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Effect of Resistance Strength Training on the Strength and Maximum Oxygen Uptake of the General Population

Fengbin Liu
College of Physical Education, Dalian University, Dalian, 116622, China

Abstract:

The maximum oxygen uptake is one important evaluation index reflecting the level of cardiopulmonary function of the human body under extreme exercise load. The role of strength training in increasing maximum oxygen uptake has not yet been determined. This paper proceeds from the perspective of intervention of strength training, selects healthy adult men without basic training as the test subjects, discusses the impact of strength training on maximum oxygen uptake based on test of maximum oxygen uptake and strength-related indexes, and analyzes the possible mechanism of action, with a view to providing certain reference for scientific strength training.

Keywords: *Maximum oxygen uptake, Strength training, Strength.*

I. INTRODUCTION

The maximum oxygen uptake (VO_2max) is a major index reflecting the level of cardiopulmonary function of the human body under extreme exercise load, which provides an important basis for estimating the physical working ability of athletes or manual workers [1]. Controversy still exists as to whether strength training can lead to increased maximum oxygen uptake. Numerous studies at home and abroad have shown that strength training does not seem to effectively increase the maximum oxygen uptake, but can improve endurance [2,3]. However, some studies have indicated that strength training can effectively increase the maximum oxygen uptake [4]. In this study, 12 weeks of progressive resistance strength training was conducted on ordinary healthy adults without strength training experience to investigate the impact of progressive resistance strength training on the strength, maximum oxygen uptake, and maximum oxygenic power of the general population, so that certain theoretical and practical references can be provided for the relevant people's scientific fitness and health improvement.

II. RESEARCH OBJECTS AND METHODS

2.1 Research Objects

40 healthy adult men who have no strength training experience and take exercise no more

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than once in a week. Based on physical examination and inquiry, the subjects had no obesity, no history of heart, lung, liver, kidney and endocrine diseases. The general information is shown in TABLE I.

TABLE I. General information of the subjects

N	Sex	Age (y)	Height (m)	Weight (kg)	Body fat (%)
40	male	35.4 ± 7.4	180 ± 4	80.6 ± 10	18.7 ± 5 %

2.2 Intervention Methods

The subjects underwent 12 weeks of progressive resistance strength training with a load set within 40%-90% 1RM. There were 2-3 times' practice a week. Each practice included warm-up and flexibility exercises 10 minutes before training, 30-40 minutes of formal training and 5 minutes of relaxation after training. The entire training was completed under the guidance of a specially-assigned person, and the training conditions and arrangements were strictly controlled. The first 4 weeks were for adaptation, with the training intensity controlled at 40-70%; from the 5th week, rapid leg extension and flexion exercises of a certain load were added. Exercise muscles included front and back thigh muscles, calf muscles, abductor and adductor muscles of the thigh, dorsal abdominal muscles, and medial and lateral abdominal muscles. The specific strength training load is shown in TABLE II.

TABLE II. Strength training load arrangement

Time	**2 weeks**	**2 weeks**	**3 weeks**	**5 weeks**
Practice frequency	2 times/week	2 times/week	5 times/2 weeks	5 times/2 weeks
Leg exercise Load (HL/HS)				
Number of	40-60%	50-70%	60-80% /25-40%	60-90% /40-60%
groups/repetitions	2-3 /10-15	3-4 /6-12	2-4 /6-12	4-5 /3-12
Other exercises				
Number of	1-3 /8-10	2-3 /8-10	2-3 /8-10	2-3 /8-10
groups/repetitions				

Note: HL = "high load" training HS = "high speed" training

Before and after the strength training program, the maximum squat weight (1RM) on the barbell stand and 60% 1RM squat jump power, maximum isometric knee extension strength, and maximum oxygen uptake were measured.

2.3 Determination of Indexes

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2.3.1 Maximum Oxygen Uptake Test

Vmax229 gas analyzer was taken for testing. Before starting the exercise, the subjects' quiet oxygen uptake and heart rate value in 1 minute were recorded, followed by exercise with increasing power at a rate of 60 circle/min until the end of the test. The set power value of the bicycle changed at set intervals (see TABLE III). Polar heart rate monitor was used in the test to record the heart rate simultaneously.

TABLE III. Power setting of cycle ergometer in VO_2max test

TIME/MIN: SEC	POWER/W
0:00—1:00	0
1:01—2:30	100
2:31—3:30	135
3:31—4:30	170
4:31—5:30	205
5:31—6:30	240
6:31—7:30	275
7:31—8:30	310
8:31—9:30	345
9:31—10:30	310
10:31—11:30	345

2.3.2 Maximum Squat Weight (1RM) on the Barbell Stand and 60% 1RM Squat jump power

The subject carried the barbell on the shoulders, fixed the position, and slowly bent the knee to 90° (reminded by an audible alarm system) before standing up as soon as possible. The barbell weight was gradually increased (5%-10%). After each squat, subject took a rest for 2 minutes and then performed the next squat until the increased weight made the subject unable to complete the squat. The maximum weight in a successful squat was 1RM weight. 60%1RM squat jump was measured 2 times, with 1 minute's rest in the interval. Squat jump power was measured using a BOSCO power meter.

2.3.3 Maximum Isometric Knee Extension Strength

Force platform was used to measure the maximum isometric pedaling force of the test subject on the cycle ergometer. During the test, the subject sat on the cycle ergometer seat, held the handlebar with both hands, placed the right foot on the pedal which was connected to the force platform through an aluminum cylinder. Before the test, the subject sat still with concentrated mind. After hearing the command, the subject quickly pedaled hard with the right leg, who would stop after reaching the maximum strength for 3 seconds. There were two tests before and after training. The butt must not leave the seat during the test, but the reactive force of the pedaling action could be countered by gripping the armrest.

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2.4 Mathematical Statistics

EXCEL 2017 and SPSS 22.0 statistical software was used for mathematical statistics and analysis on the data collected in the survey and relevant data in the experiment process. All data are expressed as mean ± standard deviation ($\bar{X}$±S). Paired T test was used for comparison before and after the experiment. P<0.05 indicates significant difference, and P<0.01 means very significant difference.

III. RESULTS AND ANALYSIS

3.1 Changes in the Strength of the Test Subjects after the Strength Training

As shown in TABLE IV and TABLE V, after strength training, significant increase is observed in the maximum squat weight (1RM) and 60% 1RM squat jump power of the test subjects(P<0.01). In the maximum isometric pedal and stretch test, before training, a significant decrease is shown in pedal and stretch force before and after VO_2max test (P<0.01); after training, the difference in pedal and stretch force is insignificant before and after VO_2max test; the difference in pedal and stretch force is insignificant before and after the training.

TABLE IV. Comparison of squat (jump) ability before and after training

Item	N	Training	After training	T	P
Maximum squat weight	40	128.5±22.4	162.3±25.8	-13.01	P<0.01
60%1RM squat jump power	40	542.6±116.2	646.3±134.8	-5.43	P<0.01

TABLE V. Comparison of maximum isometric pedal and stretch force before and after VO_2max test

	N	Before test	After test	T	P
Before training	40	1129.5±301.3	1025±288.1	2.79	P<0.01
After training	40	1126.1±219.3	1077.4±236.7	1.61	0.12
T	40	0.07	-1.17		
P	40	0.94	0.25		

The results suggest that after 12 weeks of progressive strength training, the subject's maximum dynamic power and dynamic explosive power have increased significantly, the strength endurance has also been improved to a certain extent, but the maximum static power has not improved.

3.2 Changes in Indexes such as Maximum Oxygen Uptake after the Strength Training

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As shown in TABLE VI, after training, the subject's ventilation level and maximum heart rate are basically unchanged, but the maximum oxygen uptake, relative maximum oxygen uptake, and maximum working power are significantly increased (P<0.01). Judging from the level of ventilation before and after training, cardiac output has not increased in the test, but the maximum oxygen uptake has increased. The reason is probably the increased oxygen utilization capacity of the muscles.

In order to gain a deeper understanding and discussion of this issue, the ventilation, oxygen uptake, and oxygen difference of the test subjects are compared before and after training under different working powers. The results show that: compared with that before training, as the test subject's working power increases, ventilation volume shows a downward trend, oxygen uptake volume shows an upward trend, and the oxygen difference tends to enlarge. The decrease in ventilation indicates that the body has lower requirement for cardiac output, while the increase in oxygen uptake may be caused by more muscles involved in exercise. In addition, increased oxygen difference also precisely explains the improvement of oxygen utilization capacity in the muscle. Combining the above results, we can think that the increase in maximum oxygen uptake is due to the muscle's increased oxygen utilization capacity.

TABLE VI. Comparison of maximum oxygen uptake before and after training

Index	N	Before training	After training	T	P
Ventilation (L/min)	40	121.2±28.4	123.2±29.4	-0.552	0.585
Relative maximum oxygen uptake (ml/kg/min)	40	36.83±5.53	39.48±5.57	-3.665	P<0.01
Maximum oxygen uptake (L/min)	40	2.98±0.46	3.22±0.50	-4.396	P<0.01
Respiratory quotient	40	1.31±0.10	1.24±0.07	4.517	P<0.01
Maximum heart rate (beats/min)	36	181.0±15.1	180.1±9.0	0.267	0.792
Maximum working power (W)	40	301±33	328±27	-2.25	P<0.01

According to previous reports, there are few cases that strength training increases the maximum oxygen uptake level of the practitioner [5,6]. This may have something to do with the intensity, manner, duration of strength training or the subject's training level. Because the subjects in this study are ordinary people without exercise habits and strength training experience, strength training causes a great impact on these people. After the strength training, the muscle volume increased, the capillary proliferated, the number of mitochondria in the muscle and the oxidizing ability were improved. Some studies have shown that high-intensity strength training program based on moderate load and high repetition rate in each set of movements can cause capillary proliferation [7]. The increased muscle mobilization capabilities make more muscles involved in exercise; coordination between muscles then improves, resulting in an increased movement economization level of the body, so that the body requires

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less oxygen when working at the same power [8]. Other studies have found that the increased aerobic capacity after the strength training has relation with changes in muscle fiber types. According to their report, during excessive load exercise, the mobilization of more slow muscle fibers and fewer fast muscle fibers is attributed to the increased quadriceps femoris strength. [9] Strength training promotes blood redistribution and improves local blood flow, so that active muscles get more oxygen during exercise. These changes may increase the maximum oxygen uptake level of the general population.

In addition, the strength training in this study is progressive strength training with not high training intensity which lasts for a certain period of time (more than 40 minutes each time) and resembles aerobic training to some extent. These factors may be the reason why this experiment has different results from other experiments.

IV. CONCLUSION

After 12 weeks of progressive resistance strength training, the subject's maximum dynamic power and dynamic explosive power have increased significantly, and their strength endurance has also been improved to a certain extent, but the maximum static power has not improved.

After 12 weeks of progressive resistance strength training, the subject's ventilation level and maximum heart rate are basically unchanged, but the maximum oxygen uptake, relative maximum oxygen uptake, and maximum working power are significantly improved.

The maximum oxygen uptake, relative maximum oxygen uptake and maximum working power have been significantly improved. It may have relation with the fact that this strength training is progressive strength training with not very high training intensity, which lasts for a certain time (more than 40 minutes each time) and resembles aerobic training to a certain extent.

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