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Association between soya food consumption and muscle strength in Chinese adolescents: evidence from a cross-sectional study

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Abstract

There is a strong association between soya food consumption and health, but there are few studies on the association with muscular strength, especially in adolescent groups. This study was conducted to understand the status of soya food consumption and its association with muscular strength among secondary school students in southern China. A stratified whole-group sampling method was used to investigate and test the status of soya food consumption and muscular strength of 13 220 secondary school students in southern China. Linear regression analysis and logistic regression analysis were used to analyse the correlations between soya food consumption and muscular strength. Logistic regression analysis showed that compared with secondary school students with soya food consumption ≥ 3 times/week, male students with soya food consumption ≤ 1 time/week (OR = 1·896, 95 % CI: 1·597,2·251) and female students with soya food consumption ≤ 1 time/week (OR = 2·877, 95 % CI: 2·399, 3·449) students had a higher risk of developing lower grip strength ($P < 0·001$). The frequency of soya food consumption among secondary school students in southern China was 49·00 %, 28·77 % and 22·23 % for ≥ 3 times/week, 2–3 times/week and ≤ 1 time/week, respectively. There is a positive association between soya food consumption and muscle strength among secondary school students in southern China. In the future, increasing the consumption of soybean products can be considered for the improvement of muscle strength.

Keywords: **Adolescents: Soya food consumption: Muscular strength: Correlation: China**

With the development of the social economy and continuous technological progress, the level of physical activity in daily life decreases and the opportunity to participate in various types of resistance activities decreases, which leads to a decreasing trend of people's muscle level and has a negative impact on health. Adolescents are no exception to this trend, and muscle levels have been declining year by year. A study of long-term trends in adolescents showed a significant decrease in upper limb muscular strength in 2012 compared with 1992[1]. A longitudinal study of 1 513 435 adolescents in China showed that standing long jump performance, which reflects muscular strength of the lower limbs, decreased from 171·2 cm in 1995 to 163·5 cm in 2014, and also physical fitness index, which reflects overall fitness level, decreased by 0·8 compared with 1985, which has a health development of Chinese adolescents has been adversely affected[2].

Decreased muscular strength will lead to a higher risk of various diseases, posing a serious health risk[3–5]. A study of a Chinese population confirmed that decreased muscular strength was significantly associated with all-cause mortality (OR = 1·13, 95 % CI: 1·03, 1·21)[6]. This shows that the decrease in muscular strength has many negative effects on adolescents, which deserve our attention and concern. Previous studies have confirmed that there are more factors affecting muscular strength, including dietary behaviour, lifestyle, physical activity level, exercise time, video screen time and sleep quality[7,8]. However, the impact of nutritional changes in dietary behaviour on muscular strength and function accounts for a significant portion of this[9]. It has also been found that high protein consumption has a positive impact on muscle health, with soya food consumption, represented by high-quality plant protein, being strongly associated with increased muscular strength[10]. Research on soya products and human health has been conducted for decades[11–17]. Soybeans and fermented soya products are rich in protein, dietary fiber and a variety of healthful phytochemicals, such as isoflavones, phytic acid, trypsin inhibitors and saponins[18]. Studies have also confirmed a strong association between soya product consumption and

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all-cause mortality[19]. However, the attention paid to soya products in China is far less than that paid to milk for the health of young people, and this is worthy of attention and investigation[20].

Previous studies on the association between soya product consumption and physical and mental health in Chinese populations are scarce and mainly focus on cardiovascular and muscular strength benefits in adults and the elderly[21,22]. In previous studies, there have been fewer studies on soya food consumption and muscle strength and even fewer on adolescent populations. To this end, this study investigated and tested the status of soya food consumption and muscular strength among 13 220 secondary school students in southern China. We analysed the association between soya food consumption and muscular strength among secondary school students. The study was conducted to provide a reference for the improvement and intervention of soya food consumption and muscular strength of secondary school students.

Materials and methods

Participants and procedures

A stratified whole-group sampling method was used to test and investigate the soya food consumption status and muscular strength of 13 220 middle school students in southern China. The sampling process was divided into two stages: In the first stage, four cities (Fuzhou, Guangzhou, Shangrao and Zhangzhou) were selected in southern China based on different geographic locations, and then five middle schools were selected in each city based on the distribution of schools. A total of 20 middle schools were selected as the field schools for this study. In the second stage, in each school, four teaching classes from each grade (junior high school grade 1 to junior high school grade 3) were selected as a whole, and a total of 240 teaching classes were selected for this study. A total of 13 478 questionnaires were distributed in this study, and 258 invalid questionnaires with missing main demographic information were excluded after the questionnaires were returned, and a total of 13 220 valid questionnaires were returned, with a valid return rate of 98·09 %. The specific sampling process is shown in Fig. 1.

Written informed consent from the student's parents and myself was obtained before the investigation of this study and approved by the Human Ethics Committee of Chizhou University (202104457).

Basic information and covariates

The investigation of basic information in this study included information on age, gender, school and class of the subjects. The survey of covariates included information on parents' education, duration of physical exercise, video screen time, height, weight and BMI. Parental education was categorised into elementary school and below, secondary school, high school and university and above. The duration of physical exercise refers to the duration of medium-intensity physical exercise per day, calculated based on subjects' recall of average exercise time over the past 7 d and was classified as < 30 min/d, 30–60 min/d and > 60 min/d. Screen time is the average daily exercise duration of the subjects in the past 7 d, and the screen time includes the time of watching TV, tablet computer, cell phone, etc., which is classified as < 60 min/d, 60–120 min/d and >120 min/d. BMI was calculated based on height and weight test results with the formula of weight (kg)/height (m)^2.

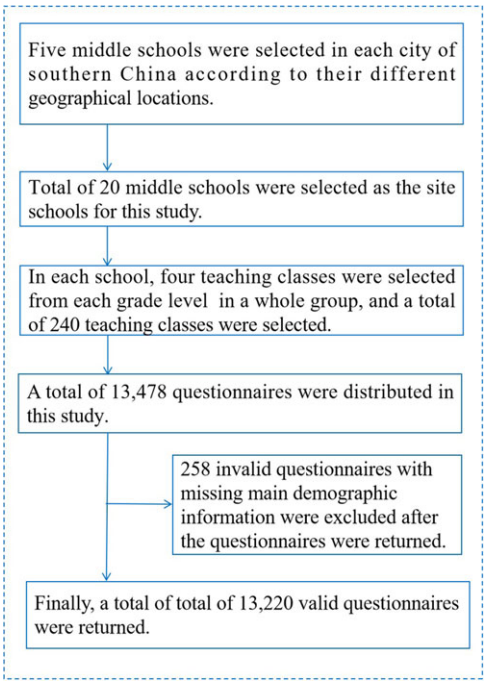

Fig. 1. Flow chart of the sampling of secondary school students in southern China.

Consumption of soya food products

The consumption of soya food mainly investigated the frequency of soya food consumption in the past 7 d of the subjects, which was divided into ≥ 3 times/week, 2–3 times/week and ≤ 1 time/week in this study. This survey was conducted through a recall survey. Participants recalled how often they consumed soya food each day for the past 7 d and recorded it on the appropriate questionnaire. The so-called soybean products are food products processed from soybean plants as the main raw material, such as soya milk, tofu, dried soybeans, bean curd and soya products.

Muscular strength

In this study, muscular strength was tested using a grip strength meter test to test the upper limb muscular strength of the subjects. The test was conducted according to the testing instruments and methods required by the Chinese National Student Physical Fitness Survey[23]. The test required the subjects to grip the strength meter with both arms naturally down and both legs naturally standing apart, using the strong hand to grip as hard as possible, and the results were measured in kilograms, accurate to 0·1 kg. The test apparatus was the SH-WL-1000 grip strength meter.

Table 1. Comparison of each variable among students in different soya food consumption in southern China

	Soya food consumption									
	≥ 3 times/week		2–3 times/week		≤ 1 times/week		Total			
Category	*n*	%	*n*	%	*n*	%	*n*	%	χ^2-value	*P*-value
Number	6478	49·00	3803	28·77	2939	22·23	13 220			
Sex										
Male	3932	60·7	1849	48·6	1040	35·4	6821	51·6	537·583	< 0·001
Female	2546	39·3	1954	51·4	1899	64·6	6399	48·4		
Father's education										
Elementary school and below	549	8·5	547	14·4	330	11·2	1426	10·8	248·996	< 0·001
Secondary school	2149	33·2	1587	41·7	1018	34·6	4754	36·0		
High School	2367	36·5	1165	30·6	995	33·9	4527	34·2		
University and above	1413	21·8	504	13·3	596	20·3	2513	19·0		
Mother's education										
Elementary school and below	844	13·0	810	21·3	484	16·5	2138	16·2	234·604	< 0·001
Secondary school	2181	33·7	1470	38·7	1006	34·2	4657	35·2		
High School	2247	34·7	1113	29·3	979	33·3	4339	32·8		
University and above	1206	18·6	410	10·8	470	16·0	2086	15·8		
Duration of physical exercise										
< 30 min/d	2650	40·9	1824	48·0	1334	45·4	5808	43·9	73·851	< 0·001
30–60 min/d	2738	42·3	1518	39·9	1217	41·4	5473	41·4		
> 60 min/d	1090	16·8	461	12·1	388	13·2	1939	14·7		
Screen time										
< 60 min/d	3662	56·5	1760	46·3	1642	55·9	7064	53·4	111·106	< 0·001
60–120 min/d	1750	27·0	1262	33·2	822	28·0	3834	29·0		
> 120 min/d	1066	16·5	781	20·5	475	16·2	2322	17·6		

Quality control

The questionnaire survey consisted of faculty members and graduate students who had passed the training and assessment. The survey was conducted in a centralised manner, and the purpose and requirements of the survey were explained to students before the survey. The questionnaires were distributed on the spot and filled in on the spot, and the questions of the subjects were answered by the staff in time during the filling-in process. The questionnaires were distributed on the spot and collected on the spot, the completeness of the completed questionnaires was checked roughly when they were collected and the subjects were asked to fill in the missing or wrong questionnaires to ensure the validity of the survey. A person was responsible for the grip strength test, and the results were registered on the test card. The grip strength meter was calibrated daily to ensure the validity of the test.

Statistical analysis

Continuous variables were expressed as mean and standard deviation (M ± SD). The presentation of count data was expressed as a percentage. Comparisons of each variable and grip strength scores between different soya food consumption frequencies were made using one-way ANOVA. Percentages were compared using the χ^2 test.

The association between soya food consumption and muscular strength was performed using linear regression analysis and logistic regression analysis. Linear regression analysis was performed using gender stratification. A linear regression analysis was performed using those who consumed soya food ≥ 3 times/week as the reference and grip strength as the dependent variable. The crude model did not control for relevant covariates; model 1 controlled for age, gender, father's education and mother's education and model 2 controlled for physical activity hours, video screen time and BMI based on model 1.

To further analyse the association between soya food consumption and muscular strength, based on the criteria for the classification of study[24], students with grip strength scores below one standard deviation, which reflects muscular strength, were defined as those with poor muscular strength by age and gender for logistic regression analysis in this study. Logistic regression analysis was performed using soya food consumption ≥ 3 times/week as the reference group. Model 1 controlled for age, gender, father's education and mother's education, and model 2 controlled for physical activity hours, video screen time and BMI based on model 1. The OR and 95 % CI of the different models were reported separately.

Data analysis was processed and analysed using SPSS25·0 software. A two-sided test level of $\alpha = 0{\cdot}05$ was used.

Results

Table 1 shows that the frequency of soya food consumption among secondary school students in southern China was 49·00 %, 28·77 % and 22·23 % for ≥ 3 times/week, 2–3 times/week and ≤ 1 time/week, respectively. The grip strength scores of secondary school students were (28·95 ± 8·74) kg. There was a statistically significant difference in the frequency of soya food consumption when comparing secondary school students by gender, father's education, mother's education, physical exercise hours and video screen time (χ^2 value = 537·583, 248·996, 234·604, 73·851, 111·106, $P < 0{\cdot}001$).

Table 2. Comparison of students' grip strength performance in different soya food consumption in southern China

Sex	Soya food consumption	Number	Grip strength		*F*-value	*P* value
			Mean	Standard deviation		
Male	≥ 3 times/week	3932	34·00	8·49	60·260	< 0·001
	2–3 times/week	1849	33·08	8·69		
	≤ 1 times/week	1040	30·63	10·21		
Female	≥ 3 times/week	2546	25·20	5·80	56·561	< 0·001
	2–3 times/week	1954	24·30	5·70		
	≤ 1 times/week	1899	23·37	5·54		
Total	≥ 3 times/week	6478	30·54	8·68	297·931	< 0·001
	2–3 times/week	3803	28·57	8·52		
	≤ 1 times/week	2939	25·94	8·29		

Table 3. Comparison of linear regression between different soya food consumption and grip strength scores of secondary school students in southern China (*n* 13 220)

Soya products consumption	Valuation (95 % CI)					
	Coarse model		Model 1		Model 2	
	Valuation	95 % CI	Valuation	95 % CI	Valuation	95 % CI
Male						
≥ 3 times/week	0·000		0·000		0·000	
2–3 times/week	–0·922	–1·41, –0·434*	–0·607	–1·066, –0·149	–0·563	–1·012, –0·114
≤ 1 times/week	–3·368	–3·971, –2·764*	–2·58	–3·144, –2·017*	–2·465	–3·015, –1·915*
Female						
≥ 3 times/week	0·000		0·000		0·000	
2–3 times/week	–0·902	–1·237, –0·566*	–0·863	–1·199, –0·526*	–0·758	–1·092, –0·425*
≤ 1 times/week	–1·831	–2·169, –1·492*	–1·721	–2·057, –1·384*	–1·371	–1·707, –1·035*
Total						
≥ 3 times/week	0·000		0·000		0·000	
2–3 times/week	–1·974	–2·316, –1·631*	–1·825	–2·162, –1·487*	–1·646	–1·978, –1·314*
≤ 1 times/week	–4·6	–4·973, –4·228*	–4·266	–4·63, –3·902*	–3·794	–4·152, –3·435*

* $P < 0·001$.

Table 2 shows that the highest grip strength scores of (34·00 ± 8·49) kg were found in secondary school boys with soya food consumption ≥ 3 times/week in southern China. The differences were statistically significant when comparing the grip strength scores of male students in secondary schools with different soya food consumption (F value = 60·260, $P < 0·001$). Grip strength scores were also highest in female students with soya food consumption ≥ 3 times/week at (25·20 ± 5·80) kg. The differences were also statistically significant when comparing the grip strength scores of female students in secondary schools with different soya food consumption (F value = 56·561, $P < 0·001$). Overall, it can be seen that students with soya food consumption ≥ 3 times/week also had the highest grip strength scores of (30·54 ± 8·68) kg. The differences were also statistically significant when comparing the grip strength scores of students in different soya food consumption (F value = 297·931, $P < 0·001$).

Table 3 shows that grip strength performance was used as the dependent variable and soya food consumption frequency was used as the independent variable. The frequency of soya food consumption ≥ 3 times/week was used as a reference. A linear regression analysis was performed with a dummy variable setting of 0,1 for soya food consumption frequency 2–3 times/week and ≤ 1 time/week. The crude model did not control for relevant variables, and model 1 controlled for age, gender, father's education and mother's education. Model 2 controlled for physical activity hours, video screen time and BMI based on model 1. The results of linear regression analysis showed that by controlling for relevant confounding variables, grip strength performance was reduced by 1·646 kg and 3·794 kg for students with soya food consumption frequency 2–3 times/week and ≤ 1 time/week, respectively, compared with secondary school students with soya food consumption frequency ≥ 3 times/week ($P < 0·001$). The same trend was found for boys and girls.

Table 4 shows that logistic regression analysis was performed with whether secondary school students had poor grip strength (yes = 1, no = 0) as the dependent variable and different soya food consumption frequencies as the independent variables (≥ 3 times/week = 1, 2–3 times/week = 2, ≤ 1 time/week = 3). Logistic regression analysis showed that by controlling for relevant confounding variables, students with soya food consumption frequency ≤ 1 time/week (OR = 2·037, 95 % CI: 1·813,2·289) had a higher risk of developing lower grip strength compared with secondary school students with soya food consumption frequency ≥ 3 times/week ($P < 0·001$). Students with a frequency of soya food consumption ≤ 1 time/week (OR = 1·896, 95 % CI: 1·597, 2·251) for boys and ≤ 1 time/week (OR = 2·877, 95 % CI: 2·399,3·449) for girls also had a higher risk of developing lower grip strength ($P < 0·001$). This

Table 4. Logistic regression comparison between different soya food consumption and grip strength performance among secondary school students in southern China (*n* 13 220)

	OR (95 % CI)					
	Coarse model		Model 1		Model 2	
Soya products consumption	OR	95 % CI	OR	95 % CI	OR	95 % CI
Male						
≥ 3 times/week	1·000		1·000		1·000	
2–3 times/week	1·164	0·999, 1·357	1·095	0·938, 1·278	1·090	0·931, 1·275
≤ 1 times/week	1·897	1·603, 2·245*	1·892	1·597, 2·243*	1·896	1·597, 2·251*
Female						
≥ 3 times/week	1·000		1·000		1·000	
2–3 times/week	1·24	1·011, 1·521	1·252	1·019, 1·539	1·191	0·967, 1·465
≤ 1 times/week	3·14	2·627, 3·752*	3·197	2·673, 3·825*	2·877	2·399, 3·449*
Total						
≥3 times/week	1·000		1·000		1·000	
2–3 times/week	1·112	0·985, 1·254	1·073	0·949, 1·212	1·047	0·925, 1·184
≤ 1 times/week	2·182	1·945, 2·447*	2·177	1·94, 2·443*	2·037	1·813, 2·289*

The crude model did not control for relevant variables. Model 1 controlled for age, gender, father's education and mother's education. Model 2 controlled for physical activity hours, video screen time and BMI based on model 1.
* $P < 0·001$.

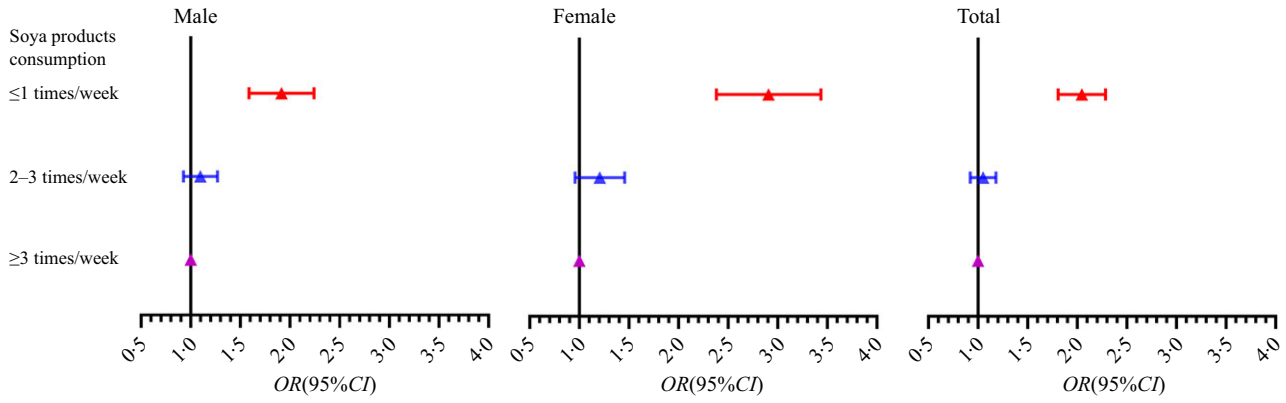

Fig. 2. Logistic regression analysis of odds ratio change trend of different soya food consumption and grip strength performance among secondary school students in southern China.

shows that there is a positive association between the frequency of soya food consumption and muscular strength in secondary school students. Trends in odds ratio of secondary school students are shown in Fig. 2.

Discussion

The health benefits of soya products have been confirmed by several studies[12,14]. However, there are few studies on soya products and adolescent physical health, especially in the context of the good availability of soybean formulations in China. In this study, we investigated the status of soya food consumption and muscular strength in Chinese secondary school students and analysed the association between them.

This study found that the frequency of soya food consumption among secondary school students in southern China was 49·00 %, 28·77 % and 22·23 % for ≥ 3 times/week, 2–3 times/week and ≤ 1 time/week, respectively. This result indicates that there are still more than two strata of adolescents who consume soya products only 1 time or less per week. Studies have confirmed that Chinese urban school-age children use 10·7 g of soya or soya products per day[21]. Unfortunately, the only studies that have been conducted on adolescent soya food products cannot be compared cross-sectionally because of different survey criteria. However, it is clear from this study that there is still a certain percentage of secondary school students who have insufficient soya food consumption, which deserves attention and concern.

This study also found that the grip strength performance of secondary school students in southern China was (28·95 ± 8·74) kg, a result that is more consistent with the grip strength performance of secondary school students aged 13–15 years in the 2019 National Student Physical Health Survey in China, which ranged from 25·16 to 29·87 kg[23]. Studies have confirmed that grip strength scores, which reflect muscular strength, are closely associated with physical health and are especially important for adolescent health and can continue into adulthood, with implications for adult health[25].

This study analysed the association between soya food consumption and muscular strength using linear regression analysis. It was found that by controlling for relevant confounding

variables, grip strength performance was reduced by 1·646 kg and 3·794 kg for students with soya food consumption frequency of 2–3 times/week and ≤ 1 time/week, respectively, compared with secondary school students with soya food consumption frequency of ≥ 3 times/week. In addition, further logistic regression analysis also showed that both male and female secondary school students with soya food consumption frequency ≤ 1 time/week had a higher risk of experiencing lower grip strength compared with secondary school students with soya food consumption frequency ≥ 3 times/week. This shows that there is a positive association between soya food consumption frequency and muscular strength in secondary school students, i.e., a higher frequency of soya food consumption has a positive effect on muscular strength.

In response to the association that exists between soya products and muscular strength, several reasons exist. First, soya is a high-quality vegetable protein that has a promotive effect on muscular strength. Studies have shown that people with high protein intake have higher muscle mass, which is a protective factor against sarcopenia[26]. Studies have also shown that adequate dietary protein intake is critical to maintaining muscle mass, with most people in Western countries consuming relatively high amounts of protein above the minimum recommended protein intake, while China's is relatively low[27–29]. It has also been confirmed that there is a strong correlation between an even distribution of daily protein intake and an increase in muscle mass[30,31]. Studies suggest that for young people and healthy adults, a meal containing about 30 grams of protein is optimal for stimulating 24-hour muscle protein synthesis[32,33]. Second, the use of soya products facilitates the prevention of obesity and has a positive impact on the improvement of muscular strength. Studies have shown that the intake of soya products increases the satiety of the stomach, thereby reducing the intake of excess energy and the accumulation of fat, which has a positive impact on the prevention of obesity[34]. It is also confirmed that the occurrence of obesity will lead to an increase in physical resistance, which will have a negative impact on the development of physical fitness and muscular strength, resulting in a decrease in muscular strength[35]. Third, the proteins in soya are beneficial to muscle protein synthesis and have a promotional effect on muscular strength. A study confirmed that soya protein has a more positive effect on muscle protein synthesis compared with animal protein and has a promotional effect on the improvement of muscular strength[36]. It has also been shown that leucine in soya protein plays an important role in muscle protein synthesis and muscle growth, positively influencing the formation of lean body mass and the synthesis of less fat, thus effectively promoting muscular strength[37].

There are some limitations in this study. First, this study is a cross-sectional survey, which can only understand the correlation between soya food consumption and muscular strength, but not the causal relationship between them. Second, this study only investigated the status of soya food consumption, but not the intake of soya products, which had some influence on the results. Third, this study only tested the grip strength index reflecting the muscular strength of the upper limbs and the standing long jump, such as the muscular strength of the lower limbs, should be added in the future to more comprehensively evaluate the association between soya products and muscular strength. Finally, the present study analysed the relationship between soya food consumption and grip strength by treating duration of exercise and screen time as covariates, and the analysis of mediating variables could be attempted in the future to better analyse the associations that exist between the variables. In addition, important influences such as physical activity should be adjusted or stratified for analysis in future studies. However, our study also has some advantages. To our knowledge, this is the first analysis of the association between soya products and muscular strength in Chinese adolescents, which provides a reference for future muscular strength promotion and intervention.

Conclusion

There is a positive association between soya food consumption and muscle strength among secondary school students in southern China. That said, consuming more soya foods is associated with higher muscle strength. In the future, increasing the consumption of soybean products can be considered for the improvement of muscle strength. Given the results of this study, it is recommended that the health literacy level of secondary school students should be continuously improved in the future to recognise the positive effects of soya food products on health, so as to increase the intake of soya food products. In addition, family guardians should ensure a reasonable nutritional diet for adolescents, safeguard the intake of soya products and actively promote the formation of an exercise environment in which adolescents actively participate in resistance exercise to further promote the improvement of muscular strength.

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The authors declare no conflict of interest.

This research investigation was approved by the Human Ethics Committee of Chizhou University (202104457).

The study was in accordance with the requirement of the World Medical Association Declaration of Helsinki and granted with consent from the students, schools and parents and written consents were signed.

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

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British Journal of Nutrition

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