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# Comparison of physical activity, sedentary time, and physical fitness among Chinese children and adolescents in Qinghai between 2019 and 2023

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**This study aimed to assess the differences in physical activity and physical fitness in 2019 and 2023 among children and adolescents in Qinghai Province. Data were collected from the Chinese National Survey on Student Constitution and Health (CNSSCH) in 2019 and 2023. The study ultimately included 13,296 participants (5,039 in 2019 and 8,257 in 2023) aged 6–22, including primary, middle, and high school students in Qinghai Province, China. Physical fitness assessments included height, weight, vital capacity, sit-and-reach distance, pull-ups, timed sit-ups, standing long jump, 50-meter dash, 800-meter run, 1000-meter run, 50 m × 8 shuttles run, and timed rope-skipping. Independent samples T-tests and multiple linear regression analyses were employed to explore differences and associations in moderate-to-vigorous physical activity (MVPA), sedentary time (SED), and physical fitness in this population in 2019 and 2023. Compared to 2019, children and adolescents measured in 2023 showed a significant increase in MVPA and a significant decrease in SED. Vital capacity improved significantly across all academic stages, with primary school girls showing improved performance in the 50 × 8 shuttles run. Secondary school students significantly declined in their performance in 800 m and 1000 m runs. Standing long jump performance improved for middle and high school students, while pull-ups declined for high school boys. Timed sit-ups declined for middle school girls, with no significant changes at primary and high school. Flexibility improved for high school boys and both middle and high school girls but decreased for primary school boys and girls, as well as for middle school boys. Timed rope-skipping was measured only in primary school students, and it improved significantly. Speed performance, measured by the 50 m dash, improved in primary school students but declined in middle and high school students. Regression analysis revealed that MVPA was positively associated with vital capacity, 800 m running, standing long jump, pull-ups, and timed sit-ups, while negatively associated with 1000 m running, timed rope-skipping, and 50 m dash. SED was positively associated with 800 m and 1000 m running performance and timed sit-ups. Our study highlights distinct trends in physical fitness across school stages, and sex associations of MVPA and SED with fitness outcomes underscore the need for tailored, region-specific health strategies in high-altitude, underdeveloped areas.**

**Keywords** Physical fitness, Children and adolescents, Qinghai Province, Moderate-to-vigorous physical activity, Sedentary time

With the rapid changes in lifestyles in modern society, children and adolescents around the globe are generally facing the dual challenges of insufficient physical activity and increased sedentary time. The World Health Organization (WHO) reports over 80% of children and adolescents globally fail to achieve the advised standard of 60 min of moderate-to-vigorous physical activity (MVPA) daily[1]. In China, the level of physical activity among children and adolescents is similarly inadequate. Available survey data indicate that the sedentary time of Chinese primary and secondary school students is increasing, mainly due to the growing use of electronic devices, technological advancements, and academic pressures[2].

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Insufficient physical activity and prolonged sedentary time are widely regarded as a significant contributor to a decline in physical fitness with adverse effects on cardiorespiratory fitness, muscle strength, bone density and numerous other health[3]. Previous research into 24-hour movement behaviours has highlighted the importance of achieving an optimal balance between light, moderate and vigorous exercise (LPA, MPA, VPA), sedentary time (SED) and sleep. Furthermore, this overarching framework highlights how these behaviours interact with each other over 24 h, suggesting that sedentary time should not be too long and that a certain intensity and amount of physical activity is achieved to have an impact on physical health and fitness[4–6]. There is a strong association of prolonged sedentary time and insufficient physical activity with an increased risk of obesity and chronic disease, which represents a significant threat to the overall health of adolescents[7].

Adequate physical activity, particularly MVPA, plays a crucial role in enhancing the physical fitness of children and adolescents[8]. Studies have shown that participation in moderate-intensity physical activity for 60 min or more per day has beneficial effects on the physical fitness of children and adolescents[5]. MVPA not only improves cardiorespiratory endurance and muscle strength but also improves body fat levels and reduces the risk of obesity and related diseases, which positively impacts the physical fitness of children and adolescents[9,10]. Furthermore, evidence indicates that reducing SED effectively enhances physical fitness, including joint and muscle function, blood circulation, and metabolic health[11].

In recent years, the Chinese government has actively promoted young people's physical fitness through policies such as the National Student Physical Fitness Standard (CNSPFS) and the National Student Physical Fitness and Health Survey (CNSSCH). In 2016, China released the Healthy China 2030 plan outline, stating that school-age children should be physically active for at least one hour daily. However, even though these policies have contributed to improving young people's physical fitness, the declining trend in young people's physical fitness and health in China is still severe. Surveys show that children and adolescents' physical fitness, including endurance and strength, has declined significantly over the past decade[12,13].

The decline in physical fitness levels is particularly evident in the less developed regions of western China. Compared to the economically developed eastern regions, children and adolescents' physical activity levels and fitness in the western region of China are markedly lower. This is primarily attributable to a combination of factors, including inadequate economic resources, an absence of sports facilities, and the distinctive characteristics of the geographical environment[14,15]. These factors collectively impede physical activity and fitness advancement among children and adolescents in the western region of China, resulting in pronounced disparities in physical fitness across areas.

Qinghai Province is situated in northwestern China at a considerable altitude and exhibits distinctive geographical and climatic attributes. The high-altitude, low-oxygen environment presents adolescents with challenges and opportunities for physical activity and physical fitness. It has been demonstrated that residing in an environment with elevated altitude can facilitate the development of respiratory muscles and enhance the capacity of the blood to transport oxygen, thus improving cardiorespiratory fitness to a certain extent[16]. However, this environment may also increase the burden on the cardiovascular system and affect muscle and bone development. The cold, dry climate of Qinghai Province further limits opportunities for outdoor activities in winter, contributing to a greater preference for indoor activities and sedentary behaviours among adolescents, which negatively affects overall physical activity. Furthermore, the prolonged sunshine and intense UV exposure in Qinghai, while facilitating vitamin D synthesis, may also present a risk to the physical fitness of children and adolescents[17,18].

The unique geographical and climatic conditions of Qinghai Province provide a valuable and distinctive research context for investigating differences in physical fitness among children and adolescents. Therefore, the main aim of this study was to examine the differences in physical activity and physical fitness between results from 2019 and those from 2023, and the secondary aim was to investigate the association of MVPA and SED with physical fitness in children and adolescents in Qinghai Province, China. By analysing the physical fitness data in 2019 and 2023, the physical fitness status of children in different school years was assessed, which provides a reference for optimising and formulating relevant health promotion policies and helping children and adolescents to improve their physical activity and health.

## Materials and methods

### Participants

Data were collected from the Chinese National Survey on Student Constitution and Health (CNSSCH) in 2019 and 2023. This survey is a joint initiative of the Ministries of Education, Health and Science and Technology, the State Ethnic Affairs Commission and the General Administration of Sport of the People's Republic of China. The CNSSCH was conducted in 30 mainland provinces, autonomous regions and municipalities, targeting school-aged students aged 6–22 years to monitor trends in health, nutrition and well-being[19]. Following the 2014 revision of the Chinese National Student Physical Health Standard (CNSSCH), the same stratified cluster sampling method was used separately in 2019 and 2023 to assess body composition, physiological function, and physical fitness among children and adolescents. Although different schools and students were evaluated every year, all participants in this study were from local schools in Qinghai Province, China. In 2019, data were collected from four regions: Haibei Tibetan Autonomous Prefecture, Xining City, Hainan Tibetan Autonomous Prefecture and Yushu Tibetan Autonomous Prefecture. In 2023, the survey covered four different regions: Xining City, Haidong City, Huangnan Tibetan Autonomous Prefecture and Golog Tibetan Autonomous Prefecture (Fig. 1). These areas were chosen to ensure a representative sample across the province, taking into account geographical, ethnic and demographic diversity. Initially, the survey covered a wide age range from primary school to university. For this study, only students from the fourth year of primary school to high school were included, as they could complete both the health and lifestyle questionnaire and the physical fitness assessment. After excluding invalid questionnaires and participants with missing fitness data, 5,039 students in 2019 and

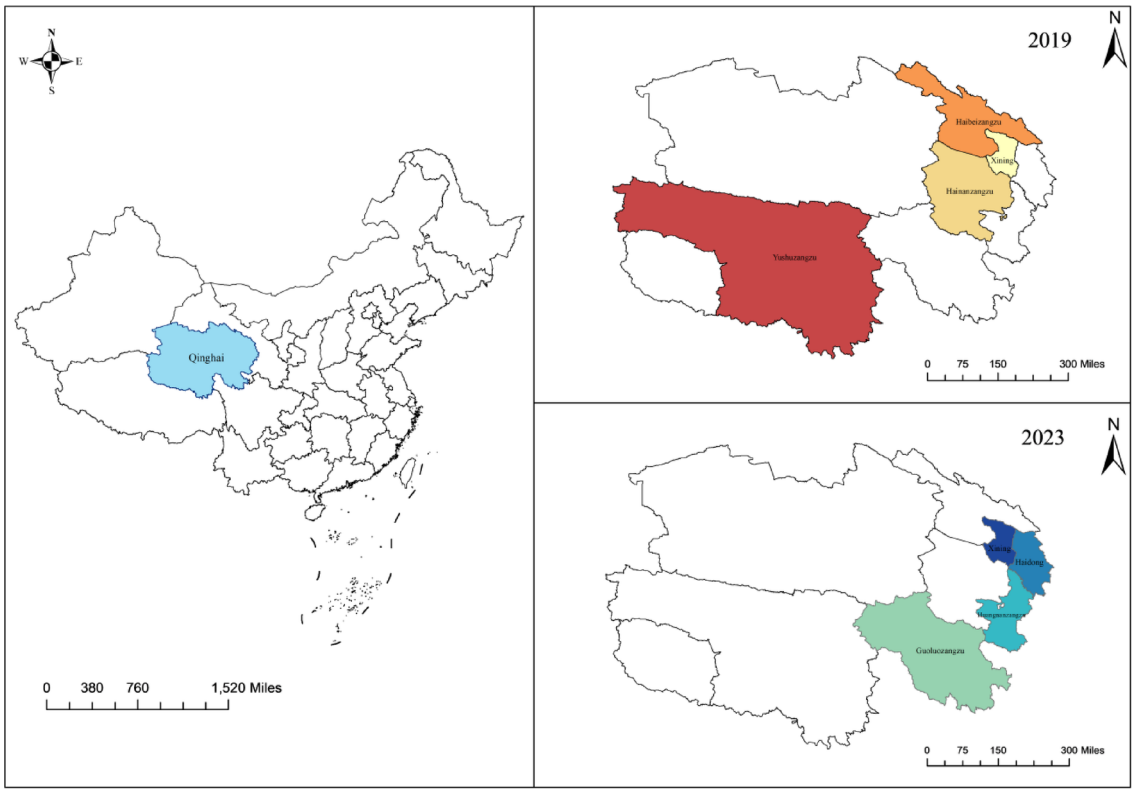


**Fig. 1**. Geographical distribution of sampled schools in 2019 and 2023.

8,257 in 2023 were included in the final analysis, spanning primary, middle and high school stages (Fig. 2). Participants were categorised into three educational stages: primary school, middle school and high school. The study was approved by the Ethics Committee of Shaanxi Normal University (202316016). All studies were conducted in strict accordance with the Declaration of Helsinki and relevant ethical guidelines. All participants and their legal guardians signed an informed consent form prior to testing. Numerical codes replaced students' names to ensure confidentiality.

## Questionnaires

The MVPA variable in this study was calculated from self-reported data collected using the Evaluation Index System of Physical Activity and Fitness of Youth (EISPAFY) questionnaire. Developed by Yueying Hu et al. at the Shanghai University of Sport and validated in the Physical Activity and Fitness in China-The Youth Study (PAFCTYS)[20], the physical activity items were adapted from the International Physical Activity Questionnaire Short Form (IPAQ-SF), which has demonstrated adequate psychometric properties in Chinese student populations[21]. The questionnaire included key items assessing physical activity (PA) and sedentary time (SED), as described below:

1. In the past seven days, how often did you engage in light, moderate and vigorous physical activity (LPA, MPA, VPA)? Please indicate the average daily duration (in minutes) for each.

    (1) Low-intensity physical activity (LPA): Activities requiring minimal physical exertion, such as slow walking, standing light housework (for example, tidying up, washing dishes), and playing musical instruments.
    (2) Moderate-intensity physical activity (MPA): Activities requiring moderate effort and causing slight increases in breathing rate, such as brisk walking, recreational cycling, and skating.
    (3) Vigorous-intensity physical activity (VPA): Activities requiring substantial effort, leading to heavy breathing and significant exertion, such as running, basketball, or fast cycling

2. In the past seven days, how much time per day on average did you spend doing sedentary activities after school, watching TV and using electronic devices, both on school days and weekends?

Participants were asked to report the frequency (days per week) and duration (minutes per day) of each type of activity for both weekdays and weekends. The average daily MVPA was calculated by summing the reported durations of MPA and VPA. Sedentary time was assessed by asking participants about the time spent on sedentary activities, such as screen time and studying, during school days and weekends. The questionnaires

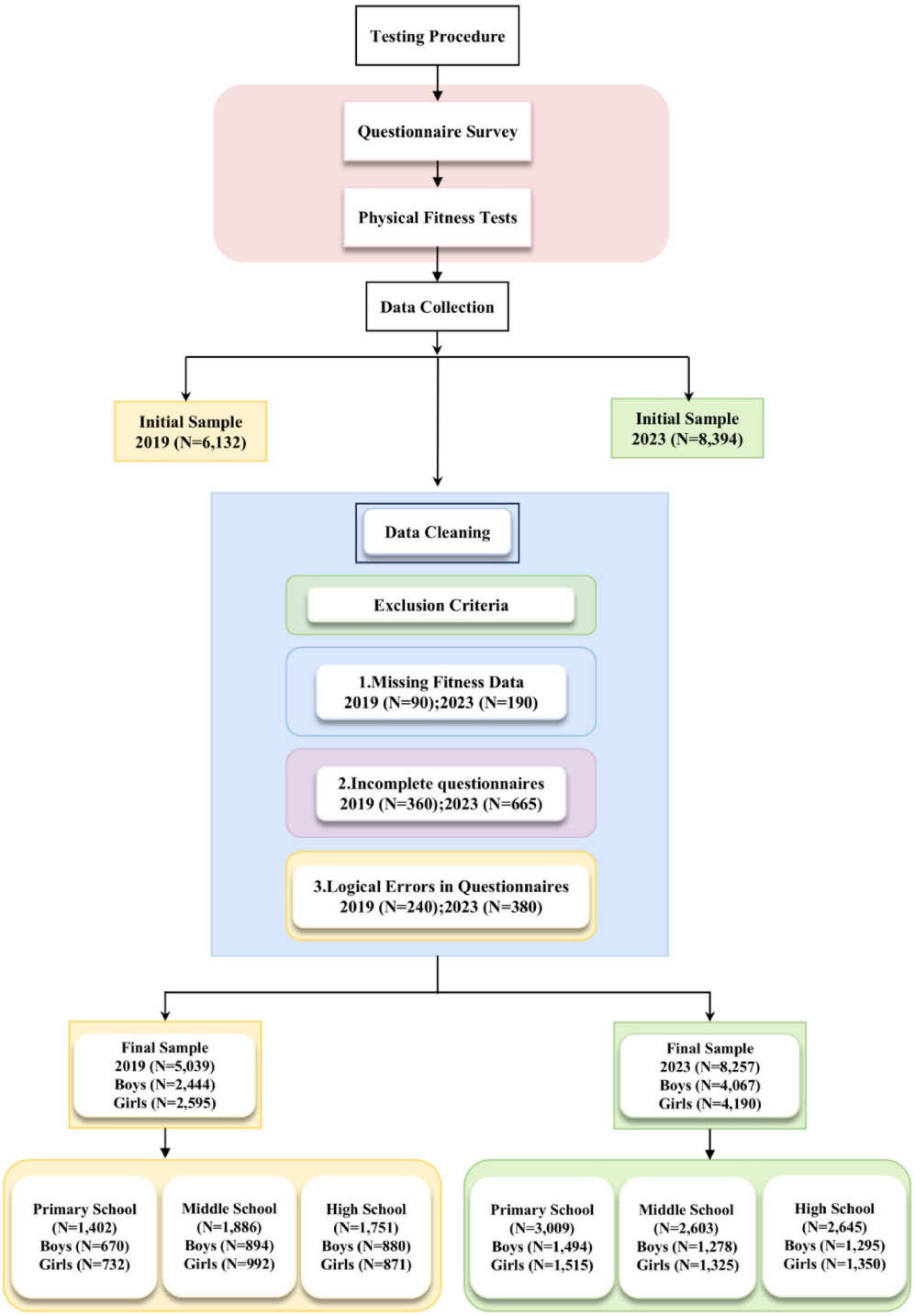


**Fig. 2**. Flowchart of the 2019 and 2023 study design and participants selection process.

were distributed and collected uniformly. Participants completed them independently, with primary school children (aged 6–12) receiving guidance from trained teachers.

## Physical fitness test

In this study, the 2014 revision of the Chinese National Student Physical Fitness Standard (CNSPFS), a widely recognised tool for assessing Chinese adolescents' health and fitness levels[22], was used to assess students' physical fitness. To minimise measurement error, the equipment was calibrated before use, and the tests were conducted uniformly in the mornings throughout November to reduce variability due to different time zones.

The assessment mainly included tests: 50 m dash, standing long jump, sit-and-reach, vital capacity, 800 m and 1000 m running, timed sit-ups, pull-ups, 50 m × 8 shuttles run and timed rope-skipping, categorised into five

domains: endurance, strength, flexibility, speed and coordination[23] (Table 1). A professional physical education teacher conducted a 30-minute warm-up before testing, which included light aerobic exercises, dynamic stretches, and joint mobility drills to prepare participants for the subsequent tests.

The physical fitness tests were carried out carefully to minimise fatigue and ensure accurate results across all domains. The session began with height and weight measurements, followed by the vital capacity test using a digital spirometer. Next, the 50 m dash was performed to assess speed. Strength evaluations followed, starting with the standing long jump to measure lower body explosive strength and continuing with pull-ups (for boys) or timed sit-ups (for girls) to evaluate upper body or core strength. After a short rest period, the sit-and-reach test was conducted to assess flexibility.

Endurance tests were conducted next, beginning with the 50 m × 8 shuttles run to measure short-duration endurance. The 800 m (for girls) and 1000 m (for boys) running were scheduled as the last endurance tests of the session, given their higher intensity and potential to cause fatigue. The coordination test, involving timed rope-skipping, was conducted after the shuttle run and before the long-distance runs. This arrangement ensured that the coordination test, which requires relatively less physical exertion, did not interfere with the performance of the final endurance tests.

To reduce potential fatigue and ensure participants performed at their optimal level, recovery periods of 2 to 10 min were provided between tests, depending on the intensity and physiological demands of each activity. All tests were conducted under the strict supervision of trained professionals to ensure methodological consistency, accuracy, and reliability in the collected data.

## Height/weight

Height and weight were measured using an all-in-one physical examination machine. Participants stood barefoot in a natural posture, and their weight (kg) and height (m) were recorded to one decimal place.

## Endurance

The endurance tests, which include the 50 m × 8 shuttles run, the 800 m running, the 1000 m running, and the vital capacity test, collectively provide a comprehensive assessment of the participants' endurance capabilities. While the vital capacity test is specifically designed to evaluate respiratory endurance, the running tests are intended to assess both aerobic and cardiovascular endurance, thereby providing a comprehensive overview of overall endurance performance.

For the running tests, the 50 m × 8 shuttles run was given to fifth and sixth graders, while the 800 m running was given to female students and the 1000 m run to male middle and high school students. Participants were divided into groups of at least two, who started together. The test began when the "run" command was given, and the timer stopped when the participant's torso crossed the finish line. Results were recorded in minutes and seconds to one decimal place. Warm-up exercises were performed before the test, and participants were guided through relaxation exercises afterwards[24].

The vital capacity test was performed using an electronic spirometer that meets specific technical criteria to ensure a margin of error of ≤ 3%[25]. Participants stood naturally, breathed deeply, and exhaled slowly and continuously without pausing. The test was conducted twice consecutively, with the highest value documented for analysis. This method evaluates respiratory health and capacity[26].

## Strength

The strength tests included assessments of upper limb strength (pull-ups), lower limb strength (standing long jump), and core strength (timed sit-ups). Pull-ups test for middle and high school boys, and timed sit-ups test for middle and high school girls and primary school boys. In addition, the standing long jump test was performed by both boys and girls middle and high school students to assess lower limb strength.

| Test | Primary school | | | Middle school | High school |
|---|---|---|---|---|---|
| | 1–2 Grades | 3–4 Grades | 5–6 Grades | | |
| Height (cm)/Weight (kg) | ▲ | ▲ | ▲ | ▲ | ▲ |
| Vital capacity (ml) | ▲ | ▲ | ▲ | ▲ | ▲ |
| Sit-and-reach (cm) | ▲ | ▲ | ▲ | ▲ | ▲ |
| Pull-ups[a] | – | – | – | ▲ | ▲ |
| Timed sit-ups[b] | – | ▲ | ▲ | ▲ | ▲ |
| Standing long jump (cm) | – | – | – | ▲ | ▲ |
| 50 m dash (s) | ▲ | ▲ | ▲ | ▲ | ▲ |
| 800 m running (girls) (s) | – | – | – | ▲ | ▲ |
| 1000 m running (boys) (s) | – | – | – | ▲ | ▲ |
| 50 m × 8 shuttles run (s) | – | – | ▲ | – | – |
| Timed rope-skipping | ▲ | ▲ | ▲ | – | – |

**Table 1**. Test projects and test group. [a]Boys in middle and high school performed pull-ups test [b]Girls and primary school boys performed timed sit-ups test

The pull-ups test required participants to jump up and grasp the bar with hands shoulder-width apart. Once in a stable position, the body was pulled upwards using both arms simultaneously, ensuring no additional movement. Completion was marked by the chin passing over the bar, and the number of successful pull-ups was recorded for evaluation[27].

For the timed sit-ups test, participants were positioned supine on a pad with their legs slightly apart and their knees bent at about 90 degrees. The fingers were interlocked behind the head, and a partner held the ankles to stabilise the lower limbs. Each sit-up was performed by raising the upper body until both elbows touched or exceeded the knees, then lowering the upper body until the shoulder blades contacted the pad. The total number of sit-ups performed within one minute was recorded[28].

The standing long jump test was performed with the subjects standing naturally with their feet slightly apart, ensuring that the toes did not cross the take-off line. Both feet were required to take off simultaneously, and no additional steps or jumps were allowed. The vertical distance from the rear edge of the take-off line to the closest landing point was measured. Each participant was given three attempts, and the optimal outcome was documented in centimetres[28].

### Flexibility

The sit-and-reach test is an essential flexibility measure. The sit-and-reach test primarily assesses the range of motion of the trunk, waist, hips and other joints in a static position. It evaluates the extension and elasticity of the joints, ligaments and muscles in these areas and indicates the student's overall physical flexibility. During the test, participants must keep their legs straight, feet flat on the floor, about 10–15 cm apart, and their upper body bent forward. The arms are extended, and the fingertips gradually push the cursor forward until no further movement is possible. The inner edge of the tester's longitudinal pedal plate marks the zero point, with inward measurements being negative and forward measurements being positive[28]. The results are recorded in centimetres, including one decimal place, and the best of two attempts is recorded.

### Coordination

The timed rope-skipping test, which is a crucial assessment for both boys and girls primary school students, assesses lower limb explosive strength and overall body coordination. The test involves recording the number of successful jumps completed within 1 minute[29].

### Speed

The 50 m dash test is conducted by grouping participants in pairs or small groups. On receiving the command "run", the participants sprint towards the finish line. The test ends when their torso crosses the vertical plane of the stopping table at the finish line[24]. Time is recorded in seconds, and the results are expressed in one decimal place.

### Statistical analysis

All quantitative variables were summarised using mean (M) and standard deviation (SD). Data analysis was conducted utilising SPSS 27.0 software (I.B.M., Chicago, IL, USA). Normality of 2019 and 2023 data was assessed using kernel density plots, and extreme outliers were eliminated based on a z-score threshold of ± 3.0. Independent samples T-tests were employed to compare the differences in MVPA and SED and physical fitness between the two years. Multiple linear regression analyses were performed separately to examine the associations of MVPA and SED with physical fitness indicators. Each model was adjusted for age, sex, and year to control for potential confounding factors. Statistical significance was set at $p < 0.05$, with $p < 0.001$ indicating stronger levels of statistical evidence.

## Results

### Analysis of differences in MVPA and SED between 2019 and 2023

Figure 3 shows a significant difference in MVPA and SED for boys and girls in different grades in 2023 compared to 2019. For boys, there was a significant increase in MVPA and a significant decrease in SED across 2019 and 2023 ($p < 0.001$). Similarly, for girls, there was a significant increase in MVPA at primary school ($p < 0.001$)and a significant decrease at middle and high school ($p = 0.006$, $p < 0.001$, respectively), and there was a significant decrease in SED at all stages ($p < 0.001$).

### Comparison of physical fitness test performance between 2019 and 2023

Figure 4 compares boys and girls in primary, middle, and high school, focusing on vital capacity, sit-and-reach, and the 50 m dash in 2019 and 2023. For boys, vital capacity increased significantly in 2023 compared to 2019 across all academic stages ($p < 0.001$). However, for sit-and-reach flexibility, while high school boys showed a significant improvement ($p < 0.001$), both primary and middle school boys showed a significant decrease ($p < 0.001$). For the 50 m dash, primary school boys showed a significant improvement ($p = 0.008$), while middle and high school boys showed a significant decrease ($p < 0.001$). Similarly, for girls, vital capacity improved significantly across all academic stages ($p < 0.001$). For sit-and-reach flexibility, middle and high school girls showed significant improvements ($p = 0.007$ and $p < 0.001$, respectively), but primary school girls were significantly reduced ($p < 0.001$). In the 50 m dash, primary school girls improved ($p < 0.001$), whereas both middle and high school girls showed a significant decline in performance ($p < 0.001$).

Figure 5 further compares the results of pull-ups, timed sit-ups, 1000 m running, 800 m running and the standing long jump for boys and girls in middle and high school. For boys, high school students showed a significant decrease in pull-ups ($p < 0.001$), while there was no significant change for middle school boys ($p = 0.117$). Similarly, middle school boys showed a significant decrease in performance in the 1000 m running

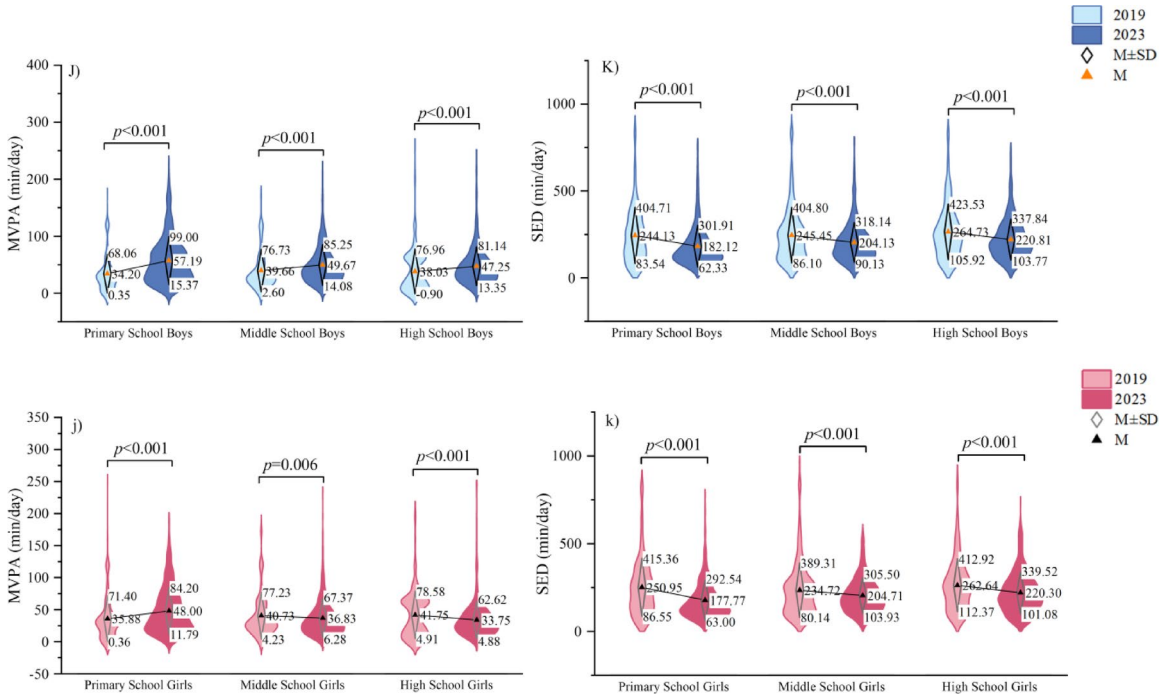


**Fig. 3**. Differences in MVPA and SED in 2019 and 2023.

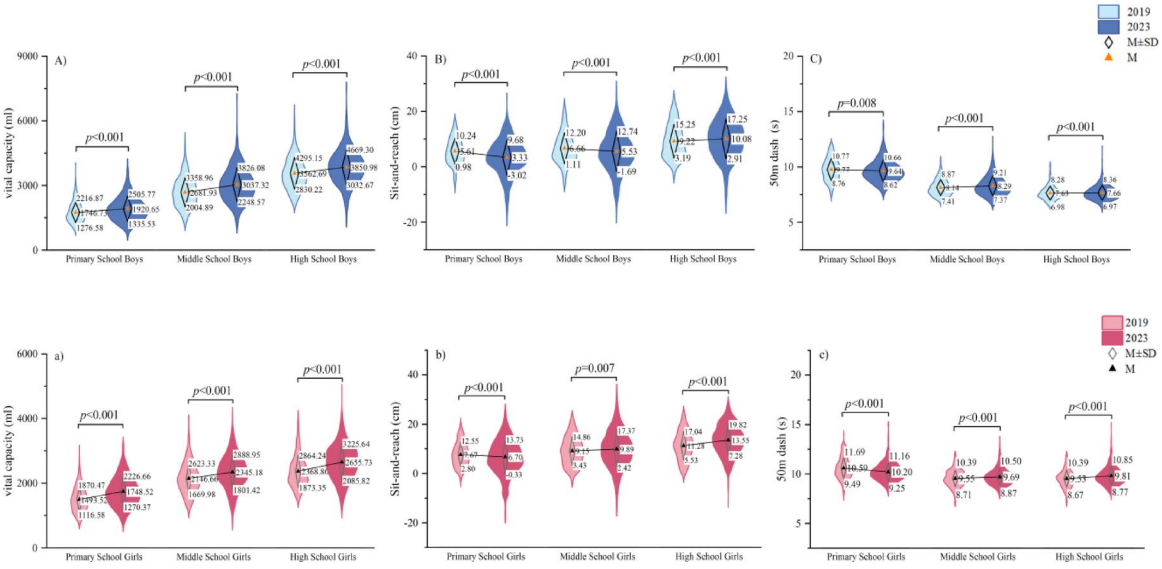


**Fig. 4**. Comparison of performance on vital capacity, sit-and-reach, and the 50 m dash in boys and girls.

($p < 0.001$), whereas there was no significant change for high school boys ($p = 0.053$). There was a significant improvement in standing long jump performance for middle school boys ($p = 0.001$) but no significant change for high school boys ($p = 0.081$). For girls, there was no significant improvement in timed sit-ups performance at high school stages ($p = 0.884$), but middle school girls showed a significant decrease in performance ($p = 0.006$). Both middle school and high school girls showed a significant decrease in 800 m running ($p < 0.001$), while the standing long jump improved significantly for both groups ($p = 0.006$, $p = 0.010$).

Figure 6 compares the results of the timed rope-skipping, 50 m×8 shuttles run and timed sit-ups for primary school boys and girls in 2019 and 2023. Significant improvements were observed in the timed rope-skipping for both boys and girls in 2023 compared to 2019 ($p < 0.001$). There was no significant difference in the 50 m×8 shuttles run for boys ($p = 0.741$), while girls showed a significant improvement ($p = 0.035$). There was also a significant decrease in the timed sit-ups performance for boys ($p < 0.001$), while there was no significant change for girls ($p = 0.060$).

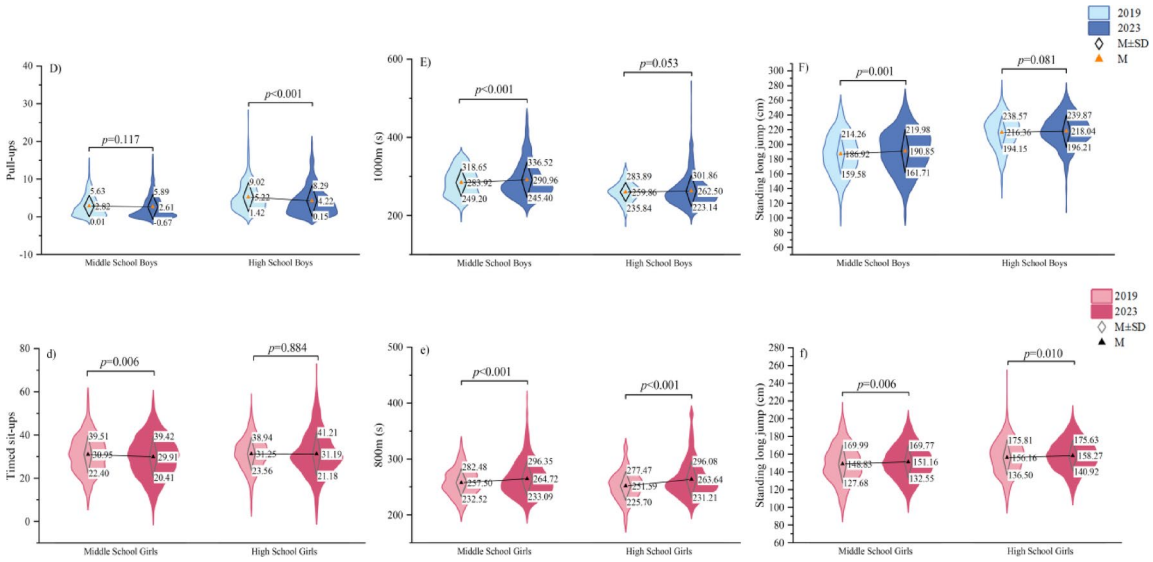


**Fig. 5**. Comparison of performance on standing long jump, pull-ups/timed sit-ups,1000 m/800 m in middle school boys and girls in middle and high school students.

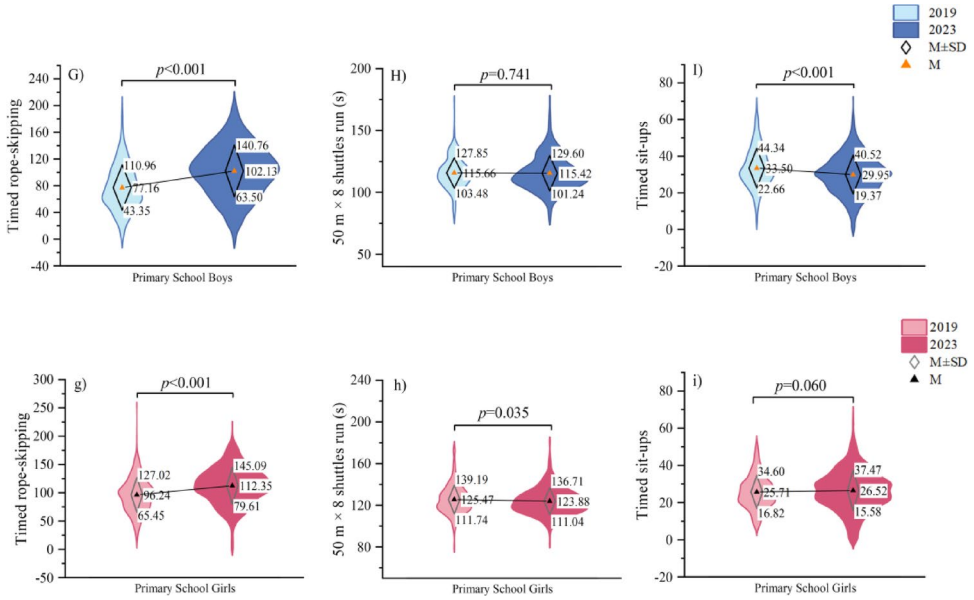


**Fig. 6**. Comparison of performance on timed rope-skipping, 50 m×8 shuttles run and timed sit-ups in primary school boys and girls.

## Association of MVPA, SED with physical fitness performance

Association of MVPA, SED with Physical Fitness Performance in Table 2. MVPA was significantly positively associated with vital capacity (B = 0.613, SE = 0.154, $p < 0.001$), 800 m running performance (B = 0.041, SE = 0.013, $p = 0.002$), pull-ups (B = 0.007, SE = 0.001 $p < 0.001$), timed sit-ups (B = 0.015, SE = 0.003, $p < 0.001$) and standing long jump (B = 0.041, SE = 0.007, $p < 0.001$), while negatively associated with 1000 m running performance (B = − 0.075, SE = 0.016, $p < 0.001$), timed rope-skipping (B = − 0.060, SE = 0.014, $p < 0.001$), and 50 m dash performance (B = − 0.002, SE = 0.000, $p < 0.001$). No significant associations were observed for sit-and-reach (B = − 0.001, SE = 0.002, $p = 0.352$) or 50 m × 8 shuttles run (B = 0.002, SE = 0.006, $p = 0.716$). Similarly, SED showed significant positive associations with 800 m running performance (B = 0.015, SE = 0.003, $p < 0.001$),1000 m running performance (B = 0.009, SE = 0.004, $p = 0.035$), and timed sit-ups (B = 0.002, SE = 0.001, $p = 0.029$). However, SED was not significantly associated with vital capacity, 50 m×8 shuttles run, pull-ups, standing long jump, sit-and-reach, timed rope-skipping or 50 m dash performance (all $p > 0.05$).

| Variable | | B | SE | *p* |
|---|---|---|---|---|
| Model 1: MVPA (min/day) | Vital capacity (ml) | 0.613 | 0.154 | < 0.001 |
| | 50 m × 8 shuttles run (s) | 0.002 | 0.006 | 0.716 |
| | 800 m running (s) | 0.041 | 0.013 | 0.002 |
| | 1000 m running (s) | −0.075 | 0.016 | < 0.001 |
| | Pull-ups | 0.007 | 0.001 | < 0.001 |
| | Timed sit-ups | 0.015 | 0.003 | < 0.001 |
| | Standing long jump (cm) | 0.041 | 0.007 | < 0.001 |
| | Sit-and-reach | −0.001 | 0.002 | 0.352 |
| | Timed rope-skipping | −0.060 | 0.014 | < 0.001 |
| | 50 m dash (s) | −0.002 | 0.000 | < 0.001 |
| Model 2: SED (min/day) | Vital capacity (ml) | 0.074 | 0.042 | 0.076 |
| | 50 m × 8 shuttles run (s) | −0.001 | 0.002 | 0.669 |
| | 800 m running (s) | 0.015 | 0.003 | < 0.001 |
| | 1000 m running (s) | 0.009 | 0.004 | 0.035 |
| | Pull-ups | −0.001 | 0.000 | 0.103 |
| | Timed sit-ups | 0.002 | 0.001 | 0.029 |
| | Standing long jump (cm) | 0.001 | 0.002 | 0.372 |
| | Sit-and-reach | < 0.001 | 0.000 | 0.856 |
| | Timed rope-skipping | −0.006 | 0.004 | 0.104 |
| | 50 m dash (s) | < 0.001 | 0.000 | 0.793 |

**Table 2**. Association of MVPA, SED with physical fitness performance. Model 1 shows associations between MVPA and physical fitness indicators, and Model 2 shows associations between SED and the same indicators. Both models are adjusted for sex, age, and year

## Discussion

This study mainly investigated the differences in physical activity and physical fitness between results from 2019 and those from 2023 using a cross-sectional comparison. Results showed a significant overall increase in MVPA and a significant decrease in SED in 2023 compared to 2019, suggesting a shift toward more active lifestyles, potentially driven by policy interventions, school activity programmes, and heightened public health awareness. Endurance, strength, flexibility, coordination and speed show different changes in different classes compared to 2019. We also investigated the association of MVPA and SED with physical fitness, and mixed associations were found in this population. Further studies are needed to better understand the association of MVPA and SED with physical fitness in children and adolescents in Qinghai Province.

For endurance, vital capacity improved significantly at all school stages. Primary school girls showed improved performance in the 50 × 8 shuttles run, while secondary school students experienced significant declines in the 800 m and 1000 m runs. Strength tests revealed improvements in the standing long jump among middle and high school students but declines in pull-ups for high school boys. Timed sit-ups declined for middle school girls, with no significant changes at primary and high school. Flexibility improved for high school boys and both middle and high school girls but decreased for primary school boys and girls, as well as for middle school boys. Coordination, measured only in primary schools through the timed rope-skipping test, improved significantly compared to 2019. In speed, primary school students improved significantly in the 50 m dash, whereas middle and high school students demonstrated significant declines.

The regression analysis results have shown that MVPA was positively associated with vital capacity, standing long jump, timed sit-ups, pull-ups, and 800 m running performance, while negatively associated with 1000 m running performance, timed rope-skipping, and 50 m dash. SED showed positive associations with 800 m and 1000 m running performance, reflecting a greater running time, and was positively associated with timed sit-ups. No significant associations were found in other variables.

These findings highlight the differing trends of physical fitness development across academic stages. The observed trends may be influenced by physiological changes during puberty, academic stress, and environmental conditions like high altitude. Future research should focus on understanding the specific needs of students at different stages of education, providing a robust theoretical and applied foundation for developing scientific and effective health promotion strategies.

Compared to 2019, the overall MVPA of children and adolescents in 2023 shows a significant increase, and SED shows a significant decrease[30]. These changes may be attributed to national policies, school initiatives promoting physical activity, and growing societal and parental attention to adolescent health. The Chinese government's "Healthy China 2030" strategy has actively encouraged adolescents to engage in at least one hour of daily physical activity. Furthermore, diversifying physical education curricula and increased outdoor activities in recent years likely contributed to greater sports participation[31].

However, MVPA decreased among girls in middle and high schools, potentially due to increased academic pressure. At these stages, students often allocate more time to exam preparation and supplementary classes, reducing opportunities for physical activity[32]. Additionally, physiological and psychological factors, such

as body weight changes or social perceptions of physical activity, may lower high school girls' willingness to exercise vigorously after puberty. The reduction in SED was significant across all academic stages, possibly due to widespread social awareness of the dangers of sedentary behaviour and measures taken by families to reduce time spent on electronic devices[30]. Most schools encouraged the reduction of SED through structured physical activities during breaks, such as organised sports or active breaks. This trend towards reducing sedentary time has helped to improve students' cardiorespiratory health and neuromuscular function.

Endurance in children and adolescents is mainly assessed by vital capacity, the 50 m × 8 shuttles run in primary school and the 800/1000 m run in secondary school. Relative to 2019, vital capacity was significantly higher for both sexes in all school years in 2023. It has been shown that the low-oxygen environment at high altitudes enhances respiratory muscle strength and blood oxygen-carrying capacity, which manifests itself as a gradual adaptive improvement in lung function[16,33]. Additionally, an increase in MVPA and a decrease in SED may also contribute, to a certain extent, to the enhancement of vital capacity. The regression analysis further indicated a significant positive association between MVPA and vital capacity, suggesting that higher physical activity levels contribute to improved respiratory function. Previous studies have shown that MVPA positively affects vital capacity and can improve lung function[34]. Regular and vigorous breathing during exercise will increase the capacity of the respiratory muscles[35]. However, the regression analysis did not show a significant association between SED and vital capacity in this study, suggesting that other factors, such as environmental or developmental influences, might play a more dominant role. While the direct association between SED and vital capacity was not evident in this study, prolonged sedentary behaviour is widely recognised in health. Prolonged sedentary behaviour is known to trigger several chronic diseases, including cardiovascular disease and impaired lung function[36]. Some studies have shown that increased sedentary time can cause fat to accumulate around the ribs, abdomen, and diaphragm. Too much fat can affect ventilation dynamics, reducing lung function[37,38].

The long-distance running endurance test showed a marked difference in performance between the different academic stages. In 2023, the 50 m × 8 shuttles run of primary school girls improved compared to 2019, suggesting better endurance in short-duration, high-intensity interval running. This improvement may be partially related to the significant increase in MVPA among primary school-aged students. However, the regression analysis did not show significant associations between the 50 m × 8 shuttles run and MVPA or SED, which may be because primary school girls have not yet experienced the physiological changes of puberty, such as increased body fat, which has less negative effect on endurance quality. However, the decreasing trend in endurance at the secondary school, with 800 m running for high school girls and 1000 m running for middle school boys, was significantly lower in 2023. Linear regression results showed that MVPA was positively associated with 800 m running in girls but negatively associated with 1000 m running in boys, while SED was positively associated with both endurance indicators. This suggests that increasing MVPA and reducing SED may benefit endurance, particularly in boys. However, despite these positive associations, endurance performance continued to decline, indicating the influence of additional factors. The hypoxic environment at high altitudes exerts a more significant physiological burden on the cardiorespiratory systems of children and adolescents[39], which may be particularly evident in endurance events such as long-distance running.

The pull-ups, standing long jump, and timed sit-ups tests reflect upper-body, lower-body, and core strength in children and adolescents. In terms of lower limb strength, this study found improvements in standing long jump performance in both middle and high school girls and middle school boys. Although middle and high school girls experienced a reduction in MVPA, their standing long jump performance still improved, which could be due to the decrease in SED. Reducing SED may help to maintain or improve lower limb strength because reduced sedentary time can activate muscles and improve muscle activity and neuromuscular coordination, thereby maintaining or improving athletic performance. This improvement in neuromuscular function was significantly enhanced after a prolonged reduction in sedentary behaviour[40]. In middle school boys, the increase in MVPA contributed significantly to the improvement in lower limb strength. Research has shown that MVPA significantly affects the activation of fast-twitch muscle fibres, which are critical for explosive movements such as the standing long jump[41]. Compared to girls, boys are generally more likely to participate in activities associated with strength and explosiveness, such as football, which helps to improve the explosive power of their lower limb muscles[42]. Furthermore, reducing SED not only helps maintain muscle strength but also improves the functionality of the neuromuscular system, leading to improved coordination and performance during physical activity[43].

In our study, the pull-ups performance of high school boys decreased significantly compared to 2019. Although MVPA increased in 2023 compared to 2019, the upper body strength qualities of the boys showed no significant improvement. Research has shown that as adolescents gain weight, the strength required to complete a pull-up increases and that weight gain negatively affects pull-up performance[22]. Meanwhile, inadequate targeted strength training was another critical factor. Failure to regularly train specific upper body muscles, particularly the back and arm muscles, led to decreased pull-up performance in boys[44,45]. Additionally, muscle atrophy resulting from diminished bone strength may occur at elevated altitudes, harming the maintenance of upper limb muscle strength.

Furthermore, significant differences in core strength between girls in different school years were observed. Specifically, the timed sit-ups performance of middle school girls decreased significantly in 2023, whereas there was no significant change in the performance of primary and high school girls. This phenomenon may be related to MVPA changes and SED. The study results showed that MVPA decreased among middle and high school girls and increased among primary school girls in 2023, which may explain the differences in core strength performance between girls of different academic stages. It has been suggested that MVPA plays a crucial role in maintaining and developing strength in the core muscle groups and that a decrease in MVPA may lead to a deterioration in core strength[46,47].

We found that high school boys and middle and high school girls showed significant improvements in sit-and-reach on the flexibility test compared to 2019, despite regression analysis not showing significant associations between MVPA, SED and flexibility. These findings may reflect broader lifestyle or developmental changes. Previous studies show that increased MVPA contributes to enhanced muscle extension and joint flexibility, whereas reduced sedentary time contributes to enhanced flexibility by assisting in maintaining joint and muscle function[48,49]. Improved flexibility in middle and high school girls may be closely linked to physiological changes during puberty, as studies indicate that flexibility typically begins to improve significantly around the age of 11 due to puberty-related developments[50]. As the body develops, joint flexibility and muscle elasticity increase, and girls are able to perform well in flexibility tests even when MVPA decreases. In addition, genetic factors may also have a potential influence on flexibility, and most girls are born with better flexibility, providing a physiological basis for their improved flexibility[51]. Prolonged sedentary behaviour has been shown to lead to the functional deterioration of joints and muscles, while reducing sedentary time promotes joint and muscle health and increases flexibility[52]. These findings suggest that flexibility development may be influenced by physiological, behavioural, and genetic factors.

In contrast, there was a significant decrease in the flexibility performance of primary and middle school boys and primary school girls compared to 2019. Despite a significant increase in MVPA and a significant decrease in SED, primary and middle school boys did not show a concomitant improvement in flexibility but instead showed a decreasing trend. This finding indicates that the impact of changes in MVPA and SED on flexibility may be constrained by physiological factors associated with growth and developmental processes. It has been suggested that adolescents typically experience rapid skeletal growth and development during pre-puberty, and this change may temporarily limit muscle extensibility and joint range of motion[53]. Furthermore, the reduction in flexibility performance among primary schoolgirls may be associated with the type of exercise employed for MVPA. Despite an increase in MVPA, these activities did not improve flexibility. The enhancement of flexibility typically necessitates the implementation of targeted training regimens, such as stretching and yoga. It is unlikely that general physical activity alone will prove an efficacious means of improving flexibility[54]. Therefore, despite an increase in overall physical activity, the absence of targeted flexibility training may be the primary factor contributing to the observed decline in flexibility among primary school girls.

In our analysis of the timed rope-skipping of primary school boys and girls, we found that the timed rope-skipping performance of both sexes improved significantly in 2023 compared to 2019. As a high-intensity explosive exercise, rope skipping not only reflects the explosive power of the lower limbs but also requires coordination of the whole body, especially when performing multiple jumps in a short period, precise rhythmic control of the whole body is crucial[55]. For boys, despite a significant increase in MVPA, regression analysis revealed a negative association between MVPA and rope-skipping performance. This may be explained by short-term muscle fatigue caused by high-intensity physical activity, which temporarily impairs neuromuscular coordination[56]. While increased MVPA likely enhances overall physical fitness, including cardiorespiratory fitness and muscular explosive power, it may not directly translate to improved performance in tasks demanding high levels of neuromuscular coordination, such as rope skipping. However, the performance of girls in the timed rope-skipping test showed an enhancement. This discrepancy may be attributed to sex-specific activity preferences, with girls demonstrating a stronger inclination towards coordination-focused activities such as yoga and skipping, which are known to promote rhythm and whole-body coordination[57].

This study showed a significant increase in 50 m dash for both boys and girls in primary school in 2023 compared to 2019, while there was a decrease in performance for both boys and girls in middle and high school. MVPA has been shown to improve muscle strength and explosiveness, which in turn improves sprinting ability in the short term[58]. This can have a positive effect on the speed of children and adolescents. Reducing SED also improves lower limb explosiveness, which positively affects speed[41]. However, middle and high school students show a significant decline in 50 m dash performance in 2023 compared to 2019. Adolescence is a critical period in which individuals rapidly gain weight and height; this physiological change can negatively affect speed qualities. Adolescent boys and girls gain weight, and, in particular, the percentage of body fat increases, which can affect the performance of fast sprinting ability[59]. In addition, as the academic load increases, particularly in middle and high school, students spend relatively less time in physical activity, especially in the absence of high-intensity training specifically targeting speed, which may further contribute to the decline in speed qualities[60]. Therefore, despite improvements in MVPA and SED, which contribute to students' overall health, specific training targeting speed skills remains inadequate, with implications for improving sports performance.

There were several strengths to this study. First, this study has a large sample size, with data collected from 5,039 students in 2019 and 8,257 students in 2023, respectively, covering a wide range of primary to high school years. Such a large sample size provides high statistical validity and strong representativeness for the results of this study. Second, by comparing the data at the two time points of 2019 and 2023, this study reveals the trend of changes in physical fitness and health across different school segments and sexes, and this longitudinal comparison provides a solid basis for policy formulation and evaluation of interventions.

Several limitations of our study should be considered. First, the participants in this study in 2019 differed from those in 2023. Thus, this was a cross-sectional study that could not definitively infer the causal effects of MVPA and SED on physical fitness. Future cohort studies might better show the long-term impact of MVPA and SED on physical fitness. Second, other potential variables, such as family socio-economic status and dietary habits, which could potentially influence the results, were not adequately controlled for. Third, the sample in this study was only from Qinghai province, which may limit the applicability of the findings to other regions. Future studies could improve the generalisability and explanatory power of the results by integrating data from more regions while controlling for potential confounders such as socioeconomic status and dietary habits. Fourth, while our study focused on MVPA and SED, it did not encompass a more comprehensive 24-hour movement behaviour framework, which includes LPA and sleep. Research has shown that the interactions between MVPA,

SED, LPA, and sleep can provide deeper insights into health outcomes. Future studies should adopt longitudinal designs to examine these interactions and explore their broader health, psychological, and environmental implications. Therefore, future studies should focus on these aspects to make the study more comprehensive and reliable.

## Conclusion

This study found that increased time spent in MVPA and a decrease in SED significantly impacted physical health indicators in children and adolescents. In particular, in terms of vital capacity and lower limb strength, students in all school stages showed varying degrees of improvement in 2023. Some improvements have been found in other variables in strength, flexibility, coordination and speed in 2023 compared to 2019. MVPA had positive effects on vital capacity, 1000 m running, standing long jump, pull-ups, 50 m dash and timed sit-ups, whereas SED had positive associations with 800 m and 1000 m running, suggesting potential negative effects on endurance. Future research should focus on longitudinal studies to assess the long-term benefits of physical activity on fitness in children and adolescents, with diverse samples to better track developmental trends.

## Data availability

The datasets generated and/or analysed during the current study are not publicly available due to the confidentiality of participant information. However, they are available from the corresponding author upon reasonable request.

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## Author contributions

L.Z. conceptualized and designed the study, performed data cleaning and organization, conducted the statistical analyses, drafted the initial manuscript, and reviewed and revised the manuscript. Z.K. and Y.S. supervised the data collection. W.Z. provided guidance on the study design, critically reviewed and revised the manuscript from preliminary draft to submission. Z.L. and Y.L. assisted with data analysis. All authors reviewed the manuscript.

## Declarations

## Competing interests

The authors declare no competing interests.

## Additional information

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