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Sex differences in the association between waist circumference and physical fitness index among Tajik adolescents in the Pamir Mountains of Xinjiang, China: an observational study

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Abstract

Background It has been reported in the literature that waist circumference (WC) was related to physical fitness in adolescents. However, the association between WC and PFI(physical fitness index), a comprehensive indicator of physical fitness, has been less studied. In addition, it is not clear whether the association between WC and PFI changes depending on altitude, ethnicity, and sex. This study further revealed the correlation between WC and PFI among adolescents in high-altitude areas and provided references for the physical and healthy development of adolescents in high-altitude areas.

Methods In this study, a total of 1705 Tajik adolescents aged 13–15 years were selected using stratified whole-population sampling. WC and physical fitness items (grip strength, standing long jump, 50 m dash, and endurance run) were assessed and a standardized method was used to calculate PFI. The association between WC and PFI was analyzed by curvilinear regression analysis.

Results The mean and standard deviation of WC and PFI for Tajik adolescents aged 13–15 years old on the Pamir Plateau in Xinjiang, China, were 68.26 ± 7.75 cm and − 2.00 ± 3.47 respectively. Comparison of PFI between groups of Tajik adolescents with different WC showed that inter-group comparisons had significant effects with effect size above 0.2. The Tajik adolescents' PFI reached its highest when WC was 61 cm for boys(-1.3207), and 60 cm for girls (-1.0556).

Conclusions The association between WC and PFI in Tajik adolescents showed an inverted "U" curve, with no sex difference. It is recommended that the WC of Tajik adolescents should be controlled between 60 and 61 cm to maintain better PFI levels. The study provides support and reference for educational policy-making and public health prevention in the Pamir Plateau in Xinjiang, China.

Keywords Waist circumference, Physical fitness index, Adolescents, Pamir Mountains

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Introduction

In recent years, with changing lifestyles, adolescents have been spending more time in static behaviors and screen time, and their levels of physical activity have been declining [1]. In addition, many changes are taking place in the dietary structure, including the continued increase in behaviors such as high-energy diets and high-sugar diets, which are leading to obesity and chronic diseases among adolescents [2]. This has been accompanied by a steady decline in physical fitness levels, including muscle strength and cardiorespiratory fitness [3]. The physical fitness index (PFI) is a comprehensive indicator of physical fitness in adolescents and has been widely used in several studies [4, 5]. Physical fitness is an important marker of adolescents' physical and mental health and academic performance and is strongly associated with most health indicators [6]. A United States study found that only 40% of adolescents have healthy cardiorespiratory fitness [7]. Adolescents in developing countries are no exception. A national survey of Chinese adolescents from 1985 to 2014 showed that adolescents' PFI in 2014 decreased by 0.8 compared to 1985 [8]. A study of adolescents in Xinjiang, China, also showed that the PFI of adolescents in Xinjiang declined to -3.8 in 2014 compared to 1985 [9]. A decline in PFI will lead to a range of adverse problems, including negative impacts on adolescents' academic performance, and mental health [5]. However, the factors affecting PFI in adolescents are multifaceted, including dietary behaviors, lifestyle, and exercise habit factors. Fewer past studies have addressed WC and PFI [10].

WC is one of the important indicators of health for adolescents, which can objectively reflect the health status of adolescents [11]. Studies show that WC is more sensitive and accurate in predicting chronic cardiovascular disease compared to body mass index (BMI) [12]. As a result, in recent years, the changes in WC among adolescents have attracted widespread attention around the world [13]. A study of American youth shows that WC is continuing to grow [14]. WC is also on the rise in Australian adolescents, posing a serious threat to cardiovascular health [15]. China is no exception, with youth WC levels showing a continuing trend of increase [16]. It is of concern that the continued increase in WC in adolescents will not only have a negative impact on adolescent health, but will also have a trajectory of negative impacts on future adult health, leading to an increased risk of chronic diseases, cardiovascular disease, diabetes, and cancer in adulthood [17, 18].

The continuing increase in WC among adolescents has many health consequences and has become a public health issue for countries around the world. In addition to this, the continued increase in WC also has a negative impact on physical fitness [19]. Studies have shown that a sustained increase in WC will result in a downward trend in muscular strength and cardiorespiratory fitness [20]. There are also studies confirming that an increase in WC will lead to a decrease in muscle strength [21]. A study of young people in Switzerland confirms that cardiorespiratory fitness and physical health tend to decline as WC and waist-to-height ratios increase [22]. It has also been shown that an increase in WC in adolescents means a continued increase in body weight, which will lead to a decrease in performance in standing long jump and endurance events, as participants need to overcome their own greater body weight resistance during the assessment of these events, which leads to a decrease in muscular strength and endurance levels [23, 24]. Therefore, there is a need to focus on the impact of changes in adolescent WC on PFI to better promote adolescent health.

Tajiks live mainly in the Pamir Plateau region of Xinjiang, China [25]. The average altitude of this region is more than 4,000 m above sea level, and living at high altitudes for a long period has led to the formation of physical characteristics of Tajik youth that are different from those of youth in the plains [26]. In addition, differences in ethnic composition, living environments, and levels of economic development have led to certain differences in the physical health of Tajik adolescents living at high altitudes and Han Chinese adolescents in the plains [25]. However, previous studies have mainly focused on the study of a particular physical health item in Tajik adolescents, such as lung capacity and BMI [25]. In contrast, studies of PFI in Tajik adolescents have not been found. At the same time, studying the association between WC and PFI in Tajik adolescents will have a positive impact on better promoting the physical fitness level of Tajik adolescents in the future. This study aimed to analyze the correlation between WC and PFI in adolescents at high altitudes, to provide a reference for the physical health development of adolescents at high altitudes. This study hypothesized that there is a negative correlation between WC and PFI and that this relationship does not change according to sex.

Methods

Study design

The present study was conducted from September to November 2023 in Tashkurgan Country, which is a country of the Xinjiang Uygur Autonomous Region and located in the southeastern part of the Pamir Plateau with an average altitude of over 4,000 m.

Two junior high schools in Tashkurgan Country were selected as the survey schools for this study. Stratified whole cluster sampling was used to identify the participants and class was used as the sampling unit [27]. As a result, all Tajik adolescents in the 1–3 grades from the two junior high schools were selected as participants for the present study.

Inclusion and exclusion criteria

Inclusion criteria for the participants

The inclusion criteria for participants in this study were: 1)both the parents were Tajik; 2)T lived in Tashkurgan County for three or more consecutive years; 3) both the adolescents and their parents volunteered to be surveyed for this study; 4)be able to participate in the relevant physical fitness program; 5) 13–15 years old.

Exclusion criteria for the participants

The exclusion criteria for participants in this study were: 1)one of the fathers or mothers was non-Tajik; 2)the participants were non-Tajik; 3)had not resided continuously in Tashkurgan County for three years or more; 4)their parents or guardians did not consent to the study's investigations; 5)the participants themselves did not want to take part in the study's investigations; 6)the participants' age was not in the range of 13–15 years.

This study adheres to the STROBE reporting guidelines requirements [28]. The specific participant sampling process is shown in Fig. 1.

This study complies with the ethical guidelines of the Declaration of Helsinki. The study investigation was tested with the informed consent of the participant's parents and the participants themselves. Participants were asked to sign a written informed consent form before testing. Participants under the age of 16 have obtained informed consent from their parents or legal guardians.

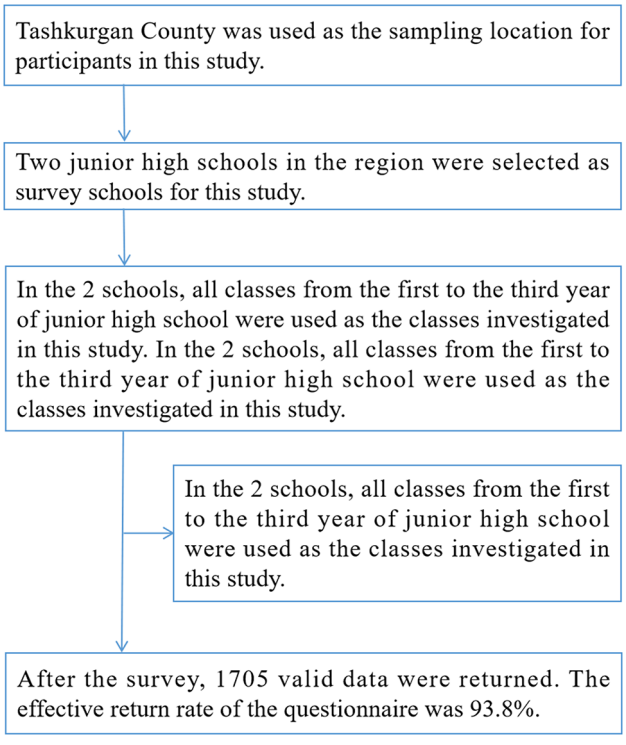

Fig. 1 Flow chart for sampling Tajik adolescent participants

This study was approved by the Human Subjects Ethics Committee of Xinjiang Normal University (202305454).

Outcome measures

Waist circumference

WC was assessed following the instrumentation and assessment methods required by the China National Survey on Students' Constitution and Health (CNSSCH) [27]. A standard GARANT EG III nylon tape measure was used for the evaluation of WC. Participants were asked to wear as little clothing as possible, circle the waist horizontally at 1 cm above the navel, and read the results of the assessment. The assessment results were accurate to 0.1 cm. After the assessment, a staff member filled in the assessment results on a test card [27]. The assessment is carried out in the school infirmary by sex.

Physical fitness index(PFI)

The PFI in this study included physical fitness items such as grip strength, standing long jump, 50 m dash, and endurance run. The assessment was conducted following the instrumentation and assessment methods required by the China National Survey on Students' Constitution and Health (CNSSCH) [27].

The specific assessment methods are as follows: (1) Grip strength, the participant is in a standing position with both arms hanging down naturally. The strong arm is used to hold the handle of the grip strength meter, and the grip strength meter is held with maximum strength. Each participant was assessed twice and the highest score was taken. The test results are accurate to 0.1 kg [27]. (2) Standing long jump, which requires the participant to perform a standing long jump. The combination is required to stand with both feet behind the starting line and jump forward as far as they can with both feet, measuring the vertical distance between their heels and the starting line. The results are accurate to 0.1 cm [27]. (3) 50 m dash, which requires participants to run a distance of 50 m quickly in the shortest possible time. The results were assessed to the nearest 0.01 s [27]. (4) Endurance run, where participants tested 1000 m for boys and 800 m for girls. Participants were asked to complete either the 1000 m–800 m in as short a time as possible. A standing start was used for the measurement. The results were assessed to the nearest "s" [27].

Standardized Z-scores were calculated based on participants' assessment results for each physical fitness item, using the mean and standard deviation of Han Chinese 13-15-year-old students from the 2019 China National Survey on Students' Constitution and Health (CNSSCH) as a reference [27]. Z-scores are calculated separately according to different ages and sex. Z-score = (actual measurements −2019 test mean) / 2019 test standard deviation. The calculation of PFI in this study included

four physical fitness events. As the 50 m dash and endurance run events were assessed using time, the shorter the time, the better the participant's performance on the assessment. Specifically for:

$$PFI = Z_{grip\,strength} + Z_{standing\,long\,jump} - Z_{50\,m\,dash} - Z_{endurance\,run}$$

Quality control

Participants are required to be well prepared for the assessment of the relevant physical fitness program to prevent physical injuries. The assessment required that as light clothing as possible be worn for the test. Assessment staff calibrated the instrument as required before each day's assessment [27]. The assessment results were filled out on an assessment card after the test, and participants were asked not to make any alterations to their assessment scores [27].

Statistical analysis

GPower 3.1 software was applied to estimate the required sample size for this study, and the minimum sample size output by the software was 1236 cases, and the minimum sample size for inclusion in this study was 1484 cases considering a 20% sample size loss. The actual sample size of this study is 1705 cases, which meets the experimental requirements [29].

The raw data from the assessment were checked against the questionnaire for verification of out-of-range values. In cases where there are missing scores for a particular assessment, the mean values are substituted according to age and sex. The different physical fitness indicators were expressed as mean and standard deviation. Data were tested for normality, and comparisons between groups of data that met normality were made using the independent samples t-test. Data that did not conform to a normal distribution were compared using the Mann-Whitney test.

The WC values of the participants were divided into four groups of WC<25th Percentile, 25th≤WC<50th Percentile, 50th≤WC<75th Percentile, and WC≥75th Percentile according to the percentile of sex and age. Comparisons of the assessment results of each physical fitness item and PFI between different WC groups were performed. Comparisons between groups were made using effect size. The effect size between the two groups was calculated based on the mean and standard deviation. According to the relevant literature, effect size=0.2 is a small effect, effect size=0.5 is a medium effect, and effect size=0.8 is a large effect [30]. The exploratory analysis revealed that there is a curvilinear correlation between WC and PFI, so a quadratic equation was used to analyze the correlation between WC and PFI. The analysis of the association between WC and PFI in this study was analyzed using curvilinear regression analysis. Curvilinear regression analysis was performed with PFI as the dependent variable and WC as the independent variable. $Y=aX^2+bX+c$; X denotes WC, Y denotes PFI; a, b, c denote constants. A statistical significance level of 0.05 was used. Data analysis and data visualization were performed using SPSS 25.0 software and Graph Pad Prism 8.0.2.

Results

This study tested 1817 Tajik adolescents aged 13–15 years on physical fitness programs and basic demographic information. After the survey, 112 invalid data were excluded and 1705 valid data were returned. The effective return rate of the questionnaire was 93.8% and 1705 data (837 boys, 49.1%) were obtained for the present study.

The mean age of the participants was (14.05±0.81) years. Overall, WC was assessed to be (68.26±7.75) cm and PFI was (-2.00±3.47) in Tajik adolescents aged 13–15 years. Comparison between sexes showed that boys (69.50±7.86) had higher WC scores than girls (67.07±7.44), and the difference was also statistically significant (t=6.558, P<0.001). PFI, as it is a non-normally distributed data, after using the Mann-Whitney test, showed that boys (-2.16±3.53) had lower PFI than girls (-1.84±3.41), and the difference was statistically significant (Z-value=-2.03, P=0.041).

Concerning the different physical fitness programs, overall, boys' performance in height, weight, grip strength, standing long jump, and 50 m dash was higher than girls, and the difference was statistically significant (t=15.069、5.729、23.282、30.791、-20.617, P<0.001); boys' endurance run scores were lower than girls, and the difference was also statistically significant (t=9.537, P<0.001). A comparison of the indicators by age group is shown in Table 1.

The WC was divided into four groups according to the percentiles of different sex and ages, and the effect size was used for comparison between groups. For boys, overall, the PFI of Tajik adolescent boys in the Pamir Plateau of Xinjiang, China, had a significant effect size of 0.2 or more for all group comparisons, except for group B, which had no significant effect compared with group C (effect size=0.1). Comparisons between groups of different items in each age group are shown in Table 2.

For girls, overall, the PFI of Tajik adolescent girls in the Pamir Plateau of Xinjiang, China, was compared among the A/D, B/D, and C/D groups, with effect sizes of 0.5, 0.6, and 0.6, respectively, with a significant effect. Other gradual comparisons had no significant effect. Comparisons between age groups for different items are shown in Table 3.

Table 1 Basic physical fitness status of Tajik adolescents on the Pamir Plateau in Xinjiang, China (M ± SD)

Age(yrs)	*N*	Height	Weight	Waist circumference	Grip strength	Standing long jump	50 m dash	Endurance run	Physical fitness index
Boys									
13yrs	248	156.21 ± 8.65	46.45 ± 10.24	67.81 ± 8.02	25.13 ± 6.91	171.86 ± 25.01	9.13 ± 1.25	316.12 ± 54.32	-1.97 ± 3.19
14yrs	296	163.02 ± 8.29	52.13 ± 10.55	69.71 ± 7.90	30.67 ± 7.85	186.19 ± 26.41	8.89 ± 1.29	300.57 ± 54.56	-2.07 ± 3.48
15yrs	293	167.66 ± 7.43	55.71 ± 9.90	70.72 ± 7.44	34.68 ± 8.40	197.38 ± 27.00	8.74 ± 1.44	288.09 ± 53.15	-2.42 ± 3.83
13-15yrs	837	162.63 ± 9.31	51.7 ± 10.88	69.50 ± 7.86	30.43 ± 8.67	185.86 ± 28.11	8.91 ± 1.34	300.81 ± 55.09	-2.16 ± 3.53
Girls									
13yrs	276	154.51 ± 6.28	46.46 ± 7.95	65.65 ± 7.40	20.93 ± 5.03	143.06 ± 21.02	10.22 ± 1.36	283.36 ± 41.98	-1.84 ± 3.18
14yrs	276	157.24 ± 5.79	48.84 ± 7.95	67.38 ± 7.53	22.36 ± 5.42	147.42 ± 22.62	10.25 ± 1.41	276.4 ± 43.01	-1.73 ± 3.33
15yrs	316	158.61 ± 5.87	51.46 ± 7.94	68.04 ± 7.23	23.24 ± 6.03	152.59 ± 22.92	10.39 ± 1.49	275.27 ± 41.3	-1.92 ± 3.67
13-15yrs	868	156.87 ± 6.21	49.04 ± 8.21	67.07 ± 7.44	22.23 ± 5.61	147.92 ± 22.56	10.29 ± 1.43	278.2 ± 42.17	-1.84 ± 3.41
Total									
13yrs	524	155.32 ± 7.53	46.46 ± 9.10	66.67 ± 7.77	22.92 ± 6.34	156.69 ± 27.11	9.71 ± 1.41	298.87 ± 50.87	-1.90 ± 3.19
14yrs	572	160.23 ± 7.75	50.54 ± 9.52	68.59 ± 7.81	26.66 ± 7.95	167.48 ± 31.35	9.54 ± 1.51	288.91 ± 50.75	-1.91 ± 3.41
15yrs	609	162.96 ± 8.05	53.51 ± 9.18	69.32 ± 7.45	28.75 ± 9.24	174.14 ± 33.53	9.59 ± 1.68	281.44 ± 47.76	-2.16 ± 3.75
13-15yrs	1705	159.7 ± 8.39	50.35 ± 9.70	68.26 ± 7.75	26.26 ± 8.35	166.54 ± 31.73	9.61 ± 1.55	289.30 ± 50.22	-2.00 ± 3.47

Figure 2 shows the trend of the levels of each physical fitness item in different WC groups by sex and age. Overall, PFI had the highest values in group C (50th ≤ WC < 75th Percentile) and the lowest values in group D (WC ≥ 75th Percentile).

After stratification by sex, curvilinear regression analyses were conducted with WC as the independent variable and PFI as the dependent variable among Tajik adolescents in the Pamir Plateau of Xinjiang, China. The following curvilinear regression equation was derived:

$$Boys: Y = -27.28 + 0.85 * X + -0.006958 * X^2 R^2 = 0.186$$

$$Girls: Y = -33.71 + 1.09 * X + -0.009096 * X^2 R^2 = 0.172$$

Note Y denotes PFI; X denotes WC.

Figure 3 shows the schematic diagram of the curvilinear regression equation of WC and PFI. The PFI of Tajik adolescents in the Pamir Plateau of Xinjiang, China, reached its highest when the WC was 61 cm for boys, at -1.3207. The PFI of girls reached its highest when the WC was 60 cm, at -1.0556.

Figure 4 shows the trend of PFI percentile changes among Tajik adolescents on the Pamir Plateau in Xinjiang, China. Overall, the PFI of Tajik adolescents, both boys and girls, showed a gradual increasing trend with increasing percentile. Boys' PFI increased from −12.18 in P1 to 5.32 in P99; girls' PFI increased from −11.34 in P1 to 5.07 in P99.

Discussion

This study assessed WC and physical fitness programs in Tajik adolescents from the Pamir Plateau in Xinjiang, China. This study evaluated the WC and PFI status of Tajik adolescents in the Pamir Plateau, Xinjiang, China. The results showed that the WC of Tajik adolescent boys was higher than that of girls, and the PFI of girls was higher than that of boys. In general, WC and PFI among Tajik adolescents showed an inverted U-shaped curve relationship.

The results showed that the WC results were (69.50 ± 7.86) cm for Tajik boys and (67.07 ± 7.44) cm for girls, and boys were higher than girls. Because girls pay more attention to their body shape compared to boys, they pay particular attention to the changes in their WC in their lives and tend to maintain a reasonable WC range by controlling their diet and increasing their exercise in life [27]. A survey of Turkish adolescents aged 14–19 years showed that boys had higher levels of WC than girls, consistent with the results of the present study, for reasons related to innate genetic factors associated with gender differences [31]. Another survey of European adolescents also showed that boys had higher WC scores than girls, because girls, compared with boys, pay more attention to their external physical beauty in life, and girls also pay more attention to diet control and exercise in life, the WC of boys is higher than that of girls [19]. There is also a survey of Lithuanian adolescents that proves the same conclusion, consistent with the findings of this study [32]. The reasons for this result are influenced by a combination of factors. First, compared with boys, the concept of aesthetics determines that girls pay more attention to their external body shape, so they are especially controlling of WC. On the other hand, girls pay more attention to dietary behavior in daily life, and

Table 2 Between-group comparisons of physical fitness items and physical fitness index among Tajik adolescents with different waist circumference ratings in the Pamir Plateau, Xinjiang, China (M ± SD, boys)

Project	Age(yrs)	WC < 25th Percentile(A)		25th ≤WC <50th Percentile(B)		50th ≤WC <75th Percentile(C)		WC ≥ 75th Percentile(D)		Effect Size (*r*) [‡]					
		N	Mean ± SD	N	Mean ± SD	N	Mean ± SD	N	Mean ± SD	A/B	A/C	A/D	B/C	B/D	C/D
Grip strength	13yrs	72	21.38 ± 4.61	85	25.49 ± 6.53	39	26.13 ± 7.68	52	28.97 ± 7.18	0.3[#]	0.4[#]	0.5[#]	0.0	0.2[#]	0.2[#]
	14yrs	53	26.28 ± 6.57	65	29.53 ± 7.79	100	31.47 ± 7.71	78	33.59 ± 7.50	0.2[#]	0.3[#]	0.5[#]	0.1	0.3[#]	0.1
	15yrs	38	29.68 ± 6.23	54	32.44 ± 6.49	112	35.51 ± 8.42	89	37.13 ± 9.06	0.2[#]	0.4[#]	0.4[#]	0.2[#]	0.3[#]	0.1
	13-15yrs	163	24.91 ± 6.60	204	28.62 ± 7.49	251	32.44 ± 8.65	219	33.94 ± 8.67	0.3[#]	0.4[#]	0.5[#]	0.2[#]	0.3[#]	0.1
Standing long jump	13yrs	72	169.00 ± 21.48	85	181.39 ± 21.76	39	180.15 ± 26.09	52	154.02 ± 23.64	0.3[#]	0.2[#]	0.3[#]	0.0	0.5[#]	0.5[#]
	14yrs	53	180.55 ± 20.62	65	192.62 ± 23.94	100	197.96 ± 25.92	78	169.58 ± 23.00	0.3[#]	0.3[#]	0.2[#]	0.1	0.4[#]	0.5[#]
	15yrs	38	193.68 ± 26.76	54	195.8 ± 28.47	112	210.51 ± 21.44	89	183.39 ± 25.01	0.0	0.3[#]	0.2[#]	0.3[#]	0.2[#]	0.5[#]
	13-15yrs	163	178.51 ± 24.45	204	188.78 ± 25.08	251	200.79 ± 26.18	219	171.50 ± 26.50	0.2[#]	0.4[#]	0.1	0.2[#]	0.3[#]	0.5[#]
50 m dash	13yrs	72	8.69 ± 0.92	85	8.66 ± 0.77	39	8.72 ± 1.03	52	10.83 ± 0.94	0.0	0.0	0.8[#]	0.0	0.8[#]	0.7[#]
	14yrs	53	8.52 ± 0.87	65	8.41 ± 0.91	100	8.15 ± 0.81	78	10.47 ± 0.86	0.1	0.2[#]	0.7[#]	0.1	0.8[#]	0.8[#]
	15yrs	38	8.20 ± 1.02	54	8.13 ± 0.95	112	7.92 ± 0.83	89	10.36 ± 1.08	0.0	0.1	0.7[#]	0.1	0.7[#]	0.8[#]
	13-15yrs	163	8.52 ± 0.94	204	8.44 ± 0.89	251	8.14 ± 0.90	219	10.51 ± 0.99	0.0	0.2[#]	0.7[#]	0.2[#]	0.7[#]	0.8[#]
Endurance run	13yrs	72	308.07 ± 38.95	85	289.25 ± 46.81	39	308.78 ± 43.69	52	376.71 ± 45.47	0.2[#]	0.0	0.6[#]	0.2[#]	0.7[#]	0.6[#]
	14yrs	53	293.02 ± 38.18	65	284.38 ± 40.62	100	269.85 ± 36.34	78	358.57 ± 49.57	0.1	0.3[#]	0.6[#]	0.2[#]	0.6[#]	0.7[#]
	15yrs	38	278.00 ± 36.75	54	264.74 ± 32.57	112	261.05 ± 39.76	89	340.58 ± 45.58	0.2[#]	0.2[#]	0.6[#]	0.1	0.7[#]	0.7[#]
	13-15yrs	163	296.17 ± 39.81	204	281.21 ± 42.50	251	271.98 ± 42.21	219	355.57 ± 48.91	0.2[#]	0.3[#]	0.6[#]	0.1	0.6[#]	0.7[#]
PFI	13yrs	72	-1.96 ± 2.35	85	-0.49 ± 2.55	39	-0.93 ± 3.16	52	-5.18 ± 2.92	0.3[#]	0.2[#]	0.5[#]	0.1	0.7[#]	0.6[#]
	14yrs	53	-2.29 ± 2.51	65	-1.10 ± 2.69	100	-0.01 ± 2.77	78	-5.35 ± 3.02	0.2[#]	0.4[#]	0.5[#]	0.2[#]	0.6[#]	0.7[#]
	15yrs	38	-2.29 ± 2.14	54	-1.42 ± 2.83	112	-0.11 ± 2.91	89	-5.99 ± 3.29	0.2[#]	0.4[#]	0.6[#]	0.2[#]	0.6[#]	0.7[#]
	13-15yrs	163	-2.14 ± 2.35	204	-0.93 ± 2.68	251	-0.20 ± 2.90	219	-5.57 ± 3.12	0.2[#]	0.3[#]	0.5[#]	0.1	0.6[#]	0.7[#]

Note[‡] effect size between different groups; [#]$P < 0.05$

girls are more controlled than boys in the intake of high-energy snacks and high-fat foods. These reasons may be important causes for girls' WC being lower than boys'. In addition, there are also studies confirming that the age group of 13–15 years old is at the peak of puberty, this stage of adolescents and young people are more curious about things and behaviors, especially boys are more curious about smoking and drinking, the occurrence of these behaviors is also an important reason leading to higher WC for boys than for girls [33]. In addition, a survey also showed that boys were more obsessed with online games compared to girls, leading to longer periods of video screen behavior, which may also be an important reason for boys' higher WC than girls' [34]. It is of concern that the WC of Tajik adolescents of the Pamir Plateau in Xinjiang, China, for both boys and girls, is low compared to that of Han Chinese adolescents of the same age group in the plains [27]. The reason for this may be because living in the Pamir Plateau, which has been a high-altitude area for a long time, and being affected by the harsh natural environment, together with the relatively low level of economic development, resulted in lower WC levels among adolescents in this region compared to those in the plains. In addition, most of the adolescents investigated in this study were boarding students at school, who had been eating in the school canteen for a long time, and their dietary behaviours were relatively homogeneous compared to those in the school canteen, as school canteens provide relatively homogeneous meals with only four to six dishes at a time, students often have food such as instant noodles for lunch or dinner, thus leading to a homogeneous diet, which may also be an important reason for the lower WC levels than those in the plains. Overall, the WC of Tajik adolescents at high altitudes was the same as that of Han Chinese in the plains, with no significant differences [27]. It shows that the changes in WC did not change because of the change in altitude.

In terms of the PFI indicator, which is a comprehensive reflection of physical fitness, boys (-2.16±3.53) had a lower PFI than girls (-1.84±3.41) among Tajik adolescents on the Pamir Plateau in Xinjiang, China. The reason for this may be that Tajik adolescent boys living at high altitudes are affected by a combination of factors such as body weight. As can be seen from Table 1, the weight of boys aged 13–15 years is 51.7 kg and that of girls is 49.04 kg, which is higher for boys than for girls, leading to lower levels of performance in the standing long jump, 50 m dash, and endurance run events, which reflect adolescent PFI. A study of American adolescents confirmed that overweight and obese adolescents have lower speed and endurance qualities than normal-weight adolescents [35]. In addition, it may also be affected by the high-altitude environment, resulting in lower oxygen content in the air. The excessive weight burden of boys compared with girls makes the body need to take in more oxygen to maintain the body's oxygen supply, which may also be an important reason for boys' PFI to be lower than girls' [36]. A survey of Tibetan adolescents at high altitudes in China showed that cardiorespiratory fitness of Tibetan adolescents before the age of 16 was lower than that in the plains, and that cardiorespiratory fitness was negatively correlated with altitude, the reason for this may be because as the altitude increases, the oxygen in the air is thinner, resulting in lower CRF levels [37]. The study also found that the muscle strength of adolescents in the plateau region was negatively correlated with altitude, indicating that their muscle strength showed a decreasing trend with increasing altitude, which may be related to the lower muscle strength brought about by the natural environment and the level of economic development in high altitude regions [38].

The present study showed that the WC and PFI of Tajik adolescents in the Pamir Plateau in Xinjiang, China, showed an inverted "U"-shaped curvilinear association for both boys and girls. The R^2 of the curvilinear regression equations for Tajik boys and girls were 0.186 and 0.172, respectively, and the equation models were significant. This indicates that there is no sex difference in the curvilinear association between WC and PFI for Tajik boys and girls. It can be seen that both boys' and girls' WC of Tajik adolescents have some negative impact on PFI at lower and higher levels. The regression equation shows that PFI was highest when the WC was 61 cm for Tajik boys and 60 cm for girls. This WC value can provide a theoretical reference for the promotion of WC and physical fitness in Tajik adolescents at high altitude. This reference value is also proposed for future exercise interventions with Tajik adolescents. A survey of Chinese adolescents showed a curvilinear association between BMI and lung capacity, with negative effects on cardiorespiratory fitness at both higher and lower BMIs, which is consistent with the findings of this study [39]. It has also been shown that WC is also curvilinearly related to cardiorespiratory fitness in adolescents, with higher WC values resulting in lower cardiorespiratory fitness in adolescents [20]. In addition, the graph of percentile trend in this study shows that the PFI of Tajik adolescents, both boys, and girls, showed a gradual trend of increase with the increase of percentile, which was relatively consistent, and there was no sex difference in the trend of change. Several studies have also confirmed that an increase in WC in adolescents inevitably leads to an increase in abdominal fat content of the body, increasing body weight, and all these changes lead to a decrease in the level of cardiorespiratory fitness and the need to overcome a greater body weight resistance when exercising, which leads to a decrease in the PFI [40, 41].

Table 3 Between-group comparisons of physical fitness items and physical fitness index among Tajik adolescents with different waist circumference ratings in the Pamir Plateau, Xinjiang, China (M ± SD, girls)

Project	Age(yrs)	WC < 25th Percentile(A)		25th ≤ WC <50th Percentile(B)		50th ≤ WC <75th Percentile(C)		WC ≥ 75th Percentile(D)		Effect Size (*r*) ‡					
		N	Mean ± SD	N	Mean ± SD	N	Mean ± SD	N	Mean ± SD	A/B	A/C	A/D	B/C	B/D	C/D
Grip strength	13yrs	103	19.13 ± 4.28	77	21.07 ± 4.80	42	23.05 ± 4.66	54	22.54 ± 5.78	0.2#	0.4#	0.3#	0.2#	0.1	0.0
	14yrs	84	20.86 ± 5.11	81	22.72 ± 6.05	52	22.58 ± 4.55	59	23.82 ± 5.25	0.2#	0.2#	0.3#	0.0	0.1	0.1
	15yrs	81	22.49 ± 4.60	64	23.56 ± 6.09	98	23.97 ± 6.08	73	22.82 ± 7.19	0.1	0.1	0.0	0.0	0.1	0.1
	13-15yrs	268	20.69 ± 4.84	222	22.39 ± 5.73	192	23.39 ± 5.42	186	23.06 ± 6.21	0.2#	0.3#	0.2#	0.1	0.1	0.0
Standing long jump	13yrs	103	142.62 ± 19.89	77	152.34 ± 19.32	42	148.33 ± 17.45	54	126.56 ± 18.33	0.2#	0.2#	0.4#	0.1	0.6#	0.5#
	14yrs	84	151.26 ± 21.59	81	155.19 ± 19.82	52	152.00 ± 17.38	59	127.27 ± 20.34	0.1	0.0	0.5#	0.1	0.6#	0.5#
	15yrs	81	154.3 ± 19.09	64	160.86 ± 22.33	98	160.59 ± 17.24	73	132.71 ± 22.48	0.2#	0.2#	0.5#	0.0	0.5#	0.6#
	13-15yrs	268	148.86 ± 20.76	222	155.83 ± 20.6	192	155.58 ± 18.02	186	129.20 ± 20.76	0.2#	0.2#	0.4#	0.0	0.5#	0.6#
50 m dash	13yrs	103	9.83 ± 1.16	77	9.88 ± 1.02	42	9.69 ± 1.06	54	11.87 ± 1.09	0.0	0.1	0.7#	0.1	0.7#	0.7#
	14yrs	84	9.77 ± 1.01	81	9.71 ± 1.03	52	9.87 ± 1.10	59	12.00 ± 1.21	0.0	0.0	0.7#	0.1	0.7#	0.7#
	15yrs	81	9.85 ± 0.97	64	9.83 ± 1.15	98	9.88 ± 1.08	73	12.16 ± 1.35	0.0	0.0	0.7#	0.0	0.7#	0.7#
	13-15yrs	268	9.82 ± 1.05	222	9.80 ± 1.06	192	9.83 ± 1.08	186	12.03 ± 1.24	0.0	0.0	0.7#	0.0	0.7#	0.7#
Endurance run	13yrs	103	272.19 ± 38.7	77	281.17 ± 41.94	42	281.19 ± 37.25	54	309.49 ± 41.43	0.1	0.1	0.4#	0.0	0.3#	0.3#
	14yrs	84	263.37 ± 36.61	81	268.35 ± 37.39	52	273.93 ± 37.87	59	308.15 ± 47.93	0.1	0.1	0.5#	0.1	0.4#	0.4#
	15yrs	81	263.38 ± 31.47	64	263.37 ± 38.42	98	266.39 ± 37.48	73	310.80 ± 38.79	0.0	0.0	0.6#	0.0	0.5#	0.5#
	13-15yrs	268	266.76 ± 36.11	222	271.36 ± 39.84	192	271.67 ± 37.81	186	309.58 ± 42.41	0.1	0.1	0.5#	0.0	0.4#	0.4#
PFI	13yrs	103	-1.55 ± 2.84	77	-0.98 ± 2.91	42	-0.53 ± 2.53	54	-4.64 ± 3.08	0.1	0.2#	0.5#	0.1	0.5#	0.6#
	14yrs	84	-1.06 ± 2.89	81	-0.55 ± 2.79	52	-1.03 ± 2.50	59	-4.92 ± 3.31	0.1	0.0	0.5#	0.1	0.6#	0.6#
	15yrs	81	-1.12 ± 2.17	64	-0.58 ± 3.39	98	-0.65 ± 3.11	73	-5.69 ± 3.42	0.1	0.1	0.6#	0.0	0.6#	0.6#
	13-15yrs	268	-1.27 ± 2.67	222	-0.71 ± 3.01	192	-0.73 ± 2.82	186	-5.14 ± 3.30	0.1	0.1	0.5#	0.0	0.6#	0.6#

Note‡ effect size between different groups; #$P < 0.05$

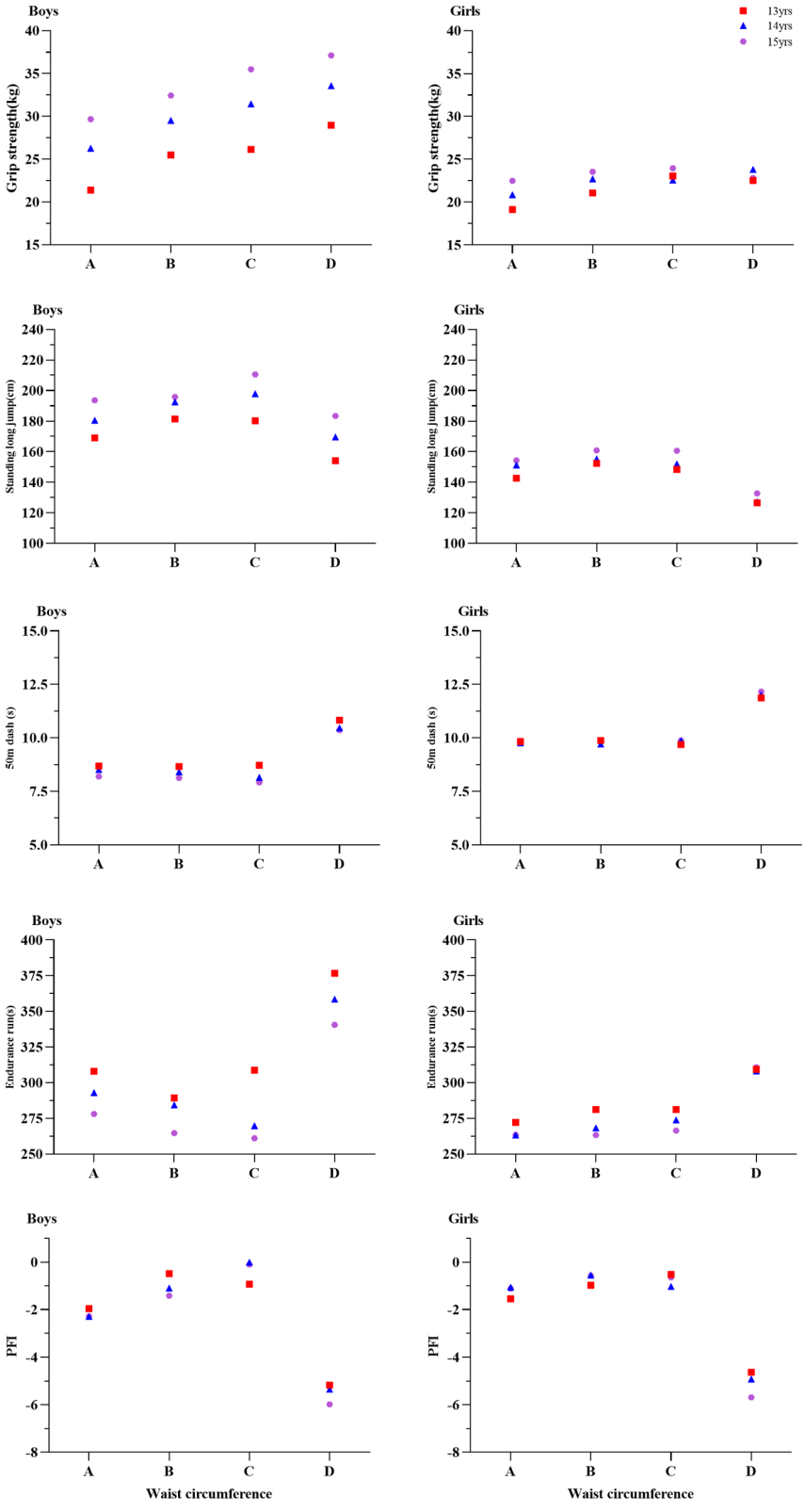

Fig. 2 Trends of physical fitness items and physical fitness index among Tajik adolescents with different waist circumference levels in the Pamir Plateau, Xinjiang, China. *Note* A indicates WC < 25th Percentile, B indicates 25th ≤ WC < 50th Percentile, C indicates 50th ≤ WC < 75th Percentile, and D indicates WC ≥ 75th Percentile. PFI, Physical Fitness Index

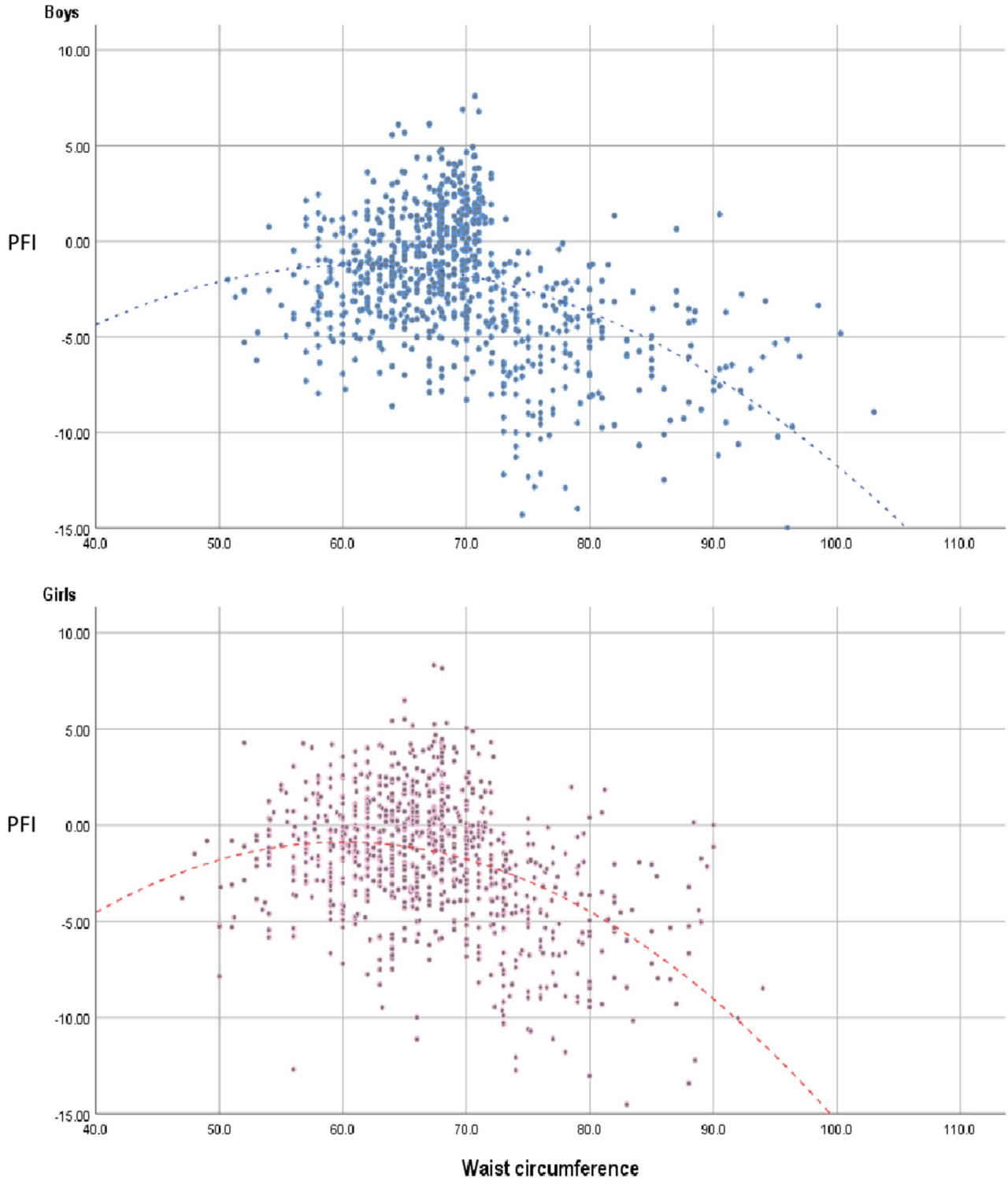

Fig. 3 Trends in the association between waist circumference and physical fitness index among Tajik adolescents in the Pamir Plateau, Xinjiang, China
Note PFI, Physical Fitness Index

This study investigated the association between WC and PFI in Tajik adolescents from the Pamir Plateau in Xinjiang, China. There are certain strengths and limitations of this study. Strengths: On the one hand, to the best of our knowledge, this study is the first to analyze the association between WC and PFI in Tajik adolescents on the Pamir Plateau in Xinjiang, China, which could provide strong support for the development of physical

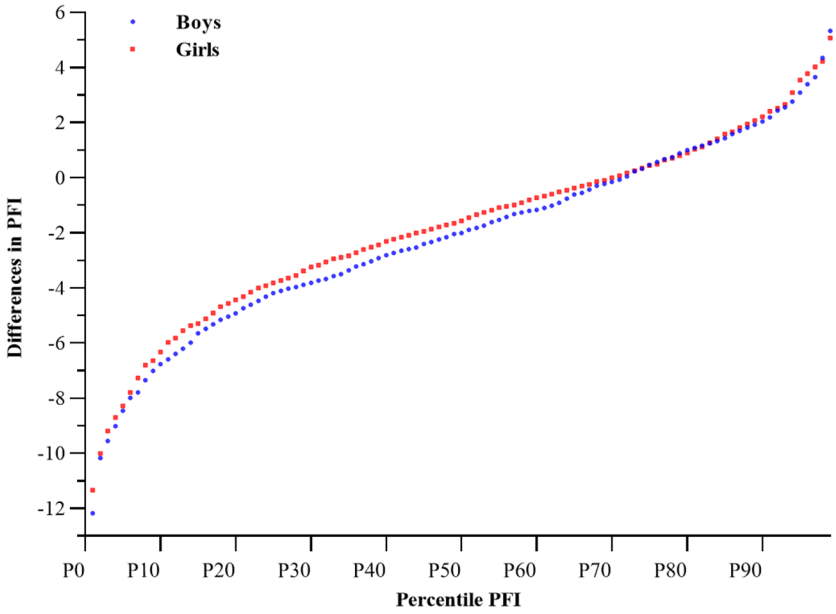

Fig. 4 Trends in Physical Fitness Index Percentile Change for Tajik Adolescents in the Pamir Plateau, Xinjiang, China *Note* PFI, Physical Fitness Index

fitness and health among Tajik adolescents in this region. On the other hand, this study has significant ethnic and geographical characteristics. The area investigated in this study is the only county in China where Tajiks live in large numbers, and with an average altitude of more than 4,000 m above sea level, the special ethnic and geographic environment is also a strength and feature of this study. However, this study also has certain limitations. Firstly, although this study investigated a large sample of Tajik adolescents aged 13–15 years old, the age range of the study was only limited to 13–15 years old, and future studies should include a larger age range of adolescents to better analyze the association that exists between WC and PFI. Secondly, this study was a cross-sectional survey study, which only allowed us to understand the association but not the causal association. Prospective cohort studies should be conducted in the future to analyze the causal associations that exist between them.

Conclusions

This study is the first to investigate the association between WC and PFI in Tajik adolescents on the Pamir Plateau in Xinjiang, China. The association between WC and PFI in Tajik adolescents showed an inverted "U" shaped curve with no sex difference. It is recommended that the WC of Tajik adolescents at high altitudes should be controlled between 60 and 61 cm to maintain a better level of PFI. In the future, the control of WC among Tajik adolescents should be emphasized in the formulation of educational policies and public health prevention in the region, to better promote the improvement of adolescents' physical fitness level.

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Author contributions
Conceptualization, Yuanjiao Chen, Ruibao Cai; Data curation, Yuanjiao Chen, Ruibao Cai; Formal analysis, Yuanjiao Chen; Funding acquisition, Ruibao Cai; Investigation, Ruibao Cai; Methodology, Ruibao Cai; Project administration, Yuanjiao Chen; Resources, Di Chai; Software, Huipan Wu; Supervision, Ruibao Cai; Validation, Di Chai; Visualization, Huipan Wu; Writing—original draft, Yuanjiao Chen, Ruibao Cai; Writing—review & editing, Yuanjiao Chen, Ruibao Cai; 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

Institutional review board statement
This study was conducted in accordance with the Declaration of Helsinki. The study investigation was tested with the informed consent of the participant's parents and the participants themselves. Participants were asked to sign a written informed consent form before testing. Participants under the age of 16 have obtained informed consent from their parents or legal guardians. Approved by the Human Subjects Ethics Committee of Xinjiang Normal University (202305454).

Consent for publication
Not Applicable.

Informed consent
Informed consent was obtained from all subjects involved in the study.

Competing interests
The authors declare no competing interests.

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References

1. Sampasa-Kanyinga H, Colman I, Goldfield GS, Janssen I, Wang J, Podinic I, Tremblay MS, Saunders TJ, Sampson M, Chaput JP. Combinations of physical activity, sedentary time, and sleep duration and their associations with depressive symptoms and other mental health problems in children and adolescents: a systematic review. Int J Behav Nutr Phy. 2020;17(1):72.
2. Ruiz LD, Zuelch ML, Dimitratos SM, Scherr RE. Adolescent obesity: Diet Quality, Psychosocial Health, and cardiometabolic risk factors. Nutrients. 2019; 12(1).
3. Schmidt S, Anedda B, Burchartz A, Eichsteller A, Kolb S, Nigg C, Niessner C, Oriwol D, Worth A, Woll A. Physical activity and screen time of children and adolescents before and during the COVID-19 lockdown in Germany: a natural experiment. Sci Rep-Uk. 2020;10(1):21780.
4. Dong Y, Chen M, Chen L, Wen B, Yang Y, Wang Z, Ma Y, Song Y, Ma J, Lau P, Individual-. Family-, and School-Level Ecological correlates with Physical Fitness among Chinese School-aged children and adolescents: a National Cross-sectional Survey in 2014. Front Nutr. 2021;8:684286.
5. Dong Y, Chen M, Song Y, Ma J, Lau P. Geographical variation in physical fitness among Chinese children and adolescents from 2005 to 2014. Front Public Health. 2021;9:694070.
6. Lang JJ, Larouche R, Tremblay MS. The association between physical fitness and health in a nationally representative sample of Canadian children and youth aged 6 to 17 years. Health Promot Chron. 2019;39(3):104–11.
7. Raghuveer G, Hartz J, Lubans DR, Takken T, Wiltz JL, Mietus-Snyder M, Perak AM, Baker-Smith C, Pietris N, Edwards NM. Cardiorespiratory Fitness in Youth: an important marker of Health: A Scientific Statement from the American Heart Association. Circulation. 2020;142(7):e101–18.
8. Dong Y, Lau P, Dong B, Zou Z, Yang Y, Wen B, Ma Y, Hu P, Song Y, Ma J, et al. Trends in physical fitness, growth, and nutritional status of Chinese children and adolescents: a retrospective analysis of 1.5 million students from six successive national surveys between 1985 and 2014. Lancet Child Adolesc. 2019;3(12):871–80.
9. Bi C, Zhang F, Gu Y, Song Y, Cai X. Secular Trend in the physical fitness of Xinjiang Children and adolescents between 1985 and 2014. Int J Env Res Pub He. 2020; 17(7).
10. Chen G, Chen J, Liu J, Hu Y, Liu Y. Relationship between body mass index and physical fitness of children and adolescents in Xinjiang, China: a cross-sectional study. BMC Public Health. 2022;22(1):1680.
11. Patnaik L, Pattnaik S, Rao EV, Sahu T. Validating Neck circumference and Waist circumference as anthropometric measures of Overweight/Obesity in adolescents. Indian Pediatr. 2017;54(5):377–80.
12. Xi B, Zong X, Kelishadi R, Litwin M, Hong YM, Poh BK, Steffen LM, Galcheva SV, Herter-Aeberli I, Nawarycz T, et al. International Waist Circumference Percentile Cutoffs for Central Obesity in children and adolescents aged 6 to 18 years. J Clin Endocr Metab. 2020;105(4):e1569–83.
13. Deusdara R, de Moura SA, Szklo M. Association between obesity, overweight, elevated Waist circumference, and insulin resistance markers among Brazilian adolescent students. Nutrients. 2022; 14(17).
14. Wang ZY, Li BC, Xing JJ, Liu SY, Zhang TT, Xu AM, Wang ZJ. Associations of waist circumference with sex steroid hormones among 4031 USA children and adolescents. Asian J Androl. 2023;25(4):505–11.
15. Bell L, Hung J, Knuiman M, Divitini M, Beilby J, Hunter M, Mollison L, Thompson P, Mcquillan B, Davis E. Body mass index and waist circumference: relationship to cardiometabolic risk factors in children–Busselton Health Study 2005–2007. J Paediatr Child H. 2013;49(11):955–62.
16. Zhang YX, Chen J, Liu XH. Profiles of anemia among school-aged children categorized by body mass index and waist circumference in Shandong, China. Pediatr Neonatol. 2021;62(2):165–71.
17. Wang L, Lee Y, Wu Y, Zhang X, Jin C, Huang Z, Wang Y, Wang Z, Kris-Etherton P, Wu S, et al. A prospective study of waist circumference trajectories and incident cardiovascular disease in China: the Kailuan Cohort Study. Am J Clin Nutr. 2021;113(2):338–47.
18. Rahmani J, Kord VH, Kontogiannis V, Ryan PM, Bawadi H, Fatahi S, Zhang Y. Waist circumference and risk of Liver Cancer: a systematic review and Meta-analysis of over 2 million cohort study participants. Liver Cancer. 2020;9(1):6–14.
19. Medrano M, Labayen I, Ruiz JR, Rodriguez G, Breidenassel C, Castillo M, Pedrero R, Widhalm K, Kafatos A, Manios Y, et al. Cardiorespiratory fitness, waist circumference and liver enzyme levels in European adolescents: the HELENA cross-sectional study. J Sci Med Sport. 2017;20(10):932–6.
20. Liu Y, Yin X, Zhang F, Li Y, Bi C, Sun Y, Li M, Zhang T. Relationship between waist circumference and cardiorespiratory fitness in Chinese children and adolescents: results from a cross-sectional survey. J Exerc Sci Fit. 2022;20(1):1–8.
21. Mckay MJ, Baldwin JN, Ferreira P, Simic M, Vanicek N, Burns J. Normative reference values for strength and flexibility of 1,000 children and adults. Neurology. 2017;88(1):36–43.
22. Staub K, Floris J, Koepke N, Trapp A, Nacht A, Scharli MS, Ruhli FJ, Bender N. Associations between anthropometric indices, blood pressure and physical fitness performance in young Swiss men: a cross-sectional study. Bmj Open. 2018;8(6):e18664.
23. Arif M, Gaur DK, Gemini N, Iqbal ZA, Alghadir AH. Correlation of percentage body Fat, Waist Circumference and Waist-to-hip ratio with abdominal muscle strength. Healthcare-Basel. 2022; 10(12).
24. Bi C, Yang J, Sun J, Song Y, Wu X, Zhang F. Benefits of normal body mass index on physical fitness: a cross-sectional study among children and adolescents in Xinjiang Uyghur Autonomous Region, China. PLoS ONE. 2019;14(8):e220863.
25. Sulaiman X, Xu WF, Cai LH, Huang XY, Cheng LF, Zhang YP. Hematologic and spirometric characteristics of Tajik and Kyrgyz highlanders in the Pamir Mountains. Am J Hum Biol. 2021;33(2):e23459.
26. Wang L, Li N, Heizhati M, Abulikemu S, Zhang D, Luo Q, Zhou L, Hong J, Hu J, Cai L et al. Prevalence, Awareness, Treatment, Control, and Related Factors of Hypertension among Tajik Nomads Living in Pamirs at High Altitude. Int J Hypertens. 2020; 2020:5406485.
27. CNSSCH Association. Report on the 2019th National Survey on Students'Constitution and Health. Beijing: China College & University; 2022.
28. Network E. STROBE Statement—Checklist of items that should be included in reports of cross-sectional studies. In., vol. 2024; 2024.
29. Kang H. Sample size determination and power analysis using the G*Power software. J Educ Eval Health P. 2021;18:17.
30. Cohen BH. Explaining psychological statistics. Brooks/Cole Pub. Co; 2008.
31. Cam HH, Ustuner TF. Prevalence of Hypertension and its association with body Mass Index and Waist Circumference among adolescents in Turkey: a cross-sectional study. J Pediatr Nurs. 2021;57:e29–33.
32. Kuciene R, Dulskiene V. Associations between body mass index, waist circumference, waist-to-height ratio, and high blood pressure among adolescents: a cross-sectional study. Sci Rep-Uk. 2019;9(1):9493.
33. Wang J, Xie Y, Xu H, Wan Y, Tao F. Moderating effects of smoking and drinking on the relationship between biological rhythm and psychological health and gender differences among adolescents. BMC Psychiatry. 2023;23(1):731.
34. Schou AC, Billieux J, Griffiths MD, Kuss DJ, Demetrovics Z, Mazzoni E, Pallesen S. The relationship between addictive use of social media and video games and symptoms of psychiatric disorders: a large-scale cross-sectional study. Psychol Addict Behav. 2016;30(2):252–62.
35. Lau XC, Chong KH, Poh BK, Ismail MN. Physical activity, fitness and the energy cost of activities: implications for obesity in children and adolescents in the tropics. Adv Food Nutr Res. 2013;70:49–101.
36. Levine BD, Stray-Gundersen J. Living high-training low: effect of moderate-altitude acclimatization with low-altitude training on performance. J Appl Physiol. 1997;83(1):102–12.
37. Zhang L, Zhang R, Zhang F, Yin X, Liu Y, Guo Y, Sun P. Comparison of Cardiorespiratory Fitness of Chinese Tibetan adolescents with their Han counterparts: a cross-sectional retrospective study. Int J Env Res Pub He. 2022; 19(24).
38. Chang Z, Ye H, Huang B, Xu J. Physical fitness of tibetan adolescents at different high altitudes in Tibet, China: a comparative study. Am J Hum Biol. 2024;36(1):e23975.
39. Qin G, Qin Y, Liu B. Association between BMI and health-related physical fitness: a cross-sectional study in Chinese high school students. Front Public Health. 2022;10:1047501.
40. Daneshpour MS, Zarkesh M, Masjoudi S, Azizi F, Hedayati M. Chromosomal regions strongly associated with waist circumference and body mass index in metabolic syndrome in a family-based study. Sci Rep-Uk. 2021;11(1):6082.

41. Alhowikan AM, Alsharqawy NE, Alazmaa NN, Saeed AI, Alhazzani YA, Alhowaish NY, Yahya A, Alhozaimi ZA, Aleid NE, Alhussain MH. Lifestyle habits and obesity indices among male adolescents in Riyadh, Saudi Arabia. Sci Rep-Uk. 2023;13(1):12099.

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