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Associations of sugar-sweetened beverage consumption and screen time with physical fitness index: a multicentre cross-sectional study among Chinese adolescents

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Abstract

Background Past research has focused on the analysis of the association between sugar-sweetened beverages consumption and screen time, respectively, and an indicator of physical fitness in adolescents. However, no studies have analyzed the interaction between sugar-sweetened beverage consumption and screen time on physical fitness index.

Methods Demographic information, lifestyle, sugar-sweetened beverage consumption and screen time were investigated and physical fitness indicators were tested in 8136 adolescents aged 13–18 years from six geographic regions of China using stage-stratified whole population sampling. The chi-square test and one-way ANOVA were used to compare the covariates. The Kruskal-Wallis test was used to compare physical fitness index between different sugar-sweetened beverage consumption and screen time groups. Generalized linear model ordered logistic regression analysis was used to analyze the interaction between sugar-sweetened beverage consumption and ST on physical fitness index.

Results The differences in physical fitness index among different sugar-sweetened beverage consumers in child adolescents were all statistically significant in boys, girls, and in total (H-value of 72.415, 16.859, and 78.544, $P < 0.001$). The differences were also statistically significant when comparing the physical fitness index of Chinese adolescents of different screen time in boys, girls, and total (H-Value of 46.307, 21.552, and 65.287, $P < 0.001$). Overall, using sugar-sweetened beverage consumption ≤ 1time/week and screen time < 60 min/d as the reference group, after adjusting for relevant covariates, adolescents in the group with an sugar-sweetened beverage consumption of ≥ 5 time/week and screen time > 120 min/d ($OR = 2.27$, 95% CI:1.78, 2.89) had the the highest risk of reduced physical fitness index ($P < 0.001$).

Conclusion Associations of sugar-sweetened beverage consumption and screen time with physical fitness indices among Chinese adolescents. Both increased sugar-sweetened beverage consumption and prolonged ST further increased the risk of lower physical fitness index in adolescents.

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Keywords Sugar-sweetened beverages, Screen time, Physical fitness index, Adolescents

Introduction

Physical fitness in adolescents is important for healthy development and will have a trajectory impact on future adult health [1]. A study of more than 750,000 Americans found that for every metabolic equivalent gained, the risk of death was reduced by 14%, and that men and women with cardiorespiratory fitness of 14 metabolic equivalents had the lowest risk of death, with reductions of 76% and 77%, respectively [2]. The study also found that men and women with the highest cardiorespiratory fitness lived 6.0 years and 6.7 years longer than those with the lowest fitness [2]. Another study also confirmed that men in both the high muscle strength and high cardiopulmonary fitness (CRF) groups had the lowest risk of death (*HR*: 0.49; 95% CI: 0.30 to 0.82), using the men in the low muscle strength and low CRF group as a reference, suggesting that there is an association between muscle strength and CRF and risk of death [3]. It is clear that there is a strong link between physical fitness and physical health. However, past research has shown that cardiorespiratory fitness in adolescents has been declining over the years. For example, a survey of physical fitness in U.S. adolescence showed that aerobic endurance declined in girls over the past few decades, but peaked in boys in the 1960s and has since declined [4]. A survey of Australian adolescents aged 6–17 years also confirmed that aerobic endurance levels among adolescents declined at an average rate of 0.24% per year between 1961 and 2002, and that this long-term decline may be related to a combination of socio-economic development, physical activity, dietary behaviors, and psychological and physiological factors [5]. In summary, the trend of declining physical fitness levels among adolescents is spreading throughout the world [6]. The reasons for this decline in physical fitness are multifaceted and closely related to economic development, changes in lifestyle, and increased light physical activity [7–9]. At the same time, it is also associated with the increase in obesity brought about by high-sugar diets, the prolongation of ST leading to a decrease in physical activity time, etc. These factors are important associated factors of the decline in physical fitness of adolescents [10]. Therefore, as a comprehensive index reflecting the physical fitness of adolescents, it is necessary to study the influencing factors of physical fitness index (PFI), which is of great significance for the improvement of cardiorespiratory fitness in the future.

Currently, sugar-sweetened beverages (SSB) has become an important public health problem that threatens the health of adolescents [11, 12]. SSB consumption continues to increase and seriously affects the health of adolescents in various countries. A survey of developing countries showed that SSB consumption among adolescents aged 6–17 years in China increased from 72.0% in 2004 to 90.2% in 2011, and was higher among boys (81.7%) than girls (79.2%), and higher among high-income (87.6%) than low-income families (73.4%) [13]. Increased SSB consumption has many adverse effects on human health, including increased obesity, elevated cardiometabolic disease, increased risk of cancer, increased dental caries, increased risk of cognitive impairment, and other very negative effects on their physical and mental health [14–16]. A survey of U.S. adults confirms the association between SSB consumption and increased mortality from cardiovascular disease (CVD) [17]. In addition, increased SSB consumption has been associated with an increased risk of rectal cancer [18, 19]. However, past studies have mainly focused on the relationship between SSB and various diseases and obesity, but less on the association between SSB and physical fitness indicators. In view of the fact that SSB consumption is gradually increasing in adolescents and has spread from developed countries to developing countries, effective control of SSB consumption in adolescents is imperative and should be given sufficient attention [20].

It has become an indisputable trend that screen time (ST) is prolonging among adolescents. Prolonged ST leads to a decrease in active time for adolescents, such as a decrease in time spent outdoors, a decrease in time spent in moderate to high intensity physical activity, and a decrease in time spent socializing offline, which has many negative impacts on the health of their adolescents. Studies have confirmed that ST prolongation is significantly associated with chronic cardiovascular disease, increased risk of cancer, decreased levels of executive functioning, increased obesity, decreased levels of mental health, and decreased levels of physical fitness. The National Youth Fitness Survey (NNYFS) showed that ST was negatively correlated with all measures of muscular strength in adolescents aged 6–15 years, and was significantly negatively correlated with pull-up ability [21]. This shows that there is a strong correlation between ST and muscle strength in adolescents. Adolescents in developing countries are no exception. A study of Saudi adolescent boys confirmed that prolonged cell phone use was associated with reduced grip strength (r=-0.22, P=0.03), and although the relationship was weak, prolongation of the ST with age may be an important factor influencing hand muscle strength [22]. ST was also negatively associated with cardiorespiratory fitness scores in intellectual adolescents [23]. A survey of Chinese elementary school students showed that ST was positively associated with obesity (β=0.23, P<0.01), thereby affecting jump rope

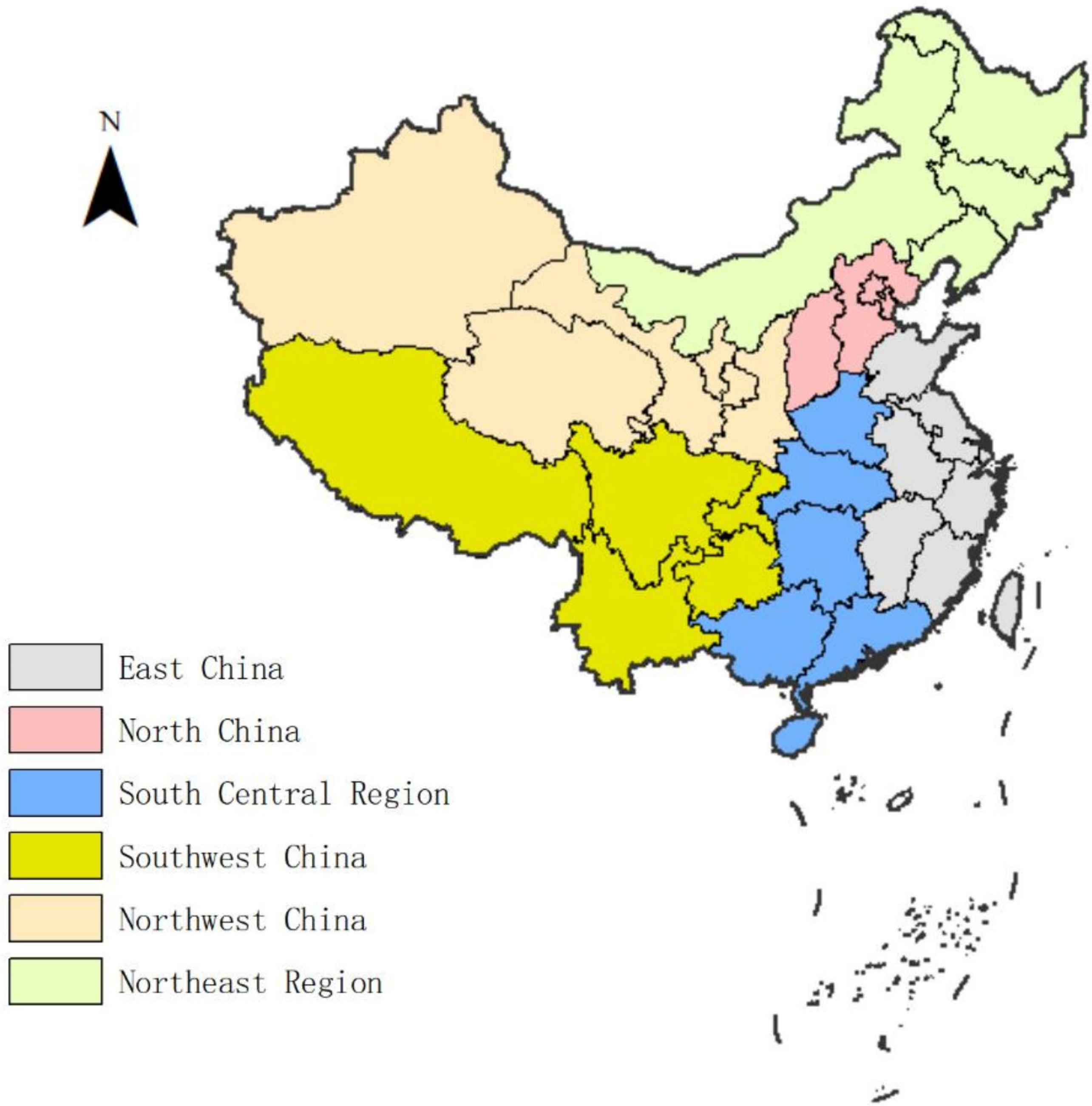

Fig. 1 Regional distribution of the sample of Chinese adolescents participants

performance [24]. It is seen that the continuous lengthening of ST leads to an increase in obesity, which in turn affects the muscle strength of adolescents. In conclusion, increased ST adversely affects the physical fitness of adolescents and is influenced by a combination of confounding factors that should warrant in-depth attention and research.

In addition, ST is not only associated with physical fitness indicators, but also with lifestyle and dietary behaviors. For example, one investigation confirmed that ST was positively associated with daily SSB consumption ($OR=1.98$), which also leads to an increased risk of obesity, affecting physical fitness levels [25]. Collating past literature shows that there is an association between SSB consumption and physical fitness in adolescents. Also there is a strong association between ST and physical fitness. Unfortunately, previous studies have focused on the association between SSB consumption or ST and a single physical fitness indicator, such as muscular strength and cardiorespiratory fitness, while fewer studies have been conducted on the association between PFI, a composite indicator of physical fitness. In addition, no studies have

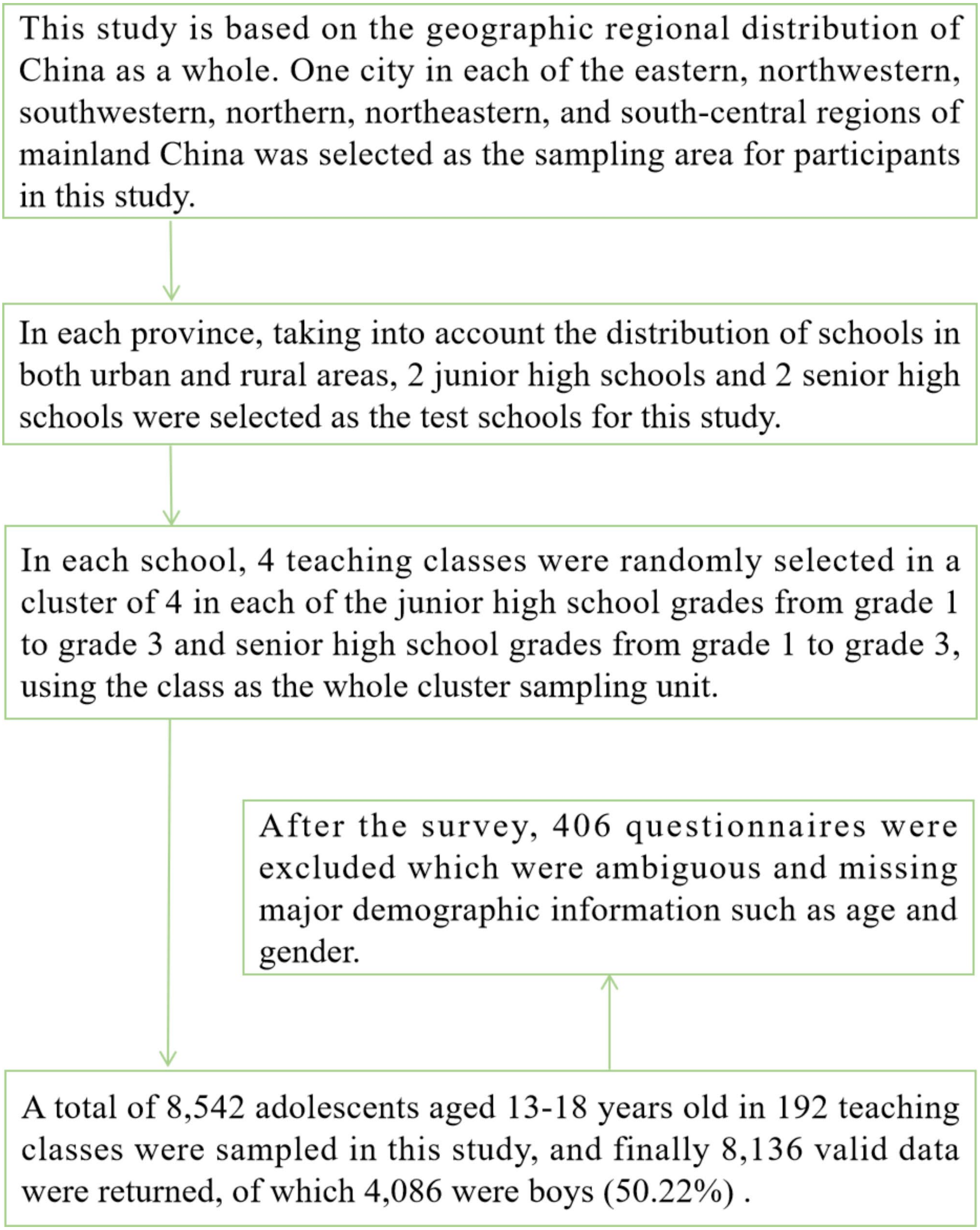

Fig. 2 Sampling flow of participants from adolescents aged 13–18 in China

been found on the association between the interaction effects of SSB consumption and ST on PFI. For this reason, the present study was conducted on Chinese adolescents aged 13–18 years, aiming to analyze the interaction between SSB consumption and ST on PFI, and to provide reference and reference for the improvement and promotion of physical fitness in Chinese adolescents. It also provides reference and assistance to the government and the education sector in formulating public health policies and education policies.

Materials and methods

Participants

In this study, participants were sampled using a three-stage stratified whole cluster sampling method. In the first stage, sampling was based on geographic regions across China (Fig. 1). Six provinces—Shanghai, Xinjiang, Yunnan, Shanxi, Jilin, and Guangxi—were selected. In the second stage, two junior and two senior high schools were chosen in each province, considering both urban and rural areas.In the third stage, in each school, four teaching classes were randomly selected in a whole cluster sampling unit of classes in each of the first to third grades of junior high school and first to third grades of senior high school. A total of 8,542 adolescents aged 13–18 years old from 192 teaching classes were selected for this study, and 406 questionnaires with ambiguous questionnaires and missing major demographic information such as age and gender were excluded from the survey, resulting in the return of 8,136 valid data, of which 4,086 (50.22%) were boys and 4,050 (49.78%) were girls. The inclusion conditions of the participants in this study were: Chinese adolescents in the age group of 13–18 years old who were in school, were physically able to participate in the tests and questionnaires of the relevant physical fitness programs, signed a written informed consent form and voluntarily accepted to be investigated in this study. The study was in accordance with the requirement of the World Medical Association Declaration of Helsinki [26]. Informed consent has been obtained from the parents of any participant under 16 years of age. This study was approved by the Xinjiang Normal University (202145632). Participants in this study were assessed from September through November 2023. The specific sampling process for this study is shown in Fig. 2.

Survey of basic demographic information

The survey of basic demographic information of this study mainly includes the region, school, grade, class, birth year, gender, height, weight. Based on the participants' birth year and test date, the age of the participants was calculated using the most recent birthday as the criterion to calculate the age of the participants in weeks, e.g., 13 means 13.0-13.9 years old. Height and weight were measured according to the instruments and methods required by the National Survey on Students' Constitution and Health (CNSSCH) [27]. The results of the height test were accurate to 0.1 centimeter and the results of the weight test were accurate to 0.1 kg. Body mass index (BMI) was calculated based on the results of the height and weight tests, as weight (kg)/height (m)^2.

Sugar-sweetened beverages(SSB)

SSB consumption was surveyed using an updated version of the 15-item Beverage Intake Questionnaire (BEVQ-15) [28]. The questionnaire was designed to assess participants' SSB consumption over the past 1 month [29]. Participants were assessed by the amount and frequency of intake of 15 beverages in the past 1 month. SSB assessed in this study included sweetened fruit juices, soft drinks, energy or sports drinks, sweetened milk, sweetened nut-based beverages, sweetened coffee, and sweetened tea beverages were all considered as SSB. Based on the BEVQ-15 assessment, we categorized SSB consumption into seven types, which were < 1 time/week, 1 time/week, 2–3 time/week, 4–6 time/week, 1 time/day, 2 time/day, and > 3 time/day. We refer to the categorization methods of other scholars' studies in the past, and in this study, we classified them into 3 categories, which are ≤ 1time/week, 2–5 time/week, ≥6 time/week [30]. Each SSB consumption in this study was recorded in milliliters (mL). Each intake was calculated on the basis of a regular sugary drink bottle in milliliters, which was 330 mL.

Screen time(ST)

The survey of ST in this study was based on the relevant entries in the National Survey on Students' Constitution and Health (CNSSCH) [27]. The survey for this study ST was divided into four entries, which were (1) Time spent lying down or sitting watching a video screen per day, Monday through Friday, on school days? including watching TV, tablet PC, desktop PC, VCR, DVD/VCD. (2) On two days of weekend, daily time spent lying down or sitting down to watch video screens? Include watching TV, tablets, desktop computers, VCRs, DVDs/VCDs. (3) Time spent playing on cell phones or computers each day, Monday through Friday, on school days? Include all types of screen display consoles, computer games, and TV games. (4) Time spent playing cell phones or playing computers per day on both days of the weekend? Including all types of screen-displayed game consoles, computer games, and TV games.This study calculates the average ST in min/day for the past seven days based on the survey time of five days on weekdays and two days on weekends.This study combined the recommended criteria of the American Academy of Pediatrics (AAP) and the classification criteria of past studies by Chinese researchers [31, 32]. In this study, we categorized the video ST into < 60 min/d, 60–120 min/d, and > 120 min/d.

Physical fitness index (PFI)

The physical fitness program of this study included items such as grip strength, sit-ups, standing long jump, sit and reach, 50-m sprint, and 800/1000 meter run.In this study, grip strength was measured using a TK661-WCS-00 type grip strength meter. The results were accurate to 0.1 kg, and the participants were required to stand with their feet naturally apart, hold the grip strength meter handle with the strong arm, and then read the results of the grip strength meter. sit-ups were performed according to the test method required by the National Survey on Students' Constitution and Health (CNSSCH), and the participants were required to stand with their feet together and bend their knees at 90 degrees, and put their arms behind their heads [27]. The test was conducted by a group of two people, with one person testing, the other pressing down on the tester's feet and touching the knee joints with both arms as one test. The test score is calculated by counting the number of times.The standing long jump test requires the participant to stand with feet naturally apart behind the starting line and measure the vertical distance between the landing point of the heel and the starting line after the jump. The results are accurate to 1 cm. The sit and reach test requires the participant to sit on the test sponge mat with both feet together and straight, with both arms stretched forward as far as they can go, reaching forward to the best of their ability, in order to read the test results. Performance is accurate to 0.1 cm. The 50-m sprint requires the participant to run a 50-meter distance as fast as possible in the shortest possible time using a standing start. The test score is accurate to 0.1s. The 800/1000 meter run requires participants to test at the track and field, with boys running the 1000 m run and girls running the 800 m run.Every effort is made to complete the 800–1000 m in the shortest possible time. The test results are accurate to 1s.The VO2max test was based on the performance of the 800-meter and 1000-meter runs, and the VO2max of the participants was deduced by a formula.The extrapolation formula is suitable for Chinese adolescents and has been validated [33]. The specific formula is:

$$\mathrm{VO_{2max}\ (L/min)} = 1.640 - 0.004 \times \mathrm{Gender\ (boys\,1, girls\,2)} \times \mathrm{Times\ (s)} + 0.037 \times \mathrm{Weight\ (kg)}$$

The PFI for this study was calculated as the sum of the Z-score scores for each physical fitness program. Specifically:

$$\mathrm{PFI} = Z_{\text{grip strength}} + Z_{\text{sit-ups}} + Z_{\text{sit and reach}} + Z_{\text{standing long jump}} - Z_{\text{50-m sprint}} - Z_{\text{800/1000-m run}}$$

Covariates

The covariates in this study included father's education, mother's education, commuting to or from school, duration of physical activity, breakfast, snacks, and dairy products in addition to age and gender. Father's and Mother's education is divided into four categories: Elementary School and below, Junior High School, High School, College and above.Commuting to or from school is categorized as Active commuting style and Negative commuting style.Duration of physical activity was categorized as <30 min/d, 30–60 min/d, 61–120 min/d, >120 min/d [27].Breakfast is divided into three categories: ≤1 times/week, 2–3 times/week, and ≥4 times/week. Snacks is divided into three categories: ≤1 times/week, 2–3 times/week, and ≥4 times/week [34].Dairy Products is categorized into ≤1 times/week, 2–3 times/week, and ≥4 times/week [35].

Quality control

The survey and test work of this study were carried out by professional staff who had been trained and assessed. Each testing staff member was responsible for a fixed number of testing items.The testing instruments were calibrated before testing every day. The calibration was done according to the method required by the National Survey on Students' Constitution and Health (CNSSCH) to guarantee the accuracy of the test data [27].The test staff filled in the test scores directly onto the cards after the test, and participants were required not to alter the test scores.The questionnaire survey was also conducted by a trained teacher.The purpose and specific requirements of the survey were explained to the participants before the survey. Participants filled out the questionnaire immediately and handed the completed questionnaire to the staff immediately. The questionnaires were coded anonymously for the survey. The questionnaires were kept and managed by a person.

Statistical analyses

The representation of each covariate in this study for the different SSB consumption and ST child adolescents was done in percentage (categorical variables) and mean ± standard deviation (continuous variables), respectively.Comparisons between categorical variables were performed using chi-square test.Comparisons between continuous variables were performed using one-way ANOVA.

The PFI in this study is a skewed distribution dataset, so the representation of the PFI is done using the median. The specific values of P50 (P25, P75) were presented separately in this study.Comparison of PFI between different SSB consumption and ST groups was performed using the Kruskal-Wallis test and H and P values were presented.

Table 1 Univariate analysis of different SSB and ST in Chinese adolescents(2023, *n* = 8136)

Characteristics	SSB consumption			χ^2-Value	*P*-Value	ST			χ^2-Value	*P*-Value
	≥ 6time/week	2-5time/week	≤ 1time/week			<60 min/d	60–120 min/d	>120 min/d		
N	1690(20.77)	4294(52.78)	2152(26.45)			4169(51.24)	2565(31.53)	1402(17.23)		
Gender										
Boys	859(50.8)	2258(52.6)	969(45.0)	33.063	<0.001	2018(48.4)	1231(48.0)	837(59.7)	60.991	<0.001
Girls	831(49.2)	2036(47.4)	1183(55.0)			2151(51.6)	1334(52.0)	565(40.3)		
Father's education										
Elementary School and below	194(11.5)	561(13.1)	291(13.5)	31.248	<0.001	558(13.4)	308(12.0)	180(12.8)	50.545	<0.001
Junior high school	546(32.3)	1627(37.9)	753(35.0)			1423(34.1)	961(37.5)	542(38.7)		
High School	608(36.0)	1416(33.0)	713(33.1)			1346(32.3)	914(35.6)	477(34.0)		
College and above	342(20.2)	690(16.1)	395(18.4)			842(20.2)	382(14.9)	203(14.5)		
Mother's education										
Elementary School and below	286(16.9)	796(18.5)	404(18.8)	11.790	0.067	776(18.6)	444(17.3)	266(19.0)	48.351	<0.001
Junior high school	557(33.0)	1547(36.0)	734(34.1)			1371(32.9)	951(37.1)	516(36.8)		
High School	558(33.0)	1293(30.1)	665(30.9)			1253(30.1)	821(32.0)	442(31.5)		
College and above	289(17.1)	658(15.3)	349(16.2)			769(18.4)	349(13.6)	178(12.7)		
Commuting to or from school										
Active commuting style	896(53.0)	2181(50.8)	1082(50.3)	3.230	0.199	2117(50.8)	1322(51.5)	720(51.4)	0.405	0.817
Negative commuting style	794(47.0)	2113(49.2)	1070(49.7)			2052(49.2)	1243(48.5)	682(48.6)		
Duration of physical activity										
<30 min/d	874(51.7)	1861(43.3)	1066(49.5)	53.611	<0.001	2166(52)	1036(40.4)	599(42.7)	121.539	<0.001
30–60 min/d	578(34.2)	1814(42.2)	783(36.4)			1510(36.2)	1114(43.4)	551(39.3)		
61–120 min/d	179(10.6)	477(11.1)	213(9.9)			347(8.3)	333(13.0)	189(13.5)		
>120 min/d	59(3.5)	142(3.3)	90(4.2)			146(3.5)	82(3.2)	63(4.5)		
Breakfast										
≤ 1 times/week	105(6.2)	219(5.1)	97(4.5)	34.529	<0.001	170(4.1)	138(5.4)	113(8.1)	113.430	<0.001
2–3 times/week	269(15.9)	790(18.4)	286(13.3)			555(13.3)	487(19.0)	303(21.6)		
≥ 4 times/week	1316(77.9)	3285(76.5)	1769(82.2)			3444(82.6)	1940(75.6)	986(70.3)		
Snacks										
≤ 1 times/week	284(16.8)	628(14.6)	621(28.9)	511.539	<0.001	782(18.8)	469(18.3)	282(20.1)	8.634	0.071
2–3 times/week	729(43.1)	2821(65.7)	1082(50.3)			2366(56.8)	1508(58.8)	758(54.1)		
≥ 4 times/week	677(40.1)	845(19.7)	449(20.9)			1021(24.5)	588(22.9)	362(25.8)		
Dairy Products										
≤ 1 times/week	140(8.3)	236(5.5)	191(8.9)	60.112	<0.001	316(7.6)	155(6.0)	96(6.8)	40.030	<0.001
2–3 times/week	516(30.5)	1659(38.6)	726(33.7)			1354(32.5)	1013(39.5)	534(38.1)		
≥ 4 times/week	1034(61.2)	2399(55.9)	1235(57.4)			2499(59.9)	1397(54.5)	772(55.1)		

Note: N, numbers; SSB consumption, Sugar-sweetened beverage consumption; ST, Screen time

The analyses of the associations between different SSB consumption and PFI, and between different ST and PFI in this study were performed by binary logistic regression analysis. Stratified according to age and gender, with PFI values > 0 and ≤ 0 as cut-off points, the group was divided into a higher PFI group and a lower PFI group [36]. PFI

Table 2 One-way ANOVA for physical fitness programs of Chinese adolescents with different SSB consumption and ST(2023, $n=8136$)

Characteristics	SSB consumption			F-Value	P-Value	ST			F-Value	P-Value
	≥6time/week	2-5time/week	≤1time/week			<60 min/d	60–120 min/d	>120 min/d		
Age(years)	15.56 ± 1.75	15.47 ± 1.71	15.52 ± 1.66	1.748	0.174	15.47 ± 1.64	15.53 ± 1.77	15.53 ± 1.79	1.171	0.310
Height	166.20 ± 8.87	166.39 ± 9.03	166.19 ± 8.48	0.474	0.623	166.57 ± 8.66	165.78 ± 8.94	166.43 ± 9.23	6.523	0.001
Weight	56.34 ± 12.65	56.23 ± 12.19	56.28 ± 11.69	0.048	0.953	56.46 ± 12.01	56.08 ± 12.1	56.04 ± 12.66	1.097	0.334
Body Mass Index	20.28 ± 3.60	20.19 ± 3.39	20.29 ± 3.44	0.711	0.491	20.24 ± 3.37	20.30 ± 3.53	20.11 ± 3.53	1.452	0.234
Grip Strength	30.34 ± 9.61	31.69 ± 10.09	31.85 ± 10.11	13.314	<0.001	31.70 ± 10.18	30.99 ± 9.92	31.55 ± 9.65	4.022	0.018
Sit-ups	22.86 ± 7.32	22.99 ± 6.87	23.20 ± 6.75	1.225	0.294	23.34 ± 6.82	22.56 ± 7.20	22.89 ± 6.75	10.393	<0.001
Standing Long Jump	184.61 ± 32.08	188.90 ± 33.89	189.85 ± 33.71	13.249	<0.001	189.18 ± 33.29	186.73 ± 34	188.29 ± 33.29	4.244	0.014
Seated Forward Bending	36.83 ± 11.92	39.31 ± 11.66	39.25 ± 11.54	29.810	<0.001	39.65 ± 11.56	37.99 ± 12.06	37.64 ± 11.43	23.961	<0.001
50-m Sprint	8.65 ± 1.27	8.50 ± 1.28	8.51 ± 1.24	8.972	<0.001	8.48 ± 1.23	8.62 ± 1.31	8.53 ± 1.28	10.023	<0.001
VO_{2max}	38.55 ± 5.78	39.61 ± 5.64	39.58 ± 5.65	22.908	<0.001	39.5 ± 5.59	39.15 ± 5.64	39.44 ± 6.05	3.174	0.042
PFI	-0.47 ± 2.68	0.03 ± 2.44	0.30 ± 2.45	45.666	<0.001	0.20 ± 2.49	-0.16 ± 2.52	-0.31 ± 2.50	30.278	<0.001

Note: SSB consumption, Sugar-sweetened beverage consumption; ST, Screen time; VO_{2max}, Maximal O_2 consumption; PFI, Physical fitness index

was analyzed as the dependent variable and SSB consumption, ST as the independent variables.The analysis was also stratified by gender.Crude Model was not adjusted for any covariates. Model 1 was analyzed by logistic regression after adjusting for age, father's education, and mother's education. Model 2 was further adjusted for commuting to or from school, duration of physical activity, breakfast, snacks, and dairy products based on Model 1.

The analysis of the interaction between SSB consumption and ST on PFI in this study was performed by means of ordered logistic regression analysis with generalized linear model module.Odds Ratio (OR) and 95% Confidence Interval (95% CI) were presented separately. The analysis was also stratified by gender.Crude Model was not adjusted for any covariates. Model 1 was analyzed by logistic regression after adjusting for age, father's education, and mother's education. Model 2 was further adjusted for commuting to or from school, duration of physical activity, breakfast, snacks, and dairy products based on Model 1.

Statistical analysis of data from this study was performed using SPSS 25.0 (version 25.0; IBM Inc., Armonk, NY) software. Graph Pad Prism 8.0.2 (Graph Pad Software, Inc., CA) was used for images.

Results

In this study, 8136 (4086 boys, 50.22%) Chinese adolescents aged 13–18 years were tested and surveyed on basic demographic information, covariates, SSB, ST and physical fitness items. The mean age of the participants was (15.50 ± 1.71) years. The results in Table 1 show that the proportions of Chinese adolescents with SSB consumption ≥ 6time/week, 2-5time/week, and ≤ 1time/week were 20.77%, 52.78%, and 26.45%, respectively. The proportions of ST < 60 min/d, 60–120 min/d, and > 120 min/d were 51.24%, 31.53%, and 17.23%, respectively.

In terms of different SSB consumption, the proportion of people with different gender, father's education, duration of physical activity, breakfast, snacks and dairy products were compared, and the difference was statistically significant ($P<0.001$).In terms of different ST, the proportion of people with gender, father's education, mother's education, duration of physical activity, breakfast,

Table 3 Comparison of PFI in Chinese adolescents with different SSB consumption, ST(2023, $n=8136$)

Gender	Categorization	N	PFI $P_{50}(P_{25}, P_{75})$	H-Value	P-Value
	SSB consumption				
Boys	≤ 1time/week	969	0.35(-1.23, 1.98)	72.415	<0.001
	2-4time/week	2258	0.04(-1.57, 1.66)		
	≥ 5time/week	859	-0.57(-2.57, 1.13)		
Girls	≤ 1time/week	1183	0.08(-1.37, 1.70)	16.859	<0.001
	2-4time/week	2036	-0.01(-1.57, 1.39)		
	≥ 5time/week	831	-0.31(-1.93, 1.34)		
Total	≤ 1time/week	2152	0.22(-1.32, 1.81)	78.544	<0.001
	2-4time/week	4294	0.01(-1.57, 1.53)		
	≥ 5time/week	1690	-0.45(-2.2, 1.22)		
	ST				
Boys	<60 min/d	2018	0.3(-1.44, 1.87)	46.307	<0.001
	60–120 min/d	1231	-0.12(-1.67, 1.49)		
	>120 min/d	837	-0.51(-2.21, 1.36)		
Girls	<60 min/d	2151	0.14(-1.37, 1.61)	21.552	<0.001
	60–120 min/d	1334	-0.21(-1.82, 1.34)		
	>120 min/d	565	-0.35(-1.83, 1.21)		
Total	<60 min/d	4169	0.2(-1.41, 1.74)	65.287	<0.001
	60–120 min/d	2565	-0.15(-1.78, 1.39)		
	>120 min/d	1402	-0.44(-2.08, 1.32)		

Note: SSB consumption, Sugar-sweetened beverage consumption; ST, Screen time; PFI, Physical fitness index and dairy products were compared, and the difference was statistically significant ($P<0.001$).

The results in Table 2 showed that the differences between different SSB consumption of Chinese adolescents in terms of grip strength, standing long jump, seated forward bending,50-m sprint, VO2max, PFI were statistically significant when compared with each other (*F*-Value of 13.314,13.249,29.810,8.972,22.908,45.666, $P<0.001$). The differences in sit-ups, seated forward bending, 50-m sprint, and PFI among Chinese adolescents of different STs were also statistically significant (*F*-Value 10.393, 23.961, 10.023, 30.278, $P<0.001$).

The results in Table 3 show that the differences in PFI among Chinese adolescents with different SSB consumption among boys, girls, and in total were all statistically significant when compared (*H*-Value of 72.415, 16.859, and 78.544, $P<0.001$).The differences were also statistically significant when comparing the PFI of Chinese adolescents of different ST in boys, girls, and in total (*H*-Value of 46.307, 21.552, and 65.287, $P<0.001$).

The results showed that overall, binary logistic regression analysis was performed with SSB consumption as the independent variable and PFI as the dependent variable.Using SSB consumption≤1time/week as the reference group, after adjusting for relevant covariates (Model 2), child adolescents with SSB consumption≥5time/week (OR=1.47,95% CI: 1.29, 1.68) had a higher risk of having a lower PFI ($P<0.001$).Overall, binary logistic regression analysis was performed with ST as the independent variable and PFI as the dependent variable. Using ST<60 min/d as the reference group, after adjusting for relevant covariates (Model 2), child-adolescents with an ST of 60–120 min/d (*OR*=1.31,95% *CI*: 1.19, 1.45) and child-adolescents with an ST of >120 min/d (*OR*=1.50,95% *CI*: 1.32, 1.70) had a lower PFI were also at higher risk ($P<0.001$). Logistic regression analyses with respect to different genders are shown in Table 4.

Figure 3 shows the trend of ORs for binary logistic regression analysis of SSB consumption, ST and PFI in Chinese adolescents.Overall, it can be seen that with SSB consumption≤1time/week and ST<60 min/d as the reference group, as SSB consumption and ST increased, the risk of lower PFI also increased, and the OR values showed an increasing trend, i.e., shifted to the right continuously. Both boys and girls showed the same trend.

The results showed that overall, SSB consumption of ≤1time/week and ST<60 min/d were used as the reference group. After adjusting for relevant covariates, adolescents in the group with SSB consumption of ≥5time/week and ST>120 min/d (OR=2.27, 95% CI:1.78, 2.89) had the highest risk of developing a lower PFI ($P<0.001$).The analysis of the interaction effect with respect to different genders is shown in Table 5.The trend of the specific ORs is shown in Fig. 4.

Table 4 Binary logistic regression analysis of SSB consumption, ST and PFI in Chinese adolescents(2023, *n*=8136)

Categorization	Lower PFI	Odds Ratio(95% Confidence Interval)		
		Crude Model	Model 1	Model 2
Boys				
SSB consumption	≤1time/week	1.00	1.00	1.00
	2-4time/week	1.22(1.05, 1.42)	1.21(1.04, 1.41)	1.21(1.04, 1.42)
	≥5time/week	1.79(1.48, 2.15) [a]	1.75(1.45, 2.11) [a]	1.69(1.4, 2.06) [a]
Girls				
SSB consumption	≤1time/week	1.00	1.00	1.00
	2-4time/week	1.08(0.94, 1.25)	1.08(0.94, 1.25)	1.07(0.92, 1.23)
	≥5time/week	1.31(1.09, 1.56) [b]	1.31(1.1, 1.57) [b]	1.29(1.07, 1.54)
Total				
SSB consumption	≤1time/week	1.00(Reference)	1.00(Reference)	1.00(Reference)
	2-4time/week	1.14(1.03, 1.27)	1.14(1.03, 1.26)	1.14(1.02, 1.26)
	≥5time/week	1.52(1.33, 1.72) [a]	1.52(1.33, 1.72) [a]	1.47(1.29, 1.68) [a]
Boys				
ST	<60 min/d	1.00	1.00	1.00
	60–120 min/d	1.30(1.12, 1.49) [a]	1.31(1.14, 1.51) [a]	1.36(1.18, 1.58) [a]
	>120 min/d	1.55(1.32, 1.83) [a]	1.57(1.33, 1.84) [a]	1.58(1.34, 1.86) [a]
Girls				
ST	<60 min/d	1.00	1.00	1.00
	60–120 min/d	1.25(1.09, 1.44) [b]	1.26(1.10, 1.44) [b]	1.28(1.11, 1.47) [b]
	>120 min/d	1.36(1.13, 1.64) [b]	1.37(1.14, 1.65) [b]	1.39(1.15, 1.67) [b]
Total				
ST	<60 min/d	1.00	1.00	1.00
	60–120 min/d	1.27(1.15, 1.41) [a]	1.28(1.16, 1.41) [a]	1.31(1.19, 1.45) [a]
	>120 min/d	1.46(1.29, 1.65) [a]	1.48(1.31, 1.67) [a]	1.50(1.32, 1.70) [a]

Note: SSB consumption, Sugar-sweetened beverage consumption; ST, Screen time; PFI, Physical fitness index. Crude Model was not adjusted for any covariates. Model 1 was analyzed by logistic regression after adjusting for age, father's education, and mother's education. Model 2 was further adjusted for commuting to or from school, duration of physical activity, breakfast, snacks, dairy products. a denotes $P<0.001$,b denotes $P<0.01$

Discussion

The results of this study showed that PFI showed a decreasing trend with the prolongation of ST. Previous studies have shown that physical fitness in adolescents shows a decreasing trend, which is closely associated with factors such as high-sugar diet, static behavioral time and prolonged video ST brought by the current lifestyle changes. For example, physical fitness among adolescents in developed countries such as New Zealand

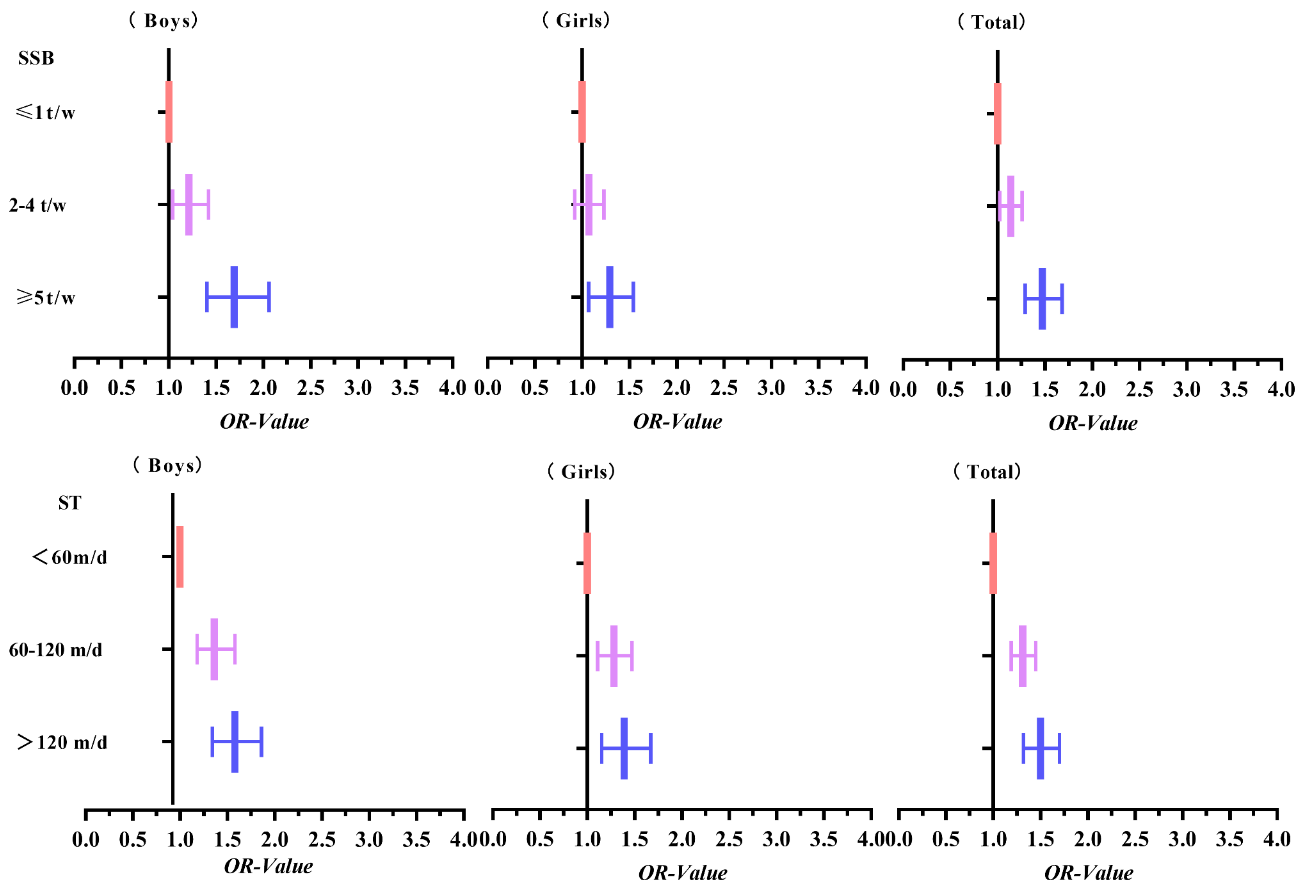

Fig. 3 Trends in OR of interaction between SSB consumption and ST on PFI in Chinese adolescents

[37]and Finland [38] have shown a downward trend and are closely associated with factors such as increased time on electronic video screens, increased time spent in light physical activity, and obesity brought about by high-energy, high-sugar diets. In addition, the decline in the physical fitness of adolescents from year to year is not only seen in developed countries, but also in developing countries. For example, a long-term trend survey of PFI of 1,513,435 Chinese adolescents showed that the PFI of Chinese adolescents decreased by 0.8 from 1985 to 2014, and the decreasing trend of PFI of obese boys was higher than that of girls, which may be mainly related to the increase of the level of economic development that brings the problem of obesity into prominence, and the emergence of the problem of obesity is mainly related to the dietary behaviors of high glucose and high energy. The emergence of obesity problem is mainly related to high-sugar, high-energy dietary behavior [39].

In recent years, there has been a growing body of research on the association of SSB consumption with increased risk of ill health and decreased levels of physical fitness.A study using the British National Diet and Nutrition Examination Program (NDNEP) confirmed the association between SSB consumption and unhealthy cardiometabolic markers in 1687 adolescents aged 4–18 years, suggesting that important health policies to discourage the consumption of sugary beverages are warranted [40]. A study in Malaysian adolescents also confirmed a significant U-shaped and inverse trend between SSB consumption and LDL cholesterol and blood pressure, with adverse effects on cardiometabolic health [41]. However, the health effects of SSB consumption extend far beyond cardiovascular health, as increased SSB consumption also has a direct impact on the physical fitness of adolescents. For example, a survey of 2393 adolescents aged 18–19 years showed an association between SSB consumption and muscular mass index (MMI), with high SSB consumption associated with decreased MMI in boys (β= -0.31) and girls (β= -0.24) and increased SSB consumption being a significant risk factor for decreased MMI. Increased SSB consumption is an important risk factor for decreased MMI [42]. Increased SSB consumption adversely affects cardiovascular health and physical fitness in adolescents, and this trend is spreading from developed to developing countries. A study of 25,893 Chinese adolescents aged 13–15 years also confirmed that high-frequency intake of SSB consumption was associated with reduced muscle

Table 5 Interaction analysis of SSB consumption and ST on PFI among Chinese adolescents(2023, *n* = 8136)

Gender	Classification of interaction		Ordered Logistic Regression	
			OR (95% CI)	*P*-value
	SSB consumption	ST		
Boys	≤ 1time/week	<60 min/d	1.00	
		60–120 min/d	1.44(1.07, 1.95)	0.016
		>120 min/d	1.63(1.15, 2.32)	0.007
	2-4time/week	<60 min/d	1.33(1.08, 1.63)	0.008
		60–120 min/d	1.54(1.23, 1.92)	<0.001
		>120 min/d	1.75(1.36, 2.25)	<0.001
	≥ 5time/week	<60 min/d	1.65(1.27, 2.16)	<0.001
		60–120 min/d	2.35(1.74, 3.18)	<0.001
		>120 min/d	2.95(2.14, 4.06)	<0.001
Girls	≤ 1time/week	<60 min/d	1.00	
		60–120 min/d	1.07(0.83, 1.39)	0.016
		>120 min/d	0.98(0.68, 1.41)	0.007
	2-4time/week	<60 min/d	0.95(0.78, 1.15)	0.008
		60–120 min/d	1.22(0.99, 1.50)	<0.001
		>120 min/d	1.43(1.09, 1.89)	<0.001
	≥ 5time/week	<60 min/d	1.10(0.87, 1.40)	<0.001
		60–120 min/d	1.65(1.23, 2.21)	<0.001
		>120 min/d	1.70(1.16, 2.50)	<0.001
Total	≤ 1time/week	<60 min/d	1.00	
		60–120 min/d	1.22(1.01, 1.49)	0.016
		>120 min/d	1.25(0.97, 1.60)	0.007
	2-4time/week	<60 min/d	1.10(0.95, 1.26)	0.008
		60–120 min/d	1.34(1.15, 1.56)	<0.001
		>120 min/d	1.53(1.28, 1.84)	<0.001
	≥ 5time/week	<60 min/d	1.32(1.10, 1.57)	<0.001
		60–120 min/d	1.93(1.57, 2.38)	<0.001
		>120 min/d	2.27(1.78, 2.89)	<0.001

Note: SSB consumption, Sugar-sweetened beverage consumption; ST, Screen time; PFI, Physical fitness index. Interaction analysis adjusted for age, father's education, mother's education, commuting to or from school, duration of physical education activity, breakfast, snacks, dairy products

strength and that SSB consumption should be effectively controlled [43]. Our study also confirmed that, after adjusting for relevant confounding variables, those with SSB consumption ≥ 5 time/week had a significantly higher risk of developing a lower PFI compared with those with SSB consumption ≤ 1 time/week in Chinese adolescents (*OR* = 1.17,95% *CI*: 1.29, 1.68). Consistent with the findings of several previous studies.

In terms of the association analysis between ST and PFI, the results of this study showed that those with ST > 120 min/d had a significantly higher risk of developing a lower PFI compared with those with ST < 60 min/d in Chinese adolescents (*OR* = 1.50, 95% *CI*: 1.32, 1.70).This suggests that PFI in Chinese adolescents shows a decreasing trend as ST continues to lengthen. The core indicators reflecting PFI were mainly cardiorespiratory fitness and muscle strength aspects.A cross-sectional survey of 1253 school-aged adolescence aged 7 to 17 years in southern Brazil showed that the risk of overweight in adolescence with ST < 2 h/d and ≥2 h/d was 19% and 24%, respectively, and that an increase in ST would lead to an increased risk of reduced CRF in adolescence [44]. A longitudinal study of 175 Japanese adolescents aged 9–12 years showed that limited restriction of excessive cell phone use is important to better ensure the healthy development of CRF in adolescents [36]. Another survey of 395 students with an average age of 12.1 years showed an association between ST and physical fitness measures of cardiorespiratory fitness and muscular strength, calling on parents and policymakers to control the negative impact of ST in adolescence's lives and health [23]. All of the above studies have shown that longer ST in adolescents will lead to a decline in muscle strength and cardiorespiratory fitness, which are the core indicators of PFI. Therefore, effective measures should be taken to control ST in adolescents to better promote physical fitness in future research and policy development.

In the present study, the interaction between SSB consumption and ST on PFI was analyzed, and the results showed that after adjusting for relevant confounding variables, the risk of lower PFI was highest in Chinese adolescents with SSB consumption ≤ 1 time/week and

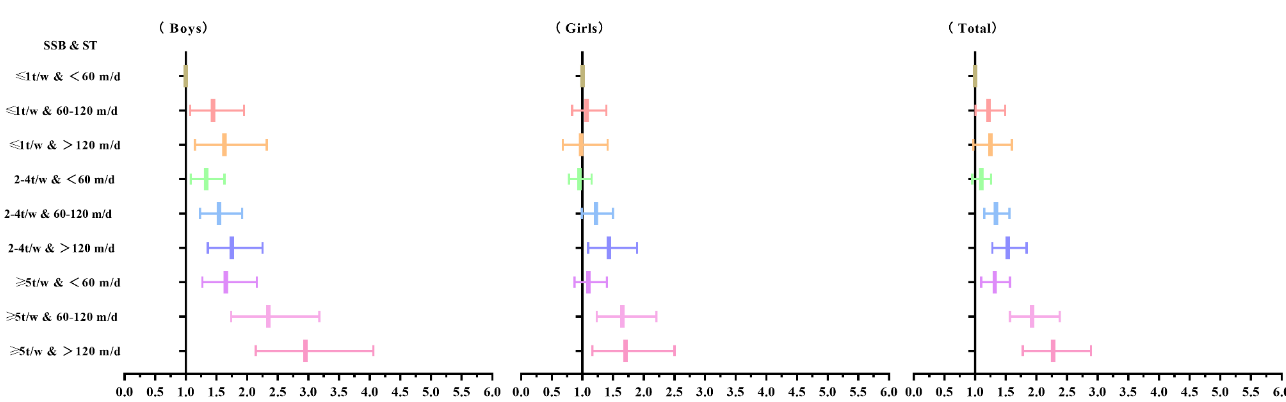

Fig. 4 Trends in OR for the interaction analysis of SSB consumption and ST on PFI among Chinese adolescents

ST < 60 min/d (*OR* = 2.27,95% *CI* = 1.78,2.89), and the risk of lower PFI was highest in adolescents with SSB consumption ≥ 5 time/week and ST > Those with SSB consumption ≥ 5time/week and ST > 120 min/d had the highest risk of lower PFI (OR = 2.27, 95% CI: 1.78,2.89) after adjusting for relevant confounding variables. A study of eating behaviors, behaviors, and obesity in adolescents aged 8–10 years confirmed that prolonged ST and excessive consumption of SSB, as well as a low-protein diet, are associated with a tendency toward metabolically unhealthy obesity and adversely affect physical fitness [45]. The lengthening of ST is bound to lead to a decrease in the time spent in active activities and a further increase in the time spent in sedentary behaviors, leading to a decrease in the level of physical activity, which in turn leads to the development of obesity. At the same time, previous studies have also confirmed that there is a positive correlation between the increase in SSB consumption and the increase in body fat content, and that obese people have a higher demand for SSB consumption, which will inevitably further aggravate the emergence of obesity, and is the main reason for the decrease in the level of physical fitness [46]. In addition, the elevated body weight resulted in participants needing to overcome their own greater body weight resistance when performing tests of physical fitness programs, such as sit-ups, standing long jump, 50-m sprint, and 800/1000-m run, leading to lower test scores. In conclusion, the interaction effects of increased SSB consumption and prolonged ST further led to a decrease in PFI, which adversely affected the physical fitness of Chinese adolescents.

There are some strengths and limitations of this study. Strengths: First, this study analyzed for the first time the interaction between SSB consumption and ST on PFI in Chinese adolescents, which provides a reference and a lesson for the promotion and intervention of PFI in the future. Second, the selection of participants in this study involved six geographical regions in China, and the participants were widely distributed and representative. However, this study also has some limitations. First, this study is a cross-sectional survey study, which can only analyze the association between SSB consumption and ST interaction corresponding to PFI, and cannot understand the causal association that exists between them. Second, this study was conducted using a questionnaire, which was influenced by the recall ability of different participants and avoided some deviation from the actual situation. Third, the covariates in this study are limited, while the factors affecting PFI are multifaceted, and more confounding variables should be included in the future to better analyze the associations that exist between them.

Conclusion

Our study found an association between SSB consumption and ST on PFI in Chinese adolescents, and both increased SSB consumption and prolonged ST further increased the risk of low PFI in adolescents. In the future, schools, families, and communities need to work together to control SSB consumption and ST in adolescents, and to reduce SSB consumption and ST.

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Author contributions
Conceptualization, Zhanjiang Fan, Tao Shi, Di Chai; Data curation, Yaorong Yang; Formal analysis, Wenbin He; Funding acquisition, Zhanjiang Fan; Investigation, Tao Shi; Methodology, Zhanjiang Fan, Tao Shi; Project administration, Zhanjiang Fan, Tao Shi; Resources, Zhanjiang Fan; Software, Tao Shi; Supervision, Yaorong Yang; Validation, Yaorong Yang, Wenbin He; Visualization, Zhanjiang Fan, Tao Shi; Writing—original draft, Zhanjiang Fan, Tao Shi; Writing—review & editing, Zhanjiang Fan, Tao Shi; All authors have read and agreed to the published version of the manuscript.

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Data availability
To protect the privacy of participants, the questionnaire data will not be disclosed to the public. If necessary, you can contact the corresponding author.

Declarations

Ethics approval and consent to participate
The study was in accordance with the requirement of the World Medical Association Declaration of Helsinki. Informed consent has been obtained from the parents of any participant under 16 years of age. This study was approved by the Xinjiang Normal University (202145632).

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Conflict of interest
The authors declare no conflict of interest.

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