.69; $z = -4.31$). The negative sign for the value of the CV fitness slope is indicative of substantial decrease in the average rate of change in CV fitness among participants during this period. The mean score for BMI was 19.82 ($z = 86.59$) and there was a significant increase in the average change in BMI (slope = .33; $z = 5.22$). The average score for academic performance was 70.43 ($z = 7.30$) and the average change in academic score decreased significantly (slope = −12.17; $z = -2.17$; Table 3).

Results from the regression paths showed that the CV fitness intercept was significantly related to the academic intercept ($z = 3.17$), suggesting that initially higher levels of CV fitness were associated with initially better academic performance. The positive sign between the CV fitness intercept and the academic slope illustrated that adolescents with better CV fitness at baseline showed a greater increase in academic performance from 7th to 9th grade than children with lower CV fitness at baseline. However, the effect was weak and not statistically significant ($z = 1.32$). The path coefficient leading from the CV fitness slope to the academic slope was significant, showing the rate of change in CV fitness was related to the rate of change in academic performance over this period ($z = 6.98$).

On the other hand, the direct effects from BMI to academic performance in both initial status and change factor were weak and not statistically significant (BMI intercept-academic intercept: $z = .20$; BMI intercept-academic slope: $z = 121$; BMI slope-academic slope: $z = -1.33$).

DISCUSSION

In this study, we collected 3-wave data and conducted several statistical analyses to examine the relationships between various components of physical fitness and subsequent academic performance over 3 school years among adolescents. Researchers have suggested that longitudinal data produce valuable information about individual differences with respect to change over time and the richness of such data increases with the number of waves of data collection.[26]

The results from the regression analyses revealed that changes in muscle strength and flexibility fitness were unrelated to academic performance, which is consistent with previous cross-sectional studies.[8,18] A longitudinal study also showed no association between muscle strength and cognitive performance in boys between 15 and 18 years of age.[11] However, this finding contrasts with prior cross-sectional research demonstrating associations between muscular power, flexibility, and academic performance in 7961 Australian schoolchildren aged 7 to 15[7] and in 254,743 American schoolchildren (grades 3-11).[4] This inconsistency may be due to the large sample size in these studies.

Several cross-sectional studies have reported that CV fitness is positively related to overall academic performance or performance in particular subjects in children and the relationship might be stronger for math than reading (or English).[5,8,9,18] A longitudinal study examining the fitness-cognition relationship also

Table 2. **Univariate and Multivariate Regression Estimates of the Relationship Between Fitness Change and Academic Performance**

	Univariate Model				Multivariate Model			
Variables	R^2	B (SE)	t	p	R^2	B (SE)	t	p
Sex†	4.9			<.001	17.3			<.001
Boys		−6.22 (1.07)	−5.83	<.001		−7.20 (1.20)	−6.06	<.001
SES‡	6.0			<.001				
Low		.82 (1.13)	.73	.468		.35 (1.25)	.28	.781
High		10.74 (1.71)	6.30	<.001		10.02 (1.91)	5.24	<.001
Weight status change§	3.0			.003				
Always underweight		−5.37 (1.72)	−3.12	.002		−3.87 (1.74)	−2.22	.027
Always overweight/obese		−2.05 (1.47)	−1.39	.164		.16 (1.60)	.10	.921
Became normal		−.90 (1.86)	−.48	.629		−.23 (1.89)	−.12	.903
Became overweight/obese		−3.93 (3.18)	−1.24	.216		.91 (3.26)	.28	.780
Became underweight		−8.03 (2.47)	−3.26	.001		−6.08 (2.55)	−2.38	.018
1600/800-m run	2.9			.001				
Pass-Pass		4.89 (1.76)	2.78	.006		4.94 (1.78)	2.77	.006
Pass-Fail		.37 (2.10)	.17	.860		.24 (2.08)	.11	.909
Fail-Pass		6.81 (2.42)	2.82	.005		5.55 (2.32)	2.39	.017
Sit-and-reach	.4			.488				
Pass-Pass		1.64 (2.26)	.73	.468				
Pass-Fail		−.11 (3.02)	−.04	.970				
Fail-Pass		4.25 (3.22)	1.32	.187				
Bent-leg Curl-ups	.9			.158				
Pass-Pass		3.49 (1.95)	1.79	.075				
Pass-Fail		.31 (2.60)	.12	.907				
Fail-Pass		3.44 (2.51)	1.37	.171				

† Omitted category is "Girl".
‡ Omitted category is "Moderate."
§ Omitted category is "Always normal."
¶ Omitted category is "Fail-Fail."

found that adolescent boys with improved CV fitness exhibited higher intelligence scores than those with decreased CV fitness.[11] The regression analyses in this study confirmed that improvement in CV fitness was significantly associated with better academic performance. In the model of LGC, those who were initially CV fit have better academic scores at baseline and the rate of change in CV fitness was related to the rate of change in academic performance.

Literature regarding the BMI-academic performance relationship remains equivocal. BMI or obesity has been found to be negatively associated with academic performance among schoolchildren in some studies.[22,30] Others (adjusted with other forms of fitness) have indicated no significant association.[4,9] Adjustment of various confounders might be one of the reasons for the difference. In this study, those who remained underweight or became underweight between 7th grade and 9th grade exhibited significantly worse academic performance than normal weight children with regression analyses. However, this result did not reach statistical significance in the model of LGC. Therefore, it remains unclear as to the significance and strength of this relationship. There are gaps in understanding this relationship for this age group.

In general therefore, CV fitness seems to be more potent than other measures of fitness in this fitness-academic performance relationship.[4-6] Researchers have hypothesized CV fitness to be a mediator explaining the link between physical exercise and cognitive function through increased cerebral blood flow, influence on brain neurotransmitter levels, and structural changes in the central nervous system.[1,11,31] Another possibility explaining associations is that physical activity provides learning experiences which help children's cognitive function.[1]

However, it is also possible that CV fitness is an indicator of positive development in children. It may be equally possible that those who are academically successful also enjoy activity and sports, thus maintaining higher levels of physical fitness. Moreover, a strong fitness-academic performance relationship was not found in this study. The capacity of children to change fitness may be limited and change in fitness is in part genetically and maturationally determined.[11,32] Additionally, intelligence may be one of the covariates in this relationship. There is a possibility that fitter children come from a more intelligent background and consequently have higher academic achievements. Given the small amount of explained variance in academic performance explained by CV fitness with these children and plausible explanation existing in each causal direction, suggestions of an effect remain speculative.

Table 3. **Parameter Estimates for Prediction of Academic Performance From CV Fitness and BMI**

Variables	Parameter	Conditional Model† Estimate	Conditional Model† z-Value
CV fitness			
Factor means			
Intercept	F1, V999	51.29	32.35‡
Slope	F2, V999	−5.69	−4.31‡
BMI			
Factor means			
Intercept	F3, V999	19.82	86.59‡
Slope	F4, V999	.33	5.22‡
Academic score			
Factor means			
Intercept	F5, V999	70.43	7.30‡
Slope	F6, V999	−12.17	−2.17‡
Regression paths			
Fitness intercept → Score intercept	F1, F5	.31	3.17‡
Fitness intercept → Score slope	F1, F6	.42	1.32
Fitness slope → Score slope	F2, F6	.53	6.98‡
BMI intercept → Score intercept	F3, F5	.03	.20
BMI intercept → Score slope	F3, F6	.73	1.82
BMI slope → Score slope	F4, F6	−.08	−1.33
Goodness of fit indices		$\chi^2(19) = 59.10$, $p < .001$ NFI = .99 CFI = .99 RMSEA = .07 (.05-.09)	

†Covariate: sex.
‡z-values greater than 1.96 indicate statistical significance ($p < .05$).

There might be potential clustering effects on the results, as this study is limited to one school district in Taiwan. Therefore, it should be undertaken with caution when generalizing the results to schoolchildren from the remainder of Taiwan or beyond.

However, as indicated in the introduction, no study has been conducted on Asian children and the cultural differences might affect the fitness-academic performance relationship. Additionally, the United States and many countries are multicultural societies. It is important to understand what the potential mechanisms underpinning any relationship are so that focused interventions can be developed. The degree to which the fitness-academic performance link varies across cultures and it may has some important light on the potential mechanism. It points out that social and cultural factors are important considerations and in a multicultural society such as United States would be particularly pertinent.

IMPLICATIONS FOR SCHOOL HEALTH

This research demonstrated that various forms of fitness have different relationships with academic performance. Improvement in CV fitness, but not muscular endurance or flexibility between 7th grade and 9th grade, is significantly related to greater academic performance. These results suggest that attempts to improving CV fitness in schoolchildren of this age is worthy of further study as it has potential to have a positive influence on academic performance. On the other hand, this study yields no robust evidence that maintaining a healthy weight has similar potential.

Human Subjects Approval Statement

This study was reviewed by the Taiwan National Science Council and the procedures for data collection followed the Taiwan Codes of Ethics for the Psychological Professions.[33]

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