Original Article

Body fat percentage in adolescents is a better predictor of exercise effect on adiposity changes: a 4-year follow-up study

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Background: Exercise is generally recognized as beneficial to prevent obesity; however, it is not clear which indicator can better reflect the benefits, especially in adolescents. The aim of this study was to describe the effects of exercise on body mass and fat indexes and to clarify the significance of different indexes in clinical use.

Methods: We conducted a prospective cohort study involving 1,941 freshmen from 2014, followed-up biennially until 2018. Various body mass and fat indexes, including weight, height, waist and hip circumference and body fat percentage (BFP), were measured. Physical activity and other variables were collected by questionnaire. All study participants were divided into two groups according to the frequency and intensity of exercise.

Results: Compared with the low frequency and intensity exercise group, the high frequency and intensity exercise group had a lower increase in BFP during the 4-year follow-up, and no significant differences were observed in the changes of other indexes between the groups. Even after adjusting, the high frequency and intensity exercise group still exhibited a higher likelihood of reducing BFP.

Conclusions: High frequency and intensity exercise provides benefits for reducing BFP. No other body mass or fat indexes showed any association. BFP could be a much more sensitive indicator to detect and control obesity in adolescents.

Keywords: Body mass index (BMI); body fat percentage (BFP); exercise; adolescents

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Introduction

The prevalence of obesity has reached an epidemic level in Western countries and is increasing in developing countries. In Asia, the prevalence of obesity has been increasing at an alarming rate in recent years, especially in China, Japan, and India (1). In 1975, the obese population in China was less than 0.1 million, which increased to 43.2 million by 2014, accounting for 16.3% of the obese population worldwide (2). Obesity in children and adolescents seems to be a major problem for the rich in low- and middle-income countries. Compared with young people of normal weight, the risk of obesity in adulthood is approximately five times higher among boys and nine times higher among girls who were obese at a young age (3). In addition, emerging evidence shows that obesity in children and adolescents is positively correlated with adult weight gain. This is problematic, as obesity in young people has been shown to increase the likelihood of overweight and obesity in adults (4), thereby increasing the risk of premature all-cause mortality (5). The increasing prevalence of obesity also increases the risk of many diseases, such as degenerative joint disease (6), type 2 diabetes (7), cardiovascular disease, and obesity-associated malignancies (8). Furthermore, obese adults who were also obese during adolescence have a higher chance of developing complications compared to those who became obese during adulthood but were of normal weight during adolescence (9,10). Without intervention, these comorbidities and obesity itself usually last into adulthood, which can lead to premature death (10,11). Given that the constellation of cardiac metabolic risk factors is considered to be changeable, the early identification and intervention for adolescents with metabolic syndrome is an important public health debate, in order to improve their status.

Exercise is a non-drug intervention, which can be used by the vast majority of the public, and may play a key role in the treatment of adolescent obesity (12,13). Body mass index (BMI) is still the most commonly used evaluation index, which can be easily identified and interpreted by practitioners. Some observational studies have shown that, relatively speaking, people who engage in more physical activity have a lower BMI than those who are less active (14,15). Unfortunately, other studies have shown that the effect of exercise on BMI is not significant. For example, except for a previous systematic review and meta-analysis focusing on exercise (16), previous studies showed that there was no significant change in the BMI of children and adolescents (17). Therefore, clarifying the influence of exercise on adolescents through other body fat indexes is crucial.

In view of the numerous factors related to obesity reported by previous studies, multiple confounding factors have not always been adjusted. Although most studies use BMI as the primary outcome, few large-scale epidemiological studies directly estimate obesity. A cross-sectional study showed that physical activity was negatively correlated with BMI and body fat percentage (BFP) in middle-aged people; for people with the same BMI, those who were more active had a lower BFP (18). Another study aimed to develop a multidisciplinary lifestyle intervention plan for 103 moderately and severely obese children and adolescents, and evaluate the additional effects of exercise intervention compared with routine care. After the intervention, the BMI z-score of the exercise group was 10% lower than the baseline score (P=0.03), however no interaction effects were observed between the groups. Meanwhile, significant intervention effects were observed in percentage of BF (%) (β=−1.52, 95% CI: −2.58 – −0.45) and lean body mass (LM) (β=1.20, 95% CI: 0.12–2.29) (19). A more comprehensive measurement method to check for obesity is appealing, in order to discover additional information beyond that provided by the BMI, especially among adolescents. Consequently, we conducted a prospective cohort study focused on the association between exercise and body mass and fat indexes, including BMI, BFP, and other indexes, in Shanghai freshmen, and aimed to identify sensitive indicators for potential intervention. We present the following article in accordance with the STROBE reporting checklist (available at https://dx.doi.org/10.21037/apm-21-1912).

Methods

Design and participants

This was a 4-year prospective follow-up study conducted in a multidisciplinary university in Shanghai, which recruited students nationwide. All freshmen in this university were enrolled in the first autumn semester of 2014. The purpose of this study was to describe and analyze the relationship between exercise and BMI, BFP, as well as other body mass and fat indexes in these college students. All students were enrolled in the study at baseline and were followed up every 2 years, so there were three visits altogether. Participants with abnormal medical examinations, including heart, liver and kidney dysfunctions, as well as those with missing visits, were excluded. Students recruited in this study came from 23 provinces and four municipalities in China, including the Han nationality and ethnic minorities. All procedures performed in this study involving human participants were in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Institutional Review Committee of Huashan Hospital, Fudan University (NO.: 2011-242) and informed consent was taken from all the participants.

Assessment of physical activity

The level of physical activity was evaluated by an effective questionnaire, and was updated every 2 years (20). The level of exercise was quantified synthetically according to the type, weekly frequency, and duration of physical activity. We estimated that the number of hours spent in moderate to intense activities (including brisk walking) per week requires at least three metabolic equivalent tasks (METs) per hour (21). We the classified high frequency and intensity exercise group as engaging moderate or vigorous exercise for at least 30 minutes daily (3.5 hours per week) (22).

Medical and anthropometric examination

Physical examinations were performed by experienced doctors in Huashan Hospital, and anthropometric evaluations were conducted by well-trained nurses in Huashan Hospital using standard methods in the school infirmary.

The students' height was accurately evaluated to within 0.1 cm using a precision stadiometer (SECA 225, Hamburg, Germany), and weight was accurately measured to within by 0.1 kg using a calibrated digital scale (SECA 861, Hamburg, Germany). The subjects only wore light underwear without shoes. Waist and hip circumferences were also measured to the nearest 0.1 cm. Waist circumference (WC) was determined at the midline from the lower rib margin to the iliac crest, and hip circumference was determined at the most convex part of pubic symphysis and gluteus maximus. The waist-hip ratio (WHR) was calculated by dividing waist circumference by hip circumference. The percentage of body fat, fat mass, and fat-free mass were measured using the sectional bioelectrical impedance analysis (BIA) scale (Tanita, BC-418, Japan).

Blood pressure was measured by trained medical staff using mercury sphygmomanometers (model XJ11D, Shanghai Medical Equipment Co., Ltd., China), stethoscopes (model TZ-1, Shanghai Medical Equipment Co., Ltd., China), and appropriate cuffs. Participants were asked to sit quietly for at least 5 minutes prior to the first reading. Systolic blood pressure (SBP) was determined at the beginning of the first Korotkoff sound, and diastolic blood pressure (DBP) was measured at the fifth Korotkoff sound. Blood pressure was measured twice, with a 5-minute interval between the two measurements, and the average values were calculated.

Other data collection

Smoking and drinking histories, as well as dietary habits were collected from the subjects at baseline using the standard operation protocol. Information on smoking was obtained separately for cigarettes, pipes, and cigars. The exposure variables related to cigarette smoking included history of smoking (never, past, current) and pack-years of smoking. An "ever smoker" was defined as an individual who self-reported smoking at least 100 cigarettes during the course of his/her lifetime or smoked pipes or cigars for 6 months or more. A "current smoker" was defined as an individual who self-reported smoking within the calendar year prior to joining the study. A "past smoker" was defined as an ever smoker who had quit smoking for more than one calendar year before joining the study. Cigarette equivalents were calculated using the conversion factor 1 cigarette =1/2 pipe =1/4 cigar; the average number of cigarette equivalents smoked/day was defined categorically as 0, 1–19, 20–39, and 40+ (23,24).

The consumption of alcoholic beverages was obtained separately for beer, wine, and hard liquor. An "ever drinker" was defined as a person who self-reported consuming at least 12 drinks of any alcoholic beverage type over his/her lifetime. A "current drinker" was defined as a person who reported drinking any type of alcoholic beverage within the calendar year prior to joining the study. A "past drinker" was defined as an ever drinker who had discontinued all drinking for more than one calendar year before joining the study. The average number of drinks consumed per week was calculated based upon the reported number of 12-ounce beers, 4-ounce glasses of wine, and 1.5-ounce shots of hard liquor consumed per week. The frequency of alcohol consumption was defined categorically as 0, >0–<7, 7–20, and >20 drinks/week (25,26). The "Dietary Habits Scale" developed by Huang (27) was used to measure the dietary habits with Cronbach's α of 0.85. There were seven good dietary habits (GDHs) on the scale; to measure if respondents consumed a good diet, we used the variable labeled "good diet". The main item was to ask respondents to self-report how often they ate "vegetables" over a 1-week period, and the response format was as follows: 1= almost never, 2= less than once a week, 3= every week, 4= once a day, and 5 = more than once a day.

Blood sample examination

Blood samples were collected in 2014 and 2018. After 12-hours overnight fasting, venous blood samples (5 mL) were obtained from the anterior elbow vein of each participant, and collected into ethylene diamine tetraacetic acid (EDTA) vacuum tubes between 7:00 and 9:00 a.m. Samples were centrifuged at 3,000 rpm, divided equally, and stored at −80 ℃. The levels of total cholesterol (TC), low-density lipoprotein cholesterol (LDL), high-density lipoprotein cholesterol (HDL), and triglycerides (TG) were measured in the clinical lab of Huashan Hospital; TC and

TG levels were determined by enzyme methods, and LDL and HDL levels were measured using the clearance method.

Study size and biases

To calculate the sample size, we collected the information of a small sample of the students. For students engaging in low and high frequency and intensity exercise, the prevalence of BFP reduction was approximately 25% and 37%, respectively. Thus, we determined that at least 390 students should be recruited in each cohort.

A potential for recall bias exists whenever historical self-report information is elicited from respondents, and thus, recall bias must have existed in the self-reported exercise information in this study. However, it is one of the most common ways to collect information, especially in epidemiological research with large samples. It offers advantages such as practicality and low cost, and is quick and easy to administer. To address the potential sources of bias, we used the blind method to collect data, and all participants were given standardized training and explanation prior to completing the questionnaire. In the whole research process, there also was lost to follow-up bias. To address this, we aimed to improve the compliance of the participants through timely health assistance and patient explanation. If participants could not be reached through all means, all information would be eliminated when analyzing and reporting the lost visitors.

Statistical analyses

Data were presented as means ± standard deviation (SD) for normally distributed continuous variables, and as medians with interquartile range (IQR) for non-normally distributed continuous variables. Categorical variables were presented as frequencies or percentages. The *t*-test or Chi-square test was used to evaluate the differences in general characteristics at baseline according to physical activity classification. An unadjusted model and a multivariate model were used to estimate the relationship between physical activity and body fat loss. Factors that exhibited significant differences in the univariate analysis were included in the multivariate analysis. The multivariate model used in this study was adjusted for age, sex, BMI, smoking, drinking, and eating. Since the variance inflation factor (VIF) was less than 10, there was no multicollinearity among the variables, which could be included in multivariate analysis. P<0.05 was considered to be statistically significant. Statistical analyses were carried out using the SPSS version 24.0 (SPSS Inc., Chicago, IL, USA).

Results

A total of 2,000 students were enrolled in the study at baseline. Fifty-nine participants were excluded because they had abnormal physical examinations, including dysfunctions of the heart, liver, and kidney, or missed visits. Among these participants, 17 were excluded due to abnormal medical examinations at baseline, 18 participants were lost to follow-up in 2016, and 24 participants were lost to follow-up in 2018. All information was eliminated when analyzing and reporting the lost visitors.

As shown in *Table 1*, 1,941 participants (average age, 17.93±0.72 years) were recruited in this study, including 735 (37.87%) males and 1,206 (62.13%) females. The mean BMI of the total population was 20.73±3.02 kg/m^2. The mean waist circumference and WHR were 69.01±10.95 cm and 0.76±0.06, respectively. The mean BFP was 22.17%±7.84%. Blood pressure measurement showed that the average SBP was 114.60±12.96 mmHg, and the average DBP was 67.19±8.98 mmHg. The entire cohort was divided into a low frequency and intensity exercise group (N=1,483, 76.40%) and a high frequency and intensity exercise group (N=458, 23.60%) based on the evaluated exercise amount. Compared to the low frequency and intensity exercise group, the proportion of males (29.33% *vs.* 65.50%, P<0.0001), average weight (56.37±10.67 *vs.* 62.35±11.86 kg, P<0.0001), BMI (20.54±2.99 *vs.* 21.34±3.01 kg/m^2, P<0.0001), waist circumference (68.52±9.88 *vs.* 72.08±9.52 cm, P<0.0001), WHR (0.76±0.06 *vs.* 0.78±0.06, P<0.0001), and SBP (113.29±12.32 *vs.* 118.93±14.03 mmHg, P<0.0001) were greater in the high frequency and intensity exercise group; however, BFP (22.26%±6.12% *vs.* 20.60%±6.87%, P<0.0001) and HDL-C (1.60±0.39 *vs.* 1.50±0.38 mmol/L, P<0.0001) were lower in this group.

All students enrolled in the study were followed up every 2 years in 2016 and 2018. As depicted in *Table 2* and *Figure 1*, follow-up in 2016 and 2018 showed that, compared to the low frequency and intensity exercise group, the weight (2016: 57.45±9.81 *vs.* 63.18±11.85 kg; 2018: 57.90±11.03 *vs.* 63.82±12.65 kg), BMI (2016: 20.89±3.11 *vs.* 21.60±3.39 kg/m^2; 2018: 20.92±3.08 *vs.* 21.76±3.28 kg/m^2), waist circumference (2016: 70.25±7.96 *vs.* 73.49±8.94 cm; 2018: 72.55±9.36 *vs.* 76.69±10.16 cm), and WHR (2016: 0.76±0.06 *vs.* 0.78±0.06; 2018: 0.77±0.07 *vs.* 0.80±0.07) of the high frequency and intensity exercise group remained

Table 1 Baseline characteristics of study participants

Characteristic	Overall study population (N=1,941)	Grouped by exercise frequency		
		Low frequency and intensity exercise group (N=1,483)	High frequency and intensity exercise group (N=458)	P value
Age (years)	17.93±0.72	17.92±0.74	17.98±0.67	0.1469
Male, n (%)	735 (37.87)	435 (29.33)	300 (65.50)	<0.0001
Weight (kg)	57.59±11.46	56.37±10.67	62.35±11.86	<0.0001
BMI (kg/m^2)	20.73±3.02	20.54±2.99	21.34±3.01	<0.0001
Waist circumference (cm)	69.01±10.95	68.52±9.88	72.08±9.52	<0.0001
WHR	0.76±0.06	0.76±0.06	0.78±0.06	<0.0001
Body fat percentage (%)	22.17±7.84	22.26±6.12	20.60±6.87	<0.0001
SBP (mmHg)	114.60±12.96	113.29±12.32	118.93±14.03	<0.0001
DBP (mmHg)	67.19±8.98	67.06±8.64	67.84±10.02	0.1044
TG (mmol/L)	0.77±0.33	0.77±0.32	0.78±0.37	0.444
Chol (mmol/L)	4.15±0.73	4.17±0.74	4.10±0.70	0.0648
LDL-C (mmol/L)	2.23±0.64	2.22±0.65	2.24±0.61	0.5929
HDL-C (mmol/L)	1.58±0.39	1.60±0.39	1.50±0.38	<0.0001

BMI, body mass index; WHR, waist-hip ratio; SBP, systolic blood pressure; DBP, diastolic blood pressure; TG, triglyceride; Chol, cholesterol; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol.

Table 2 Body mass and fat indexes, blood pressure, and serum lipids of the two groups during the follow-up period from 2014 to 2018

Characteristic	Low frequency and intensity exercise group (N=1,483)	High frequency and intensity exercise group (N=458)	P value
Weight (kg)			
2014	56.37±10.67	62.35±11.86	<0.0001
2016	57.45±9.81	63.18±11.85	<0.0001
2018	57.90±11.03	63.82±12.65	<0.0001
BMI (kg/m^2)			
2014	20.54±2.99	21.34±3.01	<0.0001
2016	20.89±3.11	21.60±3.39	<0.0001
2018	20.92±3.08	21.76±3.28	<0.0001
Waist circumference (cm)			
2014	68.52±9.88	72.08±9.52	<0.0001
2016	70.25±7.96	73.49±8.94	<0.0001
2018	72.55±9.36	76.69±10.16	<0.0001
WHR			
2014	0.76±0.06	0.78±0.06	<0.0001
2016	0.76±0.06	0.78±0.06	<0.0001
2018	0.77±0.07	0.80±0.07	<0.0001

Table 2 (*continued*)

Table 2 (*continued*)

Characteristic	Low frequency and intensity exercise group (N=1,483)	High frequency and intensity exercise group (N=458)	P value
Body fat percentage (%)			
2014	22.26±6.12	20.60±6.87	<0.0001
2016	23.62±6.07	21.44±6.14	<0.0001
2018	24.89±5.13	22.07±5.93	<0.0001
SBP (mmHg)			
2014	113.29±12.32	118.93±14.03	<0.0001
2016	115.01±13.98	116.20±14.60	0.0999
2018	117.95±14.24	119.23±14.38	0.1073
DBP (mmHg)			
2014	67.06±8.64	67.84±10.02	0.1044
2016	69.29±9.80	68.78±10.38	0.3173
2018	69.72±9.29	71.47±9.48	0.0015
TG (mmol/L)			
2014	0.77±0.32	0.78±0.37	0.444
2018	0.78±0.34	0.74±0.32	0.0237
Chol (mmol/L)			
2014	4.17±0.74	4.10±0.70	0.0648
2018	4.16±0.73	4.14±0.72	0.5369
LDL-C (mmol/L)			
2014	2.22±0.65	2.24±0.61	0.5929
2018	2.22±0.65	2.22±0.61	0.9899
HDL-C (mmol/L)			
2014	1.60±0.39	1.50±0.38	<0.0001
2018	1.58±0.38	1.58±0.41	0.9217

BMI, body mass index; WHR, waist-hip ratio; SBP, systolic blood pressure; DBP, diastolic blood pressure; TG, triglyceride; Chol, cholesterol; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol.

higher (all P<0.0001), while the BFP was significantly lower (2016: 23.62%±6.07% *vs.* 21.44%±6.14%; 2018: 24.89%±5.13% *vs.* 22.07%±5.93%; P<0.0001). In 2016 and 2018, the difference in the SBP between the two groups at baseline disappeared (2016: 115.01±13.98 *vs.* 116.20±14.60 mmHg; P=0.0999, 2018: 117.95±14.24 *vs.* 119.23±14.38 mmHg, P=0.1073). However, in 2018, the DBP of the high frequency and intensity exercise group was significantly higher than that of the low frequency group (69.72±9.29 *vs.* 71.47±9.48 mmHg, P=0.0015) (*Table 2* and *Figure 2*). In terms of the serum lipid spectrum, the TG of the high frequency and intensity exercise group in 2018 was markedly lower than that of the low frequency and intensity exercise group (0.74±0.32 *vs.* 0.78±0.34 mmol/L, P=0.0237), and the difference in HDL-C at baseline disappeared (1.58±0.41 *vs.* 1.58±0.38 mmol/L, P=0.9217) (*Table 2* and *Figure 3*).

We further analyzed the changes of these body mass and fat indexes between the two groups from 2014 to 2018. As depicted in *Table 3*, there were no significant differences in change of weight, BMI, waist circumference, WHR and blood pressure between the two groups. However, the increase in BFP in the high frequency and intensity exercise group was notably lower than that in the low

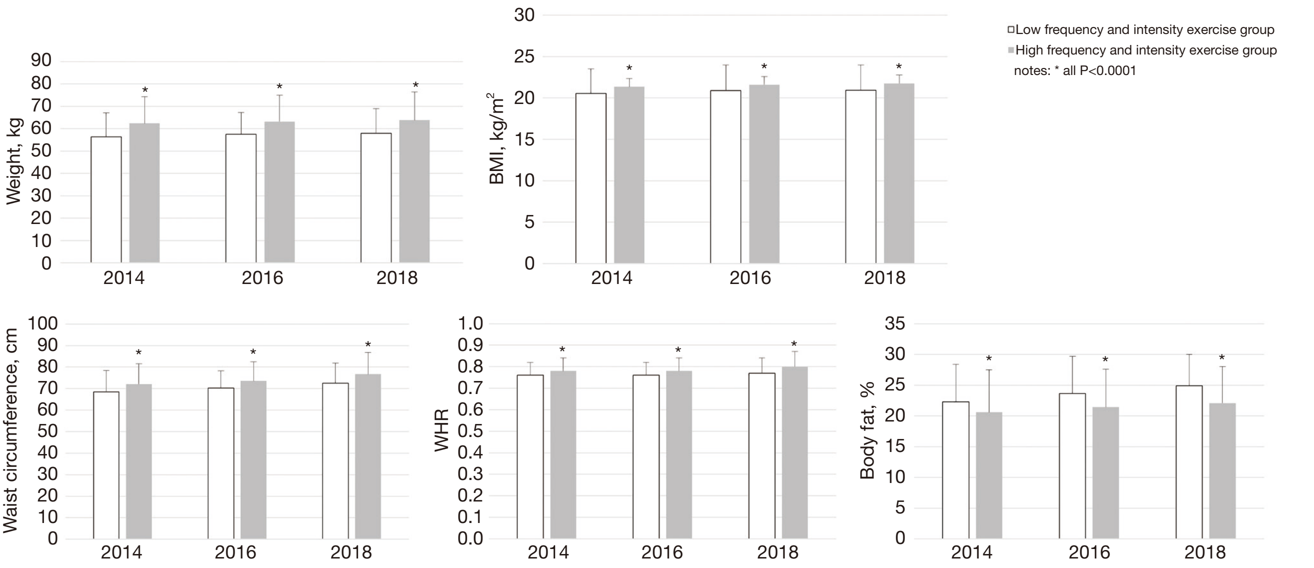

Figure 1 Differences in the body mass and fat indexes between the two groups at baseline and the follow-up in 2016 and 2018. BMI, body mass index; WHR, waist-hip ratio.

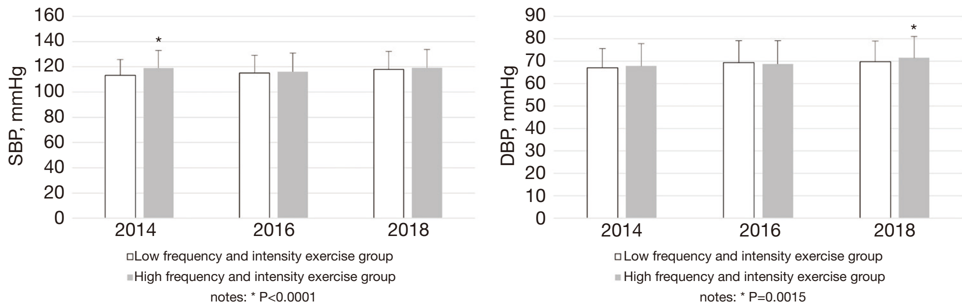

Figure 2 Difference in blood pressure between the two groups at baseline and the follow-up in 2016 and 2018. SBP, systolic blood pressure; DBP, diastolic blood pressure.

frequency and intensity exercise group [1.50 (−1.30–4.30) *vs.* 2.70 (−0.05–5.20), P=0.0289].

As detailed in *Table 4*, compared to the low frequency and intensity exercise group, the high frequency and intensity exercise group exhibited a higher likelihood of reducing BFP from 2014 to 2018 [odds ratio (OR) =1.68; 95% confidence interval (CI): 1.31–2.15). In fact, this association still existed even after adjusting for age, gender, BMI, as well as smoking, drinking, and dietary habits (OR =1.43; 95% CI: 1.09–1.86).

In *Table 5*, we analyzed the changes between different genders in the high frequency and intensity exercise group. The increase in weight and waist circumference of female were lower than that of male, no difference in changes of BMI, WHR, body fat, SBP and DBP was found between the genders.

Discussion

In our research, high frequency and intensity exercise provided benefits in reducing BFP, and no other body mass or fat indexes showed any association. Our results also showed that most body mass and fat indexes exhibited an upward trend with age. SBP, TG, and HDL-C were also significantly improved in the high frequency and intensity exercise group.

The prevalence and severity of obesity have been increasing globally across different age groups, and have more than doubled since 1980. It has long been known that obesity is associated with numerous co-morbidities, including cardiovascular diseases, diabetes mellitus (7),

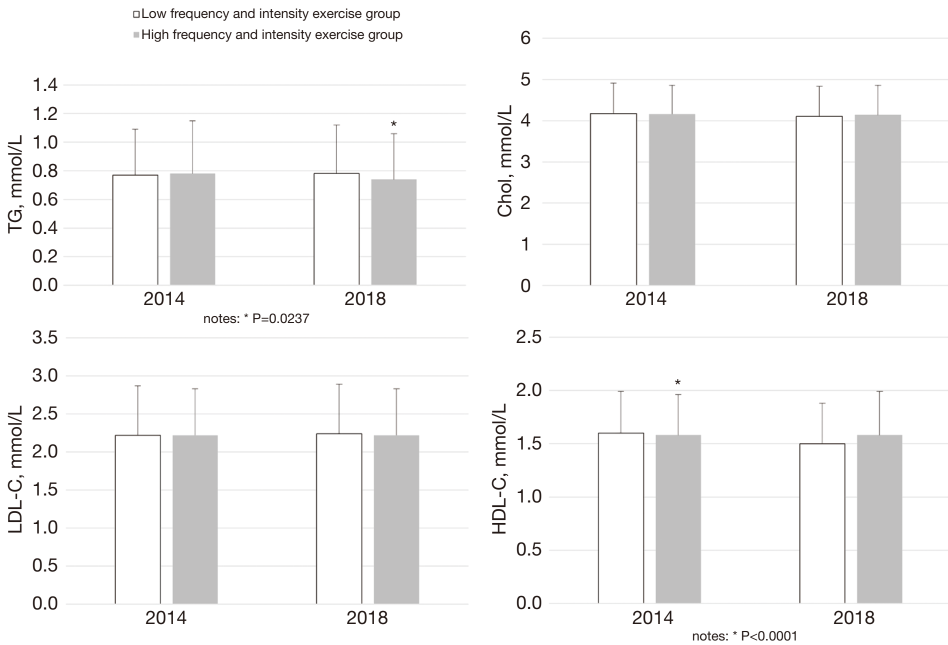

Figure 3 Differences in the serum lipid spectrum between the two groups at baseline and the follow-up in 2018. TG, triglycerides; Chol, cholesterol; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol.

Table 3 Changes in body mass and fat indexes between the two groups during the follow-up period from 2014 to 2018

	Changes, median (interquartile range)		P value
	Low frequency and intensity exercise group (N=1,483)	High frequency and intensity exercise group (N=458)	
Weight change (kg)	2.00 (–1.00–4.00)	2.00 (–1.00–5.00)	0.1102
BMI change (kg/m^2)	0.38 (–0.56–1.21)	0.40 (–0.47–1.32)	0.9484
Waist circumference change (cm)	4.00 (0.00–8.00)	5.00 (1.00–8.00)	0.0602
WHR change	0.01 (–0.03–0.05)	0.02 (–0.01–0.05)	0.6581
Body fat change (%)	2.70 (–0.05–5.20)	1.50 (–1.30–4.30)	0.0289
SBP change (mmHg)	5.00 (–3.00–14.00)	6.00 (–6.00–14.00)	0.1010
DBP change (mmHg)	3.00 (–3.00–10.00)	4.00 (–2.00–11.00)	0.5673

BMI, body mass index; WHR, waist-hip ratio; SBP, systolic blood pressure; DBP, diastolic blood pressure.

Table 4 Logistic regression analysis for OR value for the proportion of people with decreased body fat percentage from 2014 to 2018

	OR (95% CI)		Adjusted factor
	Low frequency and intensity exercise group (N=1,483)	High frequency and intensity exercise group (N=458)	
Model 1	1	1.68 (1.31–2.15)	Unadjusted
Model 2	1	1.44 (1.10–1.87)	Age, gender
Model 3	1	1.43 (1.09–1.86)	Age, gender, BMI, as well as smoking, drinking, and dietary habit

OR, odds ratio.

Table 5 Changes in body mass and fat indexes between the genders in high frequency and intensity exercise group during the follow-up period from 2014 to 2018

	Changes, median (interquartile range)		P value
	Male (N=298)	Female (N=160)	
Weight change (kg)	3.00 (0.00–6.00)	1.00 (−1.00–3.00)	0.0031
BMI change (kg/m^2)	0.67 (−0.33–1.66)	0.12 (−0.70–0.82)	0.1281
Waist circumference change (cm)	6.00 (2.00–9.00)	3.75 (−0.25–7.00)	0.0161
WHR change	0.03 (−0.00–0.06)	0.00 (−0.03–0.04)	0.1178
Body fat change (%)	1.10 (−1.60–3.80)	2.20 (−0.60–4.75)	0.2452
SBP change (mmHg)	6.00 (−6.00–14.00)	5.00 (−5.00–15.00)	0.6741
DBP change (mmHg)	3.00 (−3.00–11.00)	6.00 (0.00–11.00)	0.8715

BMI, body mass index; WHR, waist-hip ratio; SBP, systolic blood pressure; DBP, diastolic blood pressure.

musculoskeletal disorders (6), and several cancers (8). Given that the constellation of cardiac metabolic risk factors is considered to be changeable, early identification and intervention for adolescents with metabolic syndrome is an important public health debate so as to improve their status.

Adolescence is a crucial period for investing in health both in the present and into the future. Therefore, identifying areas to promote positive adolescent health behaviors and prevent negative behaviors is crucial. Although genetic factors play an important role in the pathogenesis of obesity, human behavior and lifestyle, such as physical activity (28) and eating habits (29), are also important factors in its clinical manifestations (30). In previous studies, BMI was often used to evaluate the effect of exercise on body weight. However, the effects of exercise on BMI have unfortunately been underwhelming. There have been few studies assessing the change in body composition, such as BFP. A previous cross-sectional analysis showed that individuals who were more active had a lower fat percentage than those with the same BMI as middle-aged people (18). Another recent study aimed to develop a multidisciplinary lifestyle intervention program for 103 moderately and severely obese children and adolescents, and evaluate the additional effects of exercise intervention compared with routine care. After the intervention, significant interaction effects were observed in the BFP, but no notable interaction effects were observed in the BMI z-score (19). These results suggest that body fat changes may be more sensitive than BMI in reflecting the effects of exercise. It is interesting to explore whether more comprehensive body fat measurement provides additional information beyond that captured by the BMI. Therefore, our group focused on the effects of exercise on the BMI, BFP, and other body mass and fat indicators in Shanghai university freshmen, and attempted to identify sensitive indicators for potential intervention. The freshmen recruited in this survey included various multi-ethnic and socio-economic diverse samples. As in our study, Chinese freshmen seem to be thinner than their corresponding partners in America and Europe, with a mean BMI 20.73±3.02 kg/m^2 and BFP 22.17%±7.84% (31,32). At baseline, we found that the proportion of males in the high frequency and intensity exercise group was significantly higher than that in the low frequency and intensity exercise group (65.50% *vs.* 29.33%, P<0.0001), which was consistent with previous research (33). The body weight, BMI, waist circumference, WHR, and SBP of the high frequency and intensity exercise group were higher than those of the low frequency and intensity exercise group, which explained why they had a more urgent needs for exercise (34,35). However, the BFP in the high frequency and intensity exercise group was significantly lower than that in the low frequency and intensity exercise group (20.60%±6.87% *vs.* 22.26%±6.12%, P<0.0001). This may be due to the higher proportion of men in the high frequency and intensity exercise group, while the average BFP of men is significantly lower than that of women (36,37). Therefore, this 4-year follow-up observation was particularly important to assess the impact of exercise on body mass and fat indexes.

During the follow-up period, we observed that the body mass and fat indexes and blood pressure of both groups exhibited an upward trend with age. At the end of the follow-up period, the SBP, TG, and HDL-C in the high frequency and intensity exercise group were significantly improved compared to the baseline levels. The TG level of the high frequency and intensity exercise group was markedly lower than that in low frequency and intensity exercise group, and the differences in SBP and HDL-C between two groups at baseline disappeared at the follow-up visit. These results showed that, compared with low frequency and intensity exercise, high frequency and intensity exercise could provide benefits for controlling blood pressure (38,39) and serum lipids (40,41). Along with the growth of the age, the average level of most body mass and fat indexes was still higher in the high frequency and intensity exercise group in the follow-up visit. Thus, we further compared whether there were any differences in the changes of body mass and fat indexes from 2014 to 2018, and found that the increase in BFP was significantly lower in the high frequency and intensity exercise group, while changes in other body mass and fat indexes were not notably different. This suggested that BFP could more sensitively reflect the changes in human body mass and fat content.

In order to eliminate the influence of other interfering factors on the data analysis, we conducted logistic regression analysis. The results showed that high frequency and intensity exercise was an independent influencing factor for the decline of BFP, regardless of age, gender, BMI, as well as smoking, drinking, and dietary habits. Therefore, BFP is the most sensitive indicator to reflect the effect of exercise on adolescents.

This was a prospective cohort study based on real-world evidence (RWE). The strengths of our research include a large sample size, well-trained interviewers, and the valuable data pool. We collected the data of all freshmen in this multidisciplinary university, and described their body mass and fat indexes, blood pressure, and blood lipid characteristics. Although this study was conducted in Shanghai, the included college students came from 23 provinces and four municipalities of China, including the Han nationality and ethnic minorities, and thus, could be used as a rough representation of the national data to a certain extent. Adjustment for multiple confounding factors reduced the potential impact of variable statistics. Our results support the conclusion that the BFP is a more sensitive indicator to reflect the exercise effect in Chinese adolescents.

Limitations

There are also some limitations in our research that should be noted. Firstly, the use of self-reports for exercise habits, as opposed to motion equivalent, may lead to systematic bias, as previous studies have shown that exercise time by self-reports appear to be longer than objective measurements (42). However, other studies have shown a reasonably close agreement between self-reports and objective measurements of exercise activity (43,44). Secondly, not all essential parameters are included in our research, such as sedentary behavior (28) and mental state. In the future, more prospective studies are needed to clarify the impact of the above factors on youth obesity.

Conclusions

The medical, financial, and social consequences of adolescent obesity, which is a new epidemic, are enormous, and require an urgent response from health professionals and policy makers. Prevention seems to be a promising strategy among high-risk populations (45). More sensitive indicators reflecting body mass and fat changes could help us to observe the benefits of intervention factors on body shape at an early stage. To the best of our knowledge, prospective cohort studies investigating the characteristics of different body mass and fat indexes and their relationship with exercise in Chinese Mainland freshmen are rare. BFP seems to be a more sensitive indicator of body fat status among freshmen, even after controlling for multiple confounding factors. Therefore, we suggest that young people should pay more attention to BFP in order to better prevent and manage obesity. High frequency and intensity exercise should be encouraged to benefit public health. In future research, BFP, as a sensitive index, could be helpful in controlling obesity in adolescents.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All procedures performed in this study involving human participants were in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Institutional Review Committee of Huashan Hospital, Fudan University (NO.:2011-242) and informed consent was taken from all the participants.

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