Analysis of the Correlation between Cardiorespiratory Fitness and Sports in the Youth Population

Hui Guo*, Zhuoran Li, and Meng Zhao

***Abstract*—The level of cardiopulmonary function of young people is generally in a downward trend. In order to scientifically and reasonably improve the level of cardiopulmonary function of young people through physical exercise, the effect of daily physical exercise habits on cardiopulmonary function of young people aged 18-39 years old was studied. The maximum oxygen uptake and other cardiopulmonary function indexes of 120 college students and young teachers were measured through cardiopulmonary exercise test. The correlation analysis of each index was performed using SPSS 19.0, and their daily exercise habits were investigated using questionnaires. The influencing factors included whether they had exercise habits, the number of days of moderate intensity exercise in a week, the most frequent exercise items, and whether they had strength training or flexibility training. Single factor analysis of variance was used to study the influence of daily exercise habits on the level of cardiopulmonary function. The indexes of aerobic metabolism of the subjects with exercise habits were significantly better than those without daily exercise habits (P<0.01), and the maximum oxygen uptake of the subjects who exercised more than three times a week with moderate intensity was significantly higher than that of the subjects who exercised less than three times a week (P<0.01). By analyzing the influence of different daily physical exercise habits on cardiopulmonary function, we can guide young people to carry out scientific, effective and reasonable physical exercise and improve cardiopulmonary function.**

***Index Terms*—Cardiopulmonary exercise test, cardiorespiratory fitness, physical exercise, maximum oxygen uptake**

I. Introduction

With the rise of national fitness, the decline in physical health level is gradually attracting attention. Cardiorespiratory fitness is an important component of physical health, and good cardiorespiratory fitness is the basis for the development of various functions and qualities of the human body, and cardiorespiratory endurance is also the most effective predictor of mortality and morbidity [1]. Physical activity, cardiorespiratory endurance, risk of cardiovascular death, and risk of total death were strongly, negatively, and independently correlated [2]. Therefore, to effectively prevent cardiovascular and other chronic diseases, the level of cardiorespiratory fitness should be improved.

Nowadays, with the improvement of living standards, the convenience of transportation and the lack of exercise, the aerobic capacity of young people has decreased, the tolerance to long-term exercise has decreased, the cardiopulmonary function has decreased, and the risk of cardiovascular disease has increased [3]. Daily physical activity has a great impact on cardiopulmonary function, moderate and individualized exercise can effectively improve the level of cardiopulmonary function and play a role in the prevention and control of the growing number of cardiovascular and cerebrovascular diseases [4]. Therefore, young people need to be able to plan their physical activity scientifically and rationally to improve their cardiorespiratory fitness.

The level of cardiorespiratory fitness can be directly reflected by a cardiopulmonary exercise test to measure aerobic metabolic indices. Treadmills and power bikes are the most commonly used methods to measure an individual's maximum oxygen uptake [5]. The power car step-by-step incremental load test (graded exercise test, GXT) is a laboratory use of power car for direct testing of maximum oxygen uptake [6]. The maximum oxygen uptake [7] and the oxygen pulse [8] measured in the experiment both reflect well the human cardiorespiratory function.

The main objective of this study is to evaluate the effect of daily physical activity habits on the level of cardiorespiratory fitness in young people aged 18-39 years, including school students and teachers, to analyze the correlation between physical activity habits and the level of cardiorespiratory fitness, to draw attention to physical health problems and the prevention of chronic diseases such as cardiovascular diseases, to arrange physical activity scientifically and rationally, to improve physical health.

II. Materials and Methods

A. Human Participants

The test subjects were 120 university students and young teachers aged 18 to 39 years, of whom 62 were male (age 27.92±6.16) and 58 were female (age 27.91±6.66).

B. Equipment

Special instruments for the fifth national physical fitness monitoring are using to measure height, body mass, body fat percentage, lean body mass, and lung capacity, and the German Ergoline power cart is using for step-by-step incremental load experiments, and the German CortexMetaMax 3B exercise cardiorespiratory fitness tester is using to measure maximum oxygen uptake, oxygen pulse, and other aerobic metabolic indexes.

Manuscript received May 23, 2023; revised June 30, 2023; accepted August 23, 2023.

Hui Guo is with the Institute of Sports Equipment Industry Technology, Shenyang University of Technology, Shenyang 110870, China.

Zhuoran Li was with the Biomedical Engineering, Shenyang University of Technology, Shenyang 110870, China.

Meng Zhao is with the Biomedical Engineering, Shenyang University of Technology, Shenyang 110870, China.

*Correspondence: guohui@sut.edu.cn (H.G.)

doi:10.18178/ijssh.2023.13.6.1179

C. Experimental Process

Subjects were tested on basic physical and health indicators, including their height, body mass, vital capacity, percentage of body fat, vital capacity, etc. The subjects were required to carry out the stepwise load test of power car. The load scheme is that the initial load is 25w, each step is increased by 25w, the duration of each step is 2min, and the whole speed is kept at 60r/s [9]. The criteria for termination of the progressive load test were 1) heart rate at or above maximum heart rate (maximum heart rate is 220-age), 2) plateau in oxygen uptake, 3) respiratory quotient exceeding 1.15 [10], and 4) subject exhaustion with subjective fatigue feeling of 18 and inability to persist despite repeated encouragement [11].

D. Indicators

The questionnaire was administered to the subjects through the "Adult Cardiorespiratory Endurance Comparison Test Card", which included whether they had an exercise habit, the number of moderate intensity exercises performed in a week, the most frequent sports, whether they performed strength training and whether they performed flexibility training.

The routine indicators of national physique monitoring include body mass, height, BMI (BMI=body mass/kg ÷ (height/m)2), body fat percentage, lean body mass (defatted body mass), vital capacity, etc.

The indicators of cardiopulmonary function evaluation measured in the step-by-step incremental load experiment include maximum relative oxygen uptake, absolute oxygen uptake, absolute carbon dioxide excretion, oxygen pulse, and tidal volume.

E. Statistical Analysis

SPSS 19.0 software was used for analysis, and the descriptive statistics of the measured data were expressed as mean ± standard deviation. The test subjects were divided into two groups according to whether they exercised or not, into two groups for different exercise frequencies (divided into the group of 3 times per week and above and the group of fewer than 3 times per week), into four groups for different training items performed most frequently, and into two groups each for strength training and flexibility training. The Z-score of each cardiorespiratory endurance evaluation index was derived, and the Z-score of each index was summed for each individual to obtain the fitness index [12], which indicates the health status of cardiorespiratory function. The fitness indices were classified as “healthy cardiorespiratory function” and “sub-healthy cardiorespiratory function” according to the fitness indices greater than or equal to 0 and less than 0, respectively [13]. The Pearson χ2 test was used to compare exercise habits with the physical fitness index [14]. The influence of exercise habits on various indexes of cardiopulmonary function was analyzed by multivariate logistic regression model, and the difference was statistically significant with P<0.05.

III. Results

A. Descriptive Statistic

The measured height, body mass, body fat percentage, spirometry, maximal oxygen uptake, and oxygen pulse were subjected to descriptive statistics, as shown in Table I.

TABLE I: Statistics of Each Index for Testers of Different Genders (Mean ± Standard Deviation)

	Number of people	BMI ($kg \cdot m^{-2}$)	Body fat rate(%)
male	62	24.1±3.7	21.9±6.2
female	58	22.2±3.1	27.8±6.1
t -value		2.94	-5.24
P -value		0.00	0.00
Body weight (kg)	**Spirometry (ml)**	**Maximum oxygen uptake (ml/min/kg)**	**Oxygen pulse (ml)**
57.1±6.9	3998±662	28.7±6.7	12.6±2.9
43.2±4.7	2929±599	24.0±5.4	8.6±2.5
12.74	9.14	4.14	7.90
0.00	0.00	0.00	0.00

As can be seen in Table I, the BMI and lean body mass of the subjects were lower in females than in males, the percentage of body fat was higher than in males, and the aerobic metabolic indexes including lung capacity, relative oxygen uptake, and oxygen pulse were lower than in males. The study found that there was no significant difference in the maximum oxygen uptake between men and women before puberty, and the difference in the maximum oxygen uptake began to become obvious after the age of 12-13 years [15]. The differences between sexes in maximal oxygen uptake and all other aerobic metabolic indices were statistically significant(P<0.05).

B. The Relationship between Exercise Habits and Cardiorespiratory Fitness

1) Pearson χ2 test

The Pearson χ^2 test was used to compare each exercise habit with the physical fitness index obtained from the Z score, and the results are shown in Table II.

TABLE II: The Relationship between Exercise Habits and Cardiorespiratory Fitness In Youth Population

Variables	Cardiorespiratory subfitness		Cardiorespiratory subfitness		χ^2	P-value
	Frequency	Percentage（%）	Frequency	Percentage（%）		
Whether exercise						
Yes	23	44.2	46	86.8	21.10	0.000
Not	29	55.8	7	13.2		
Exercise frequency						
≥3times one week	45	81.8	32	56.1	8.59	0.003
<3 times one week	10	18.2	25	43.9		
Most frequent sport						
Walking	26	83.9	17	37.0	17.73	0.001
Running	3	9.7	8	17.4		
Ping Pong, Badminton, Tennis	1	3.2	6	13.0		
Soccer, basketball, volleyball	1	3.2	15	32.6		
Whether						

to train for strength						
Yes	7	12.7	19	33.3	6.67	0.010
Not	48	87.3	38	66.7		
Whether to take flexibility training						
Yes	6	10.9	16	28.1	5.22	0.022
Not	49	89.1	41	71.9		

As can be seen from Table II, in terms of whether or not they have exercise habits, the youth population had the highest health fitness detection rate (86.8%) for "exercise habits" with a χ2 value of 21.10 and a lower cardiorespiratory fitness detection rate (13.2%) for "no exercise habits". The difference was statistically highly significant (P<0.001). Regarding the frequency of exercise in a week, the detection rate of cardiorespiratory fitness (56.1%) was higher for "moderate intensity exercise more than or equal to 3 days a week," with a χ2 value of 8.59, and the difference was statistically significant (P<0.01). Regarding the most frequently played sports, the detection rate of cardiorespiratory fitness (3.2%) was the lowest in "Ping, feather and tennis" and "soccer, basketball and volleyball," with a χ2 value of 17.73, a statistically significant difference (P<0.01).

2) Effect of the presence or absence of exercise habits on cardiorespiratory fitness

A one-way ANOVA was performed on all cardiorespiratory endurance indices for both groups of subjects with and without exercise and exercise habits, and the results are shown in Table III.

TABLE III: COMPARISON OF AEROBIC METABOLIC CAPACITY OF PEOPLE WITH DIFFERENT EXERCISE HABITS

Whether exercise	Number of people	Statistical value	Spirometry（ml）	Body fat rate（%）	Body weight （kg）	Maximum oxygen uptake （ml/min/kg）	Oxygen pulse （ml）
Tes	72		3755±721	23.5±6.5	52.0±8.9	28.0±6.3	11.5±3.1
Not	37		2898±659	26.8±7.0	45.6±7.6	24.1±6.3	8.8±2.7
Total	109		3461±808	24.6±6.8	49.8±9.0	26.7±6.5	10.6±3.3
		F-value	36.30	5.80	13.88	9.39	20.25
		P-value	0.00	0.01	0.00	0.00	0.00

As can be seen from Table III, test subjects with daily exercise habits had significantly higher lung capacity, significantly lower body fat percentage, and higher relative oxygen uptake, absolute oxygen uptake, oxygen pulse and tidal volume compared to those without daily exercise habits, with all differences being statistically significant (P<0.01).

3) Effects of moderate intensity exercise frequency on cardiorespiratory fitness

Moderate intensity Continuous Training（MICT）is an activity that causes the body to sweat slightly, breathe faster, and have a faster heart rate, such as brisk walking and cycling, and is one of the most common forms of exercise performed by the general public to burn calories, promote lipolysis, and significantly improve cardiorespiratory fitness.

In the population with exercise habits, comparing the maximum oxygen uptake of testers who performed moderate intensity exercise for more than 3 days a week with those who performed less than 3 days, the results are shown in Table IV.

TABLE IV: FREQUENCY OF MODERATE INTENSITY EXERCISE IN RELATION TO MAXIMUM RELATIVE OXYGEN UPTAKE

Exercise frequency	Number of people	Statistical value	Maximum oxygen uptake （ml/min/kg）
≥3times/week	35		30.2±5.7
<3 times/week	35		25.8±6.1
Total	70		28.0±6.3
		F-value	9.91
		P-value	0.00

As shown in Table IV, the maximum oxygen uptake was significantly higher (p<0.01) in subjects who performed moderate-intensity exercise for more than 3 days in a week (30.2±5.7 ml/min/kg) compared to those who performed less than 3 days (25.8±6.1 ml/min/kg). Moderate-intensity exercise is the same as daily physical activity (PA) [16], which produces energy expenditure by increasing basal level metabolism through skeletal muscle contraction [17]. By performing regular moderate-intensity exercise on a weekly basis, it is possible to maintain an appropriate level of fitness, which also plays an important role in disease prevention and health promotion [18].

4) The effect of the training program on cardiorespiratory fitness

The questionnaire survey and statistics were conducted on the most frequently performed training programs of 70 of the 120 people with exercise habits, and a one-way ANOVA was conducted on the maximum oxygen uptake and oxygen pulse corresponding to the four most frequently performed training programs. The results are shown in Table V.

TABLE V: EFFECT OF TYPE OF DAILY EXERCISE ON AEROBIC METABOLIC CAPACITY

Most frequent sport	Number of people	Statistical value	Maximum oxygen uptake （ml/min/kg）	Oxygen pulse （ml）
Walking	43		25.0±5.3	9.6±3.1
Running	13		27.1±5.2	12.1±3.0
Ping Pong, Badminton, Tennis	7		31.3±4.9	12.6±1.3
Soccer, basketball, volleyball	16		32.7±5.7	13.6±3.0
Total	79		27.47±6.1	11.1±3.3
		F-value	9.37	8.50
		P-value	0.00	0.00

It can be seen from Table V that the fourth group of people with training items of football, basketball and volleyball are the best in aerobic metabolism, the third group of Ping Pang, badminton, tennis category of maximum oxygen uptake second, the second group of running again, the first group of walking, walking maximum oxygen uptake is the lowest, the difference between the groups are statistically significant (P

< 0.01).

5) Effects of strength training and flexibility training on cardiorespiratory fitness

A one-way ANOVA was performed on the maximum relative oxygen uptake of those who performed strength exercises versus those who did not, and the results are shown in Table VI.

TABLE VI: EFFECT OF STRENGTH TRAINING ON MAXIMAL OXYGEN UPTAKE

Whether to train for strength	Number of people	Statistical value	Maximum oxygen uptake （ml/min/kg）
Yes	25		30.1±6.7
Not	45		26.9±5.8
Total	70		28.0±6.3
		F-value	4.46
		P-value	0.04

As shown in Table VI, the maximum oxygen uptake of subjects undergoing strength training (26.9 ± 5.8 ml/min/kg) was significantly higher than that of subjects without strength training (30.1 ± 6.7 ml/min/kg) (P<0.05). During strength training, lactic acid is metabolized into glucose or glycogen, and the demand for O2 will increase [19]. Therefore, the ability of muscles to consume or use oxygen determines the level of oxygen uptake. Compared with the testers without strength training, proper strength training can greatly improve the maximum oxygen uptake of the testers [20].

Compared with strength training, there is a small difference in the maximum oxygen uptake between the two groups of flexibility training or not, and there is no obvious effect of strength training on the maximum oxygen uptake.

IV. DISCUSSION

With the development of society, people's living standards are improving with each passing day. Many sub-health, obesity, and other problems caused by not paying attention to physical exercise are also gradually highlighted. The higher the degree of obesity, the worse the aerobic exercise capacity due to low-fat energy supply capacity [21]. And excessive obesity can also lead to a decrease in human pulmonary ventilation function [22]. The decrease in the level of cardiopulmonary function can cause many cardiovascular diseases and other chronic diseases. In this study, we measured the aerobic metabolic indexes under the incremental load test in young people aged 18-39 years old, including university students and teachers, to show more intuitively the effects of exercise habits and different exercise programs and exercise frequencies on the level of cardiorespiratory fitness.

Those with daily exercise habits performed better in all basic physical indicators and all aerobic metabolic indicators. The exercise group had greater lung capacity than the non-exercise group (P<0.01), and has less body fat percentage than the non-exercise group (P<0.01). Those with daily exercise habits had higher maximal oxygen uptake (28.0±6.3 ml/min/kg) and oxygen pulse than the non-exercise group's. Hawkins [23] found that maximum oxygen uptake in adults decreases at a rate of 0.4-0.5 ml/kg/min per year (9%-10%/10 years) at 25-30 years of age in those without exercise habits, while in contrast, men who perform intense regular physical exercise (Excluding the elderly), the rate of decline is less. Thus, maintaining an exercise habit is essential to improve cardiorespiratory fitness. Therefore, persisting in sports can improve the heart and lung function, and achieve the effect of physical fitness and disease prevention.

In the population with exercise habits, the maximal oxygen uptake was higher (p<0.01) in testers who exercised more than three days a week at moderate intensity (30.2±5.7 ml/min/kg) compared to those who exercised less than three days at moderate intensity (25.8±6.1 ml/min/kg), while using high-intensity interval training (HIIT) and moderate-intensity continuous training (MICT) The improvement in maximal oxygen uptake was the same for both training modes, the only difference being the duration of the exercise [24]. Therefore, in terms of exercise efficiency and the intensity of exercise that the body can withstand, for young people who want to effectively improve their level of cardiorespiratory fitness through physical exercise, more than three times a week of moderate-intensity exercise can be performed to maintain physical vitality and improve physical health. According to the Guidelines and Recommended Standards on Physical Activity for Adults, physical activity of moderate or vigorous intensity not less than 30 min per day no less than five times a week is necessary to improve cardiorespiratory fitness and exercise levels and maintain physical health [25], therefore, 3-5 times a week of moderate-intensity exercise is a reasonable and effective exercise arrangement when physical conditions allow.

Among the four most common training activities obtained from the questionnaire, the relative oxygen uptake was significantly higher in those who performed soccer, basketball, and volleyball-type activities (32.7±5.7 ml/min/kg), followed by table tennis, badminton, and tennis-type (31.3±4.9 ml/min/kg), and the maximum oxygen uptake in the running population (27.1±5.2 ml/min/kg) was higher compared to The maximum oxygen uptake of the walking population (25.0±5.3 ml/min/kg) was higher, but lower compared to ball sports. The same results were obtained for the comparison between spirometry and oxygen pulse groups, and the differences between the groups were statistically significant by one-way ANOVA test (P<0.01). He Chengbin [26] found that skeletal muscle content was higher in students with special training in volleyball and basketball compared to students with other specialties, and skeletal muscle has a tremendous ability to increase blood flow and VO2 [27], so the relative oxygen uptake was significantly higher in people with soccer, basketball, and volleyball-type activities. Ball games have the characteristics of being short and fast, and due to the variety of movements and the need for strength confrontation, they will mobilize more muscles during exercise, and to a certain extent, they can raise the maximum oxygen uptake and improve cardiorespiratory fitness faster and more effectively than running and walking. Therefore, under the condition that physical fitness allows, more kinds of exercise programs can also make the body not adapt to a kind of exercise, maintain the body's vitality, and more effectively improve cardiorespiratory function.

By analyzing the effect of strength training and flexibility training on maximal oxygen uptake, we can see that strength training can increase maximal oxygen uptake more significantly. This is because strength training activates more muscle groups in the body, increasing muscle content and the number and activity of mitochondria in muscle cells, which are the main site of aerobic respiration, and the more muscle content, the greater the aerobic metabolic capacity [28]. For those who want to improve their cardiorespiratory fitness level, strength training should be appropriately arranged in daily exercise to improve aerobic capacity. Although flexibility training has a relatively small effect on maximal oxygen uptake, flexibility is an important component of physical fitness, reflecting the range of motion of the body's joints and the ability to stretch muscles, tendons, and other soft tissues. The lack of flexibility may lead to hamstring strain or other functional losses during exercise [29], therefore, proper arrangement of flexibility training in daily life can increase the range of motion and prevent sports injuries while maintaining good body form.

In conclusion, with the rise of national sports, maintaining good scientific sports habits is crucial for the physical health of young people. Young people should find the most suitable exercise program and frequency within their ability according to their actual situation, carry out physical exercise scientifically and reasonably, improve their cardiorespiratory function, improve physical fitness, maintain good exercise habits, and reduce the risk of diseases.

In the follow-up study, we will try to carry out a long-term comparative experiment to compare the changes of cardio-pulmonary function indicators such as oxygen intake of people who adhere to a certain exercise habit before and after a certain period of time, and more clearly compare the impact of different exercise habits on the improvement of cardio-pulmonary function, and increase the questionnaire items, such as smoking, diet, stress, occupation, etc, Compare the effects of various living habits and sports habits on cardiopulmonary function horizontally to increase the reference of research results and guide young people to improve their physical health.

V. Conclusion

The exercise group had a higher lung capacity than the non-exercise group ($P<0.01$) and a significantly lower body fat percentage than the non-exercise group ($P<0.01$), while the maximum oxygen uptake (28.0±6.3 ml/min/kg) and oxygen pulse rate of those with daily exercise habits were higher than those of the non-exercise group. The maximum oxygen uptake (24.1±6.3ml/min/kg) and oxygen pulse rate of the group with daily exercise habits were higher than those of the non-exercise group. It can be seen that adherence to physical activity can effectively improve the body's cardiorespiratory function and achieve the effect of strengthening the body and preventing diseases.

Among the people with exercise habits, the maximum oxygen uptake was higher in the test subjects who exercised more than three days a week at moderate intensity (30.2±5.7 ml/min/kg) compared with those who exercised less than three days at moderate intensity (25.8±6.1 ml/min/kg) ($p<0.01$). For young people who want to improve their cardiorespiratory fitness through physical exercise, 3-5 times a week of moderate intensity exercise is a reasonable and effective exercise schedule if physical conditions allow.

Among the four most common training activities obtained from the questionnaire, the relative oxygen uptake was significantly higher in soccer, basketball, and volleyball (32.7±5.7 ml/min/kg), followed by table tennis, badminton, and tennis (31.3±4.9 ml/min/kg), and the maximum oxygen uptake in running (27.1±5.2 ml/min/kg) compared to The maximum oxygen uptake of the walking population (25.0±5.3 ml/min/kg) was higher, but lower compared to ball sports. The same results were obtained for the intergroup comparison of spirometry and oxygen pulse, and the differences between the groups were statistically significant by one-way ANOVA test ($p<0.01$).

The results of the analysis of the effect of whether or not strength training and flexibility training on maximal oxygen uptake showed that strength training could more significantly increase maximal oxygen uptake. For those who want to improve the level of cardiorespiratory fitness, strength training should be appropriately arranged in daily exercise to improve aerobic capacity.

Conflict of Interest

The authors declare no conflict of interest

Author Contributions

Hui Guo, Zhuoran Li, and Meng Zhao conducted the research; Zhuoran Li analyzed the data; Meng Zhao collate test data and screen valid data； Zhuoran Li wrote the paper; all authors had approved the final version.

References

[1] I. G. Anduaga, P. Corres, and A. M. Betolaza, "Effects of different aerobic exercise programmes with nutritional intervention in sedentary adults with overweight/obesity and hypertension: EXERDIET-HTA study," *European Journal of Preventive Cardiology*, pp. 343–353,2018.

[2] C. Faselis, M. Doumas, and A. Pittaras, "Exercise capacity and all-cause mortality in male veterans with hypertension aged >/=70 years," *Hypertension*, vol. 64, no. 1, pp. 30–35, 2014.

[3] J. W. Deng and L. Cao, "Reviews on high-intensity interval training for health promotion in children and adolescents," C*hina Sport Science and Technology*, vol. 55, no. 06, pp. 21–34, 2019.

[4] C. E. Caldas, J. L. Hay, and D. S. Kehler, "Effects of high-intensity interval training versus moderate-intensity continuous training on blood pressure in adults with pre-to established hypertension: a systematic review and meta-analysis of randomized trials," *Sports Medicine*, pp. 1–16, 2018.

[5] F. Nagle, B. Balke, and G. Baptista, "Compatibility of progressive treadmill, bicycle and step tests based on oxygen uptake responses," *Medicine and science in sports*, vol. 3, no. 4, pp. 149–154, 1971.

[6] Ross R M, "ATS/ACCP statement on cardiopulmonary exercise testing," *American Journal of Respiratory and Critical Care Medicine*, vol. 167, no. 10, p. 1451,2003.

[7] R. B. David, "Limiting factors for maximum oxygen uptake and determinants of endurance performance," *Medicine and Science in Sports & Exercise*, vol. 32, no. 1, 2000.

[8] D. Popovic, N. Kumar, and S. Chaudhry, "Improvements in key cardiopulmonary exercise testing variables following cardiac rehabilitation in patients with coronary artery disease," *Journal of Cardiopulmonary Rehabilitation & Prevention*, vol. 38, no. 5, pp. 5–8, 2018.

[9] G. McKay and E. W. Banister, "A comparison of maximum oxygen uptake determination by bicycle ergometry at various pedaling frequencies and by treadmill running at various speeds," *European Journal of Applied Physiology and Occupational Physiology*, vol. 35, no. 3, pp. 191–200, 1976.

[10] B. Issekutz, N. C. Birkhead, and K. Rodahl, "Use of respiratory quotients in assessment of aerobic work capacity," *Journal of Occupational Medicine*, vol. 4, no. 5, 1962.
[11] M. J. Zhang, Z. Y. Yan, and G. H. Zhao, "Effects of orienteering program on the physical fitness of middle school students," *Journal of Xian Physical Education University*, vol. 28, no. 2, pp. 218–222, 2011.
[12] Y. Huang and R. M. Malina, "BMI and health-related physical fitness in Taiwanese youth 9-18 years," *Medicine and Science in Sports and Exercise*, vol. 39, no. 4, pp. 701–708, 2007.
[13] Y. Qiang, X. J. Yin, S. Ren, Y. Liu, and C. J. Bi, "Research on the relationship between living habits and physical fitness of children and adolescents," *Journal of Physical Education*, vol. 28, no. 4, pp. 119–124, 2021.
[14] J. Hartz, L. Y. Ling, and C. Ayers, "Clustering of health behaviors and cardiorespiratory fitness among us adolescents," *Journal of Adolescent Health*, vol. 62, no. 5, pp. 583–590, 2018.
[15] V. Billat, J. Beillot, and J. Jan, "Gender effect on the relationship of time limit at 100% VO2max with other bioenergetic characteristics," *Medicine and Science in Sports and Exercise*, vol. 28, no. 8, pp. 1049–1055,1996
[16] A. Nilsson, S. Brage, and C. Riddoch, "Comparison of equations for predicting energy expenditure from accelerometer counts in children," *Scandinavian Journal of Medicine & Science in Sports*, vol. 18, no. 5, pp. 643–650, 2008.
[17] J. C. Carl, E. P. Kenneth, and M. C. Gregory, "Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research," *Public Health Reports*, vol. 100, no. 2, pp. 126–131, 1985.
[18] C. Bouchard, "Physical activity and health: Introduction to the dose-response symposium," *Medicine and Science in Sports and Exercise*, vol. 33, no. 6, pp. 347–350, 2001.
[19] E. H. James, C. Richard, and M. C. Dan, "Oxygen uptake as related to work rate increment during cycle ergometer exercise," *European Journal of Applied Physiology and Occupational Physiology*, vol. 57, no. 2, pp. 140–145, 1988.
[20] A. H. Kathryn and G. H. Robert, "Physiological response to circuit weight training in borderline hypertensive subjects," *Medicine and Science in Sports and Exercise*, vol. 19, no. 3, pp. 246–252, 1987.
[21] P. G. Kopelman and P. G. Kopelman, "Obesity as a medical problem," *Nature*, vol. 404, no. 6778, pp. 635–643, 2000.
[22] W. D. Bennett, "Effect of body size on breathing pattern and fine-particle deposition in children," *Journal of Applied Physiology*, vol. 97, no. 3, pp. 821–826, 2004.
[23] S. Hawkins and R. Wiswel, "Rate and mechanism of maximal oxygen consumption decline with aging: implications for exercise training," *Sports Medicine*, vol. 33, no. 12, 2003.
[24] B. J. Sawyer, W. J. Tucker, and D. M. Bhammar, "Effects of high-intensity interval training and moderate-intensity continuous training on endothelial function and cardiometabolic risk markers in obese adults," *Journal of Applied Physiology*, vol. 121, no. 2, pp. 279–288, 2016.
[25] J. L. Thompson, "Exercise in improving health v. performance," in *Proc. Nutrition Society*, vol. 68, no. 1, pp. 29–33, 2009.
[26] M. A. Ju, P. Zhang, L. R. Yang, and X. Y. Hu Xiao, "Body composition of different kinds of athletes," *Journal of Beijing Sport University*, vol. 34, no. 6, pp. 125–127+130, 2011.
[27] B. Saltin, "Hemodynamic adaptations to exercise," *American Journal of Cardiology*, vol. 55, no. 10, pp. 42–47, 1985.
[28] R. G. Larry and L. P. Michael, "Circuit weight training: a critical review of its physiological benefits," *Taylor and Francis*, vol. 9, no. 1, 2016.
[29] C. Askling, T. Saartok, and A. Thorstensson, "Type of acute hamstring strain affects flexibility, strength, and time to return to pre-injury level," *British Journal of Sports Medicine*, vol. 40, no. 1, pp. 40–44, 2006.