# Relationships between athletic ability and academic performance in primary school students: A 3-year follow-up study

Hao Zong Ji[1]*, Cui Jin Bai[2], Yun Yang[1], Wu Xiang Dong[1], Qian Ze Yi[1], Wu Dan Ping[3], Tang Yi[4], Zheng Hong Xia[1], Zhang Zhi Min[1], Xu Jing Long[1], Zhang Teng Fei[1], Wang Jun Ji[1], Li Zhen[5], Gao Zhuang[6] and Li Ying Ke[7]

[1]Physical Education Teaching and Research Group, Chongqing Liangjiang Yucai Middle School, Chongqing, China, [2]School of Physical Education, Chinese Center of Exercise Epidemiology, Northeast Normal University, Changchun, China, [3]Physical Education Teaching and Research Group, Chengdu Caotang Primary School West Branch, Chengdu, China, [4]English Teaching and Research Group, Chongqing Bishan Yuhu Primary School, Chongqing, China, [5]Sports Teaching and Research Group of Xingchen School, Affiliated Middle School of West University, Chongqing, China, [6]College of Physical Education, Yunnan University, Kunming, China, [7]School of Physical Education, Southwest University, Chongqing, China

**Background:** The aim of this study was to examine whether academic performance is associated with students' athletic ability in primary school.

**Methods:** A 3-year follow-up study was conducted among 1,136 Chinese students. Sit-up and jump rope testers were used to measure 1-min sit-ups and 1-min jump ropes, respectively. Meanwhile, the Pittsburgh Sleep Quality Scale and the Beck Depression Inventory were used to estimate sleep quality and depression levels. The end-of-semester examinations were used to evaluate students' academic performance during the follow-up period.

**Results:** After adjusting for confounders, the mean change in Chinese language performance for participants stratified by 1-min sit-ups at baseline was 0.35 (95% CI: −0.37 to 0.76) for level 1 (slowest), 0.52 (95% CI: −0.54 to 1.08) for level 2, and 1.72 (95% CI: 1.14 to 2.30) for level 3 (fastest) ($P$ for trend = 0.003); the mean change in math scores was 0.28 (95% CI: −0.50 to 0.95) for level 1 (slowest), 0.95 (95% CI: 0.38 to 1.52) for level 2, and 1.41 (95% CI: 0.82 to 1.99) for level 3 (fastest) ($P$ for trend = 0.048). The mean change in foreign language scores was −0.45 (95% CI: −0.99 to −0.93) for level 1 (slowest), −0.14 (95% CI: −0.44 to 0.41) for level 2, and 0.69 (95% CI: 0.25 to 1.13) for level 3 (fastest) ($P$ for trend = 0.004). The mean change in Chinese language performance for participants stratified by 1-min jump ropes at the baseline was 0.30 (95% CI: −0.16 to 0.76) for level 1 (slowest), 1.09 (95% CI: 0.42 to 1.76) for level 2, and 1.74 (95% CI: 1.14 to 2.35) for level 3 (fastest) ($P$ for trend = 0.001). The mean change in math scores was 0.41 (95% CI: −0.11 to 0.92) for level 1 (slowest), 1.44 (95% CI: 0.69 to 2.19) for level 2, and 1.43 (95% CI: 0.76 to 2.10) for level 3 (fastest) ($P$ for trend = 0.019). The mean change in foreign language performance was −0.71 (95% CI: −1.08 to −0.33) for level 1 (slowest), 0.95 (95% CI: −0.40 to 1.50) for level 2, and 0.91 (95% CI: 0.41 to 1.41) for level 3 (fastest) ($P$ for trend < 0.001).

**Conclusion:** This study suggests that participation in jump rope and sit-up exercises may positively affect students' academic performance.

# Introduction

Under the current education system in China, students' academic performance is the key to their access to higher education opportunities and superior educational resources, placing the question of how to effectively improve students' academic performance at the center of attention among society, schools, and families.

With the benefits of physical activity on children's physical development being universally acknowledged, a large number of foreign epidemiological surveys in recent years have also shown significant positive correlations between the amount and frequency of physical activity that the adolescent children participated in and their school behavioral performance (1–3). This correlation can be evidenced by the finding of Chaddock et al. (4) who discovered that exercise reduced activation of the prefrontal cortex and improved behavioral performance on executive control tasks in children. This association was further heightened by Han (5) study, which demonstrated that students with higher levels of physical fitness tended to have higher academic achievement. Based on many research results, experts in China, as well as in other countries, hope to help students improve their academic performance by increasing their engagement in physical activities. However, an objective and accurate evaluation of the frequency with which students participate in physical activity can be difficult to achieve in practice. Compared with frequency measurement, a comprehensive exercise capacity measurement is not only more accurate but also easier and faster to conduct and, thus, can truly reflect the daily physical activity level.

While there is no shortage of studies investigating the association between physical activity and children's behavior, most studies on the relationship between athletic ability and academic performance have been conducted in foreign countries (4, 6). The populations are mostly secondary school and college students. In the meantime, studies have yet to be conducted among Chinese students. Therefore, the object of the evaluation was to broaden the empirical base with a focus on Chinese students in primary school. Through the test of sports ability and academic performance of 1,136 third-grade primary school students in Chengdu, this study explores the relationship between sports ability and academic performance to provide theoretical support for improving primary school students' academic performance.

# Materials and methods

## Study population

The initial study was conducted in June 2019 among school children in Cheng du, China. The initial sample consisted of 1,494 pupils from primary schools, aged 10–11 (mean 10.6) years. These children underwent an athletic ability examination and completed a self-administered questionnaire; this provided information on demographics, academic performance, anthropometrics, and lifestyle factors. The same methodology was used on a follow-up, which will

TABLE 1 Single item scoring table for boys' 1-min jump rope (unit: times).

| Grade | Score | Third grade | Fourth grade | Fifth grade | Sixth grade |
|---|---|---|---|---|---|
| Excellent | 100 | 126 | 137 | 148 | 157 |
| | 95 | 121 | 132 | 143 | 152 |
| | 90 | 116 | 127 | 138 | 147 |
| Good | 85 | 110 | 121 | 132 | 141 |
| | 80 | 104 | 115 | 126 | 135 |
| Pass | 78 | 97 | 108 | 119 | 128 |
| | 76 | 90 | 101 | 112 | 121 |
| | 74 | 83 | 94 | 105 | 114 |
| | 72 | 76 | 87 | 98 | 107 |
| | 70 | 69 | 80 | 91 | 100 |
| | 68 | 62 | 73 | 84 | 93 |
| | 66 | 55 | 66 | 77 | 86 |
| | 64 | 48 | 59 | 70 | 79 |
| | 62 | 41 | 52 | 63 | 72 |
| | 60 | 34 | 45 | 56 | 65 |
| Fail | 50 | 31 | 42 | 53 | 62 |
| | 40 | 28 | 39 | 50 | 59 |
| | 30 | 25 | 36 | 47 | 56 |
| | 20 | 22 | 33 | 44 | 53 |
| | 10 | 19 | 30 | 41 | 50 |

TABLE 2 Single item scoring table for girls' 1-min jump rope (unit: times).

| Grade | Score | Third grade | Fourth grade | Fifth grade | Sixth grade |
|---|---|---|---|---|---|
| Excellent | 100 | 139 | 149 | 158 | 166 |
| | 95 | 132 | 142 | 151 | 159 |
| | 90 | 125 | 135 | 144 | 152 |
| Good | 85 | 117 | 127 | 136 | 144 |
| | 80 | 109 | 119 | 128 | 136 |
| Pass | 78 | 102 | 112 | 121 | 129 |
| | 76 | 95 | 105 | 114 | 122 |
| | 74 | 88 | 98 | 107 | 115 |
| | 72 | 81 | 91 | 100 | 108 |
| | 70 | 74 | 84 | 93 | 101 |
| | 68 | 67 | 77 | 86 | 94 |
| | 66 | 60 | 70 | 79 | 87 |
| | 64 | 53 | 63 | 72 | 80 |
| | 62 | 46 | 56 | 65 | 73 |
| | 60 | 39 | 49 | 58 | 66 |
| Fail | 50 | 36 | 46 | 55 | 63 |
| | 40 | 33 | 43 | 52 | 60 |
| | 30 | 30 | 40 | 49 | 57 |
| | 20 | 27 | 37 | 46 | 54 |
| | 10 | 24 | 34 | 43 | 51 |

be explained in detail in the following paragraphs. Each child's family, contacted by phone, was informed about the study's aim and invited to participate. Meanwhile, certain participants were excluded for the following reasons:

failure to provide written informed consent for analysis of their data ($n = 12$),
missing data for the assessment ($n = 133$) or other variables ($n = 65$),
existing contraindications to exercise ($n = 75$),
body deformity ($n = 10$) at the baseline, and
missing athletic ability assessment data for 2022 ($n = 63$).

Therefore, the follow-up study included 1,136 (634 male and 502 female) participants. Ethics approval was obtained from the Institutional Review Board of the College of Physical Education of Southwest University, and written parental consent for the minors was also received before the study began.

## Measurement of athletic ability

Students' muscular endurance was assessed using 1-min rope skipping and 1-min sit-ups. The total duration of the assessment was 20 min, with rope skipping and sit-up assessment taking up 5 min and the follow-up questionnaire 15 min. The exercise ability of the investigated population was tested in June 2019, June 2021,

and June 2022, respectively. The 1-min rope jumping test requires the subject to stand in the test area, start jumping rope after hearing the instructions in 3.2.1, and stop jumping rope after hearing the end instructions. The sensor would automatically record and save the test results, and this test uses the h5 tester. One-min setup requires the subject to lie on the mat, legs slightly apart, feet set on the padded instrument, knees at an approximately 90-degree angle, two fingers crossed on the back of the brain, and waist with a special electronic test belt. The participant begins to sit up when the instrument is heard to emit a "drop drop" chime. Sitting on the back must be coherent, and there is a tone. The instrument automatically counts 1. If one up and one sitting action are not in place, with no tone, then this sit-up would not count. The athlete ability of students is evaluated based on the physical health standards of Chinese students. The specific evaluation standards are as follows: During the test, we found that the number of failed students was small, and it was pointless to classify them separately for data analysis. Therefore, the passing grade and the failing grade were combined. Thus, in the subsequent data analysis, 1-min rope skipping and 1-min sit-ups were three classified variables. The evaluation criteria are shown in Tables 1–4.

## Assessment of academic performance

This survey takes the students' Chinese, mathematics, and English scores in a 90-min examination at the end of the academic year as the core criterion for academic performance evaluation. The

TABLE 3 Scoring table of 1-min sit-ups for boys (unit: times).

| Grade | Score | Third grade | Fourth grade | Fifth grade | Sixth grade |
|---|---|---|---|---|---|
| Excellent | 100 | 48 | 49 | 50 | 51 |
| | 95 | 45 | 46 | 47 | 48 |
| | 90 | 42 | 43 | 44 | 45 |
| Good | 85 | 39 | 40 | 41 | 42 |
| | 80 | 36 | 37 | 38 | 39 |
| Pass | 78 | 34 | 35 | 36 | 37 |
| | 76 | 32 | 33 | 34 | 35 |
| | 74 | 30 | 31 | 32 | 33 |
| | 72 | 28 | 29 | 30 | 31 |
| | 70 | 26 | 27 | 28 | 29 |
| | 68 | 24 | 25 | 26 | 27 |
| | 66 | 22 | 23 | 24 | 25 |
| | 64 | 20 | 21 | 22 | 23 |
| | 62 | 18 | 19 | 20 | 21 |
| | 60 | 16 | 17 | 18 | 19 |
| Fail | 50 | 14 | 15 | 16 | 17 |
| | 40 | 12 | 13 | 14 | 15 |
| | 30 | 10 | 11 | 12 | 13 |
| | 20 | 8 | 9 | 10 | 11 |
| | 10 | 6 | 7 | 8 | 9 |

TABLE 4 Single score table of 1-min sit-ups for girls (unit: times).

| Grade | Score | Third grade | Fourth grade | Fifth grade | Sixth grade |
|---|---|---|---|---|---|
| Excellent | 100 | 46 | 47 | 48 | 49 |
| | 95 | 44 | 45 | 46 | 47 |
| | 90 | 42 | 43 | 44 | 45 |
| Good | 85 | 39 | 40 | 41 | 42 |
| | 80 | 36 | 37 | 38 | 39 |
| Pass | 78 | 34 | 35 | 36 | 37 |
| | 76 | 32 | 33 | 34 | 35 |
| | 74 | 30 | 31 | 32 | 33 |
| | 72 | 28 | 29 | 30 | 31 |
| | 70 | 26 | 27 | 28 | 29 |
| | 68 | 24 | 25 | 26 | 27 |
| | 66 | 22 | 23 | 24 | 25 |
| | 64 | 20 | 21 | 22 | 23 |
| | 62 | 18 | 19 | 20 | 21 |
| | 60 | 16 | 17 | 18 | 19 |
| Fail | 50 | 14 | 15 | 16 | 17 |
| | 40 | 12 | 13 | 14 | 15 |
| | 30 | 10 | 11 | 12 | 13 |
| | 20 | 8 | 9 | 10 | 11 |
| | 10 | 6 | 7 | 8 | 9 |

**TABLE 5** The participants' baseline characteristics, according to categories of 1-min jump rope and 1-min sit-ups.

| Characteristic | | One min rope skipping | | | | One minute sit ups | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Lower (N = 565) | Middle (N = 341) | Upper (N = 230) | P for linear trend | Lower (N = 391) | Middle (N = 400) | Upper (N = 340) | P for linear trend |
| Sex | Male | 313 | 176 | 145 | 0.005 | 235 | 197 | 197 | 0.045 |
| | Female | 252 | 165 | 85 | | 156 | 203 | 143 | |
| Age (years) | | 10.40 (10.36, 10.44) | 10.35 (10.30, 10.40) | 10.1 (10.23, 10.35) | 0.014 | 10.32 (10.27, 10.37) | 10.38 (10.34, 10.43) | 10.40 (10.35, 10.45) | 0.064 |
| Only child | Yes | 432 | 235 | 175 | 0.74 | 235 | 309 | 298 | <0.001 |
| | No | 133 | 106 | 50 | | 156 | 91 | 42 | |
| Body mass index (kg/m2) | | 20.50 (19.88, 21.12) | 19.42 (19.07, 19.77) | 18.82 (18.57, 19.07) | 0.000 | 20.97 (20.54, 21.39) | 18.71 (18.43, 18.99) | 18.20 (17.93, 18.47) | <0.001 |
| Sleep quality | | 8.00 (7.74, 8.26) | 7.77 (7.50, 8.04) | 7.66 (7.32, 7.99) | 0.26 | 8.01 (7.73, 8.31) | 7.54 (7.27, 7.80) | 8.06 (7.75, 8.38) | 0.018 |
| Depression level | | 12.16 (11.47, 12.85) | 11.92 (11.15, 12.69) | 11.42 (10.50, 12.34) | 0.48 | 12.90 (12.03, 13.76) | 11.95 (11.20, 12.71) | 11.12 (10.37, 11.85) | 0.008 |
| Parents marital status | First marriage | 371 | 255 | 158 | 0.87 | 268 | 269 | 247 | 0.23 |
| | Divorce | 80 | 39 | 26 | | 53 | 49 | 43 | |
| | Remarriage | 114 | 47 | 41 | | 70 | 82 | 50 | |
| Father education | High school degree or below | 467 | 293 | 193 | 0.19 | 336 | 328 | 289 | 0.68 |
| | Bachelor degree or above | 98 | 48 | 32 | | 55 | 72 | 51 | |
| Mather education | High school degree or below | 456 | 286 | 186 | 0.73 | 319 | 311 | 280 | 0.091 |
| | Bachelor degree or above | 109 | 73 | 39 | | 72 | 89 | 60 | |
| Mobile phone usage (h/Day) | <1 h | 413 | 259 | 189 | 0.02 | 310 | 313 | 238 | 0.001 |
| | 1–2 h | 132 | 68 | 34 | | 75 | 73 | 86 | |
| | >2 h | 20 | 14 | 2 | | 16 | 14 | 6 | |
| Left-behind children | Yes | 57 | 35 | 21 | 0.001 | 42 | 36 | 35 | 0.841 |
| | No | 508 | 306 | 204 | | 349 | 364 | 305 | |

Continuous variables without a normal distribution were log-transformed and are expressed as the estimated geometric means (95% confidence intervals). Linear trends were assessed using ANCOVA for continuous variables and logistic regression analyses for categorical variables.

TABLE 6  Multivariable-adjusted relationships of 1-min jump rope with change in academic performance during the 3-year follow-up period.

| | $n = 1,131$ | Number of participants | Model 2[a] | Model 2[b] | Model 3[c] |
|---|---|---|---|---|---|
| Chinese | 1 (slowest) | 322 | 0.40 (−0.66, 0.86) | 0.31 (−0.15, 0.78) | 0.30 (−0.16, 0.76) |
| | 2 | 260 | 1.09 (0.42, 1.76) | 1.17 (0.50, 1.84) | 1.09 (0.42, 1.76) |
| | 3 (Fastest) | 549 | 1.59 (0.98, 2.19) | 1.67 (1.05, 2.28) | 1.74 (1.14, 2.35) |
| | Pd | | 0.008 | 0.002 | 0.001 |
| Maths | 1 (slowest) | 322 | 0.89 (−0.12, 0.90) | 0.39 (−0.13, 0.89) | 0.41 (−0.11, 0.92) |
| | 2 | 260 | 1.13 (0.58, 2.06) | 1.35 (0.61, 2.09) | 1.44 (0.69, 2.19) |
| | 3 (Fastest) | 549 | 1.59 (0.92, 2.25) | 1.48 (0.81, 2.15) | 1.43 (0.76, 2.10) |
| | Pd | | 0.01 | 0.016 | 0.019 |
| English | 1 (slowest) | 322 | −0.72 (−1.09, −0.34) | −0.71 (−1.09, −0.34) | −0.71 (−1.08, −0.33) |
| | 2 | 260 | 0.93 (0.38, 1.47) | 0.92 (−0.39, 1.47) | 0.95 (−0.40, 1.50) |
| | 3 (Fastest) | 549 | 0.93 (0.44, 1.43) | 0.94 (0.44, 1.44) | 0.91 (0.41, 1.41) |
| | p[d] | | <0.001 | <0.001 | <0.001 |

[a]Model 1: Adjusted for sex (categorical variable) and age (continuous variable) at the baseline. [b]Model 2: Adjusted for the variables in model 1 and parents' educational level (categorical variable: high school degree or below and bachelor degree or above), parents' marital status (categorical variable: first marriage, divorce, or remarriage), BMI (continuous variable), only child (categorical variable: yes or no), and left-behind children (categorical variable: yes or no) at the baseline. [c]Model 3: Adjusted for the variables in model 2 and sleep quality (continuous variable), mobile phone usage (h/Day, categorical variable:<1 h, 1–2 h, and >2 h), depression level (continuous variable) at the baseline. [d]Linear trends were assessed using ANCOVA.

academic achievements of the survey population were collected in June 2019, June 2021, and June 2022, respectively. The grade was coded as follows: 4 outstanding (>90), 3 good (89–80), 2 passed (79–60), and a failure (<60).

## Confounding variables

Demographic variables and lifestyle factors were assessed using a self-administered questionnaire. Variables and factors assessed by the questionnaire included: sex (males or females), age (continuous variable), only child (yes or no), self-reported body mass index (continuous variable), parents' marital status (first marriage, divorce, or remarriage), mobile phone usage (h/day) (<1 h, 1–2 h, or >2 h), and left-behind children (which means children who grow up away from their parents) (yes or no) with established reliability and validity for assessing subjective sleep quality and quantitative sleep–wake parameters in the previous month (from self-reported measurements of sleep latency, duration, and efficiency). The answers to the 19 questions in PSQI are divided into seven parts in proportion, with a total score of 0–21. The higher the score, the worse the sleep (7). The Beck Depression Inventory (BDI) (8) was used to examine the severity of depression. It consists of 21 items. A higher score means a more severe depressive state.

## Statistical analysis

All statistical analyses were performed with SPSS software (version 20.0; SPSS, Chicago, IL, USA). For the baseline characteristics of participants, continuous variables are expressed as means and 95% confidence intervals, and categorical variables are expressed as percentages. Continuous data with skewed distributions, as determined using the Kolmogorov–Smirnov test, were logarithmically transformed. Analysis of covariance (ANCOVA) and logistic regression analysis were used to compare the baseline

characteristics of the categorized group after adjustment for sex and age. One-min rope skipping and 1-min sit-ups were considered independent variables, and baseline variables were considered dependent variables. ANCOVA was also used to estimate the change in academic performance based on the categories of 1-min rope skipping and 1-min sit-ups. Model 1: adjusted for sex (categorical variable) and age (continuous variable) at the baseline. Model 2: adjusted for the variables in Model 1 and parents' educational level (categorical variable: high school degree or below and bachelor degree or above), parents' marital status (categorical variable: first marriage, divorce, or remarriage), BMI (continuous variable), only child (categorical variable: yes or no), and left-behind children (categorical variable: yes or no), at the baseline. Model 3: adjusted for the variables in Model 2 and sleep quality (continuous variable), mobile phone usage (h/day, categorical variable: <1 h, 1–2 h, and >2 h), and depression level (continuous variable) at the baseline.

## Results

The participants' baseline characteristics, according to categories of 1-min rope skipping and 1-min sit-ups, are shown in Table 5. Participants who reported higher levels of 1-min jump rope were generally younger, had lower body mass index, spent less time on their phones, and consisted of a higher proportion of males and a lower proportion of left-behind children (P for trend: 0.014, <0.001, 0.02, and 0.001, respectively). Other baseline characteristics did not differ significantly between categories. Similarly, participants with higher levels of 1-min sit-ups were reported to have higher proportions of males and only children, lower body mass index, better sleep quality, lower levels of depression, and less cell phone usage (P for trend: 0.05, <0.001, <0.001, 0.018, 0.008, and <0.001, respectively). Table 6 shows the relationship between a 1-min jump rope grade at the baseline and a change in academic performance during the 3-year follow-up. After adjusting for all covariates, the higher the 1-min jump rope grade, the higher the improvement in test scores. In Model 3, the mean change in Chinese language

TABLE 7  Multivariable-adjusted relationships of 1-min sit-ups with change in academic performance during the 3-year follow-up period.

| | n = 1,131 | Number of participants | Model 2[a] | Model 2[b] | Model 3[c] |
|---|---|---|---|---|---|
| Chinese | 1 (slowest) | 276 | 0.38 (−0.34, 1.11) | 0.29 (−0.44, 1.02) | 0.35 (−0.37, 0.76) |
| | 2 | 436 | 1.09 (−0.12, 1.13) | 0.53 (−0.39, 1.10) | 0.52 (−0.54, 1.08) |
| | 3 (Fastest) | 419 | 1.59 (1.07, 2.24) | 1.75 (1.16, 2.33) | 1.72 (1.14, 2.30) |
| | Pd | | 0.008 | 0.002 | 0.003 |
| Maths | 1 (slowest) | 276 | 0.66 (−0.65, 0.78) | 0.20 (−0.52, 0.93) | 0.28 (−0.50, 0.95) |
| | 2 | 436 | 0.99 (0.41, 1.55) | 0.97 (0.40, 1.54) | 0.95 (0.38, 1.52) |
| | 3 (Fastest) | 419 | 1.48 (0.89, 2.06) | 1.40 (0.82, 1.99) | 1.41 (0.82, 1.99) |
| | Pd | | 0.011 | 0.045 | 0.048 |
| English | 1 (slowest) | 276 | −0.38 (−0.91, 0.16) | −0.46 (−1.00, 0.84) | −0.45 (−0.99, −0.93) |
| | 2 | 436 | 0.22 (−0.45, 0.40) | −0.12 (−0.44, 0.42) | −0.14 (−0.44, 0.41) |
| | 3 (Fastest) | 419 | 0.65 (0.21, 1.08) | 0.69 (0.25, 1.13) | 0.69 (0.25, 1.13) |
| | p[d] | | 0.009 | 0.004 | 0.004 |

[a]Model 1: Adjusted for sex (categorical variable) and age (continuous variable) (categorical variable) at the baseline. [b]Model 2: Adjusted for the variables in model 1 and parents' educational level (categorical variable: high school degree or below and bachelor degree or above), parents' marital status (categorical variable: first marriage, divorce, or remarriage), BMI (continuous variable), only child (categorical variable: yes or no), and left–behind children (categorical variable: yes or no) at the baseline. [c]Model 3: Adjusted for the variables in model 2 and sleep quality (continuous variable), mobile phone usage (h/Day, categorical variable: <1h, 1–2h, and >2h), and depression level (continuous variable) at the baseline. [d]Linear trends were assessed using ANCOVA.

performance in the 1-min jump rope grade was 0.30 (95% CI: −0.16 to 0.76) for level 1 (slowest), 1.09(95% CI: 0.42 to 1.76) for level 2, and 1.74 (95% CI: 1.14 to 2.35) for level 3 (fastest) ($P$ for trend = 0.001); the mean change in mathematics performance in the 1-min jump rope grade was 0.41 (95% CI: −0.11 to 0.92) for level 1 (slowest), 1.44 (95% CI: 0.69 to 2.19) for level 2, and 1.43 (95% CI: 0.76 to 2.10) for level 3 (fastest) ($P$ for trend = 0.019). The mean change in foreign language performance in the 1-min jump rope grade was −0.71 (95% CI: −1.08 to −0.33) for level 1 (slowest), 0.95(95% CI: −0.40 to 1.50) for level 2, and 0.91 (95% CI: 0.41 to 1.41) for level 3 (fastest) ($P$ for trend <0.001).

Table 7 shows the relationship between 1-min sit-ups grade at the baseline and change in academic performance during the 3-year follow-up. After adjusting for all covariates, the higher the 1-min sit-ups grade, the higher the improvement in testing score. In Model 3, the mean change in Chinese language performance in the 1-min jump rope grade was 0.35 (95% CI: −0.37 to 0.76) for level 1 (slowest), 0.52 (95% CI: −0.54 to 1.08) for level 2, and 1.72 (95% CI: 1.14 to 2.30) for level 3 (fastest) ($P$ for trend = 0.003); the mean change in mathematics performance in the 1-min jump rope grade was 0.28 (95% CI: −0.50 to 0.95) for level 1 (slowest), 0.95 (0.38 to 1.52) for level 2, and 1.41 (95% CI: 0.82 to 1.99) for level 3 (fastest) ($P$ for trend = 0.048). The mean change in foreign language performance in the 1-min jump rope grade was −0.45(95% CI:−0.99 to−0.93) for level 1 (slowest), −0.14 (95% CI: −0.44 to 0.41) for level 2, and 0.69 (95% CI: 0.25 to 1.13) for level 3 (fastest) (P for trend = 0.004).

## Discussion

This 3-year longitudinal study examined the relationship between 1-min jump rope and sit-up grades with academic performance over time in Chinese students. These results showed that higher baseline grades of 1-min jump rope and sit-up were significantly associated with increased academic performance after adjusting for confounding factors These results showed that the better performance of these two tests at the baseline is associated with better

academic achievement in the follow-up. Our findings suggest that performing 1-min jump rope and sit-up exercises has a positive effect on the academic performance of Chinese students.

The results of this longitudinal study support the hypothesis that higher levels of 1-min jump rope and 1-min sit-ups at the baseline were significantly associated with improved academic performance among Chinese children at 3 years of follow-up. The result of the study is generally consistent with the results of previous studies, such as Liao et al. (9) who found a significant positive correlation between curl scores and students' academic performance in a curl test administered to Taiwanese high school students. The result is also in line with that of Kim et al. (10) study showing that 12 weeks of skipping rope training was effective in improving the academic self-efficacy of obese female students, which in turn led to a boost in academic performance. Chen et al. (11) found that jump rope training was effective in improving cardiovascular fitness, muscular endurance, flexibility and strength, and cognitive function in a 12-week exercise intervention with obese adolescents. The 1-min rope skipping mainly tests the children's muscular endurance level, which can also reflect the students' coordination and speed quality to a certain extent. On the other hand, the 1-min sit-ups mainly test the students' abdominal flexor and hip muscle endurance levels. The results of this study infer that levels of muscular endurance may affect students' academic performance. This result is consistent with previously reported findings in children and adolescents, which suggest that adding muscular endurance training to our daily exercise routine may help to improve academic performance in elementary school students. Bass et al. (12) study found that male middle school students with higher levels of muscular endurance were 2–5 times more likely to pass math and reading tests than students with lower levels.

However, it is worth mentioning that some studies have shown no significant correlation between students' academic performance and muscle function. This may be due to differences in the age of the respondents, as well as differences in muscle function testing methods and test content. For the relationship between muscular endurance and academic performance, we infer that the reason

may be due to the fact that levels of muscular endurance were in several aspects related to cognitive function, such as attention, memory, and reaction speed, a finding supported by Shigeta et al. (13). Therefore, students with higher levels of muscular endurance are normally better than students with low levels of muscular endurance, which may be one of the reasons for the difference in their academic performance; second, students with higher muscular endurance may do more muscle exercises or physical activities that require muscles in daily life. Kobilo et al. (14) found that treatment with the adenylate-activated protein kinase activator AICAR significantly enhanced the spatial memory of aged mice, whereas skeletal muscle-specific AMPKα2 subunit knockdown inhibited this effect, suggesting a strong link between the skeletal muscle and brain. Nearly 10 years of research found that the skeletal muscle is an endocrine organ that can produce and release cytokines and peptides that affect brain metabolism during muscle contraction. For example, exercise can modulate brain-derived neurotrophic by stimulating skeletal muscle BDNF (brain-derived neurotrophic factor), isrisin (Iris), interleukin-6 (IL-6) (CTSB), Exercise can modulate, for example, brain-derived neurotrophic by stimulating skeletal muscle BDNF (brain-derived neurotrophic factor), isrisin (Iris), interleukin-6 (IL-6) (CTSB), muscle growth inhibitor (MSTN), insulin-like growth factor-1 (IGF-1), vascular endothelial growth factor (VEGF), and myostatin (MSTN), level. After entering the blood circulation, the related muscle factors can cross the blood–brain barrier (BBB) and are involved in maintaining neuronal structure and function structure and function, improving synaptic plasticity, reducing central inflammation, and increasing cerebral angiogenesis. Brain-derived neurotrophic factor (BDNF) is a member of the neurotrophic factor family and is currently the most studied neurotrophic factor involved in the regulation of adult neurogenesis and synaptic plasticity muscle factors involved in the regulation of neurogenesis and synaptic plasticity in adults. Studies have shown that circulating BDNF crosses the blood–brain barrier and can stimulate the production of the hippocampus to stimulate central trophic factor production and improve short-term cognitive performance and long-term morphological adaptation in the brain. Longitudinal studies have shown that during exercise, skeletal muscle secretes a transcriptional co-activator called PGC-1α of which FNDC5 is a downstream protein. During exercise, FNDC5 is broken down into irisin in the exercising muscle (15). Irisin is associated with neural differentiation, crosses the blood–brain barrier, acts on endothelial cell receptors or brain BDNF receptors, and directly regulates hippocampal gene expression. Brain-derived neurotrophic factor (BDNF) promotes neurotic proliferation, growth, differentiation, and synaptic regeneration, which are key functions related to learning, memory, and biological regeneration (16). Thus, frequent muscle activity may improve brain metabolism by enhancing the production of cytokines and peptides. This study shows that regular participation in rope skipping and sit-ups can effectively improve the academic performance of primary school students.

One limitation of this study, inherited from previous morpheme studies, is that the subjects of this survey are primary school students in Chengdu, which means that the findings are not wholly generalizable to students in other areas and whether the research results can be applied to other regions and populations need further research. Second, although the survey is conducted through the authoritative scale, the subjective factors of participants may still affect the research results.

## Conclusion

In conclusion, after adjusting many covariates, this study found that higher levels of 1-min jump rope and 1-min sit-ups at the baseline were significantly associated with improved academic performance among Chinese children at 3 years of follow-up. This study suggests that participation in jump rope and sit-up exercises may positively affect the improvement of students' academic performance. Further intervention studies are needed to explore the causality between 1-min jump rope and sit-up grades with academic performance.

## Data availability statement

The original contributions presented in the study are included in the article/supplementary files, further inquiries can be directed to the corresponding author.

## Ethics statement

Ethics approval was obtained from the Institutional Review Board of the College of Physical Education of Southwest University. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

## Author contributions

HJ, CB, and YY have given substantial contributions to the conception or the design of the manuscript. QY, WP, ZM, ZX, GZ, XL, ZF, WJ, and LK contributed to the acquisition, analysis and interpretation of the data. TY made an important contribution to the polishing of the manuscript. HJ had critically revised the manuscript. All authors participated to drafting the manuscript, read, and approved the final version of the manuscript.

## Funding

## Acknowledgments

## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

## References

1. Gsa B, Fnba C, Lspa D. Prospective associations between participation in leisure-time physical activity at age six and academic performance at age 12. *Prev Med.* (2019) 118:135–41. doi: 10.1016/j.ypmed.2018.10.017

2. Mccluskey M, Al-Shallawi AN, Penk D, Bridges J, Gilson N, et al. Evaluating associations between physical activity and growth, academic attainment, and socioeconomic factors in primary school children - a prospective cohort study. *J Phys Activ Res.* (2021) 6:112–21. doi: 10.12691/jpar-6-2-8

3. Lima RA, Pfeiffer KA, Møller NC, Andersen LB, Bugge A. Physical activity and sedentary time are positively associated with academic performance: a 3-year longitudinal study. *J Phys Act Health.* (2019) 16:177–183. doi: 10.1123/jpah.2017-0587

4. Chaddock L, Hillman CH, Buck SM, Cohen NJ. Aerobic fitness and executive control of relational memory in preadolescent children. *Med Sci Sports Exer.* (2011) 43:344–9. doi: 10.1249/MSS.0b013e3181e9af48

5. Han G S. The relationship between physical fitness and academic achievement among adolescents in South Korea. *J Phys Ther Sci.* (2018) 30:605–8. doi: 10.1589/jpts.30.605

6. Kulinna PH, Stylianou M, Dyson B, Banville D, Dryden C, Colby R. The Effect of an Authentic Acute Physical Education Session of Dance on Elementary Students' Selective Attention. *Biomed Res Int.* (2018) 2018:1–8. doi: 10.1155/2018/8790283

7. Buysse DJ, Reynolds III CF, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Res.* (1989) 28:193–213. doi: 10.1016/0165-1781(89)90047-4

8. Beck AT, Steer RA, Ball R, Ranieri W. Comparison of beck depression inventories -IA and -II in psychiatric outpatients. *J Person Assess.* (1996) 67:588. doi: 10.1207/s15327752jpa6703_13

9. Kim J, Son WM, Headid III RJ, Pekas EJ, Noble JM, Park SY. The effects of a 12-week jump rope exercise program on body composition, insulin sensitivity, and academic self-efficacy in obese adolescent girls. *J Pediatr Endocrinol Metabol.* (2020) 33:129–37. doi: 10.1515/jpem-2019-0327

10. Chen F, Chen S, Chu I, Liu J, Chang Y. Multicomponent exercise intervention and metacognition in obese preadolescents: A randomized controlled study. *J Sport Exerc Psychol.* (2017) 39:302–12. doi: 10.1123/jsep.2017-0013

11. Hillman CH, Castelli DM, Buck SM. Aerobic fitness and neurocognitive function in healthy preadolescent children. *Med Sci Sports Exerc.* (2005) 37:1967–74. doi: 10.1249/01.mss.0000176680.79702.ce

12. Bass RW, Brown DD, Laurson KR, Coleman MM. Physical fitness and academic performance in middle school students. *Acta Pdiatrica.* (2013) 102:832–7. doi: 10.1111/apa.12278

13. Shigeta TT, Leahy AA, Smith JJ, Eather N, Lubans DR, Hillman CH. Aerobic and muscular fitness associations with adolescent cognitive control: 2029 Board #185 May 30 2:00 PM - 3:30 PM. *Med Sci Sports Exer.* (2019) 51:548. doi: 10.1249/01.mss.0000562147.77946.67

14. Kobilo T, Guerrieri D, Zhang Y, Collica SC, Becker KG, van Praag H. AMPK agonist AICAR improves cognition and motor coordination in young and aged mice. *Learn Mem.* (2014) 21:119–26. doi: 10.1101/lm.033332.113

15. Delezie J, Handschin C. Endocrine crosstalk between skele-tal muscle and the brain. *Front Neurol.* (2018) 9:698. doi: 10.3389/fneur.2018.00698

16. Kim H-J, Lee H-J, So B, Son JS, Yoon D, Song W. Effect of aerobic training and resistance training on circulating irisin level and their association with change of body composition in overweight /obese adults: a pilot study. *Physiol Res.* (2016) 65:271–9. doi: 10.33549/physiolres.932997