



A study of the effects of synergistic flexibility and strength training on athletes' sports performance

Jian Li^{1,*}

¹ Department of Physical Education, Qufu Normal University, Qufu, Shandong, 273165, China

SUMMARY: *The synergistic level of flexibility and strength quality of athletes is directly related to the technical play, this paper takes 20 male athletes of level 2 and above freestyle wrestling as the object, randomly divided into experimental group and control group to carry out the research on the influence of flexibility and strength training. The test indexes covered functional screening and athletic performance, and SPSS26.0 was used for repeated measures ANOVA and independent samples T-test. The results showed that: (1) there was no significant difference between the two groups in the pre-test and the six sports performance indicators ($P>0.05$), the experimental group in the post-test was significantly higher than the control group in the indicators of pull-ups and in-situ vertical jumps ($P<0.05$), and the score of the experimental group in the post-test of the functional screening was significantly higher than that of the control group in the post-test (17.9 ± 1.36) (15.2 ± 1.62). (2) Repeated-measures ANOVA showed that the variance structure of strength-dominant, jumping, speed and comprehensive indexes had their own emphasis, and the synergistic effect of training method and time on strength and speed indexes was significant. The study showed that the synergistic training of flexibility and strength can effectively improve the performance of freestyle wrestlers.*

KEYWORDS: *athletes; flexibility training; strength training; athletic performance; functional screening*

1 Introduction

In recent years, competitive sports have flourished, and athletes' sports performance directly affects the results of the game and is one of the most important factors to attract the audience to watch the event, so it has attracted the attention of the Ministry of Sports and research departments and other people from all walks of life [1-3]. Sports performance is not only limited to athletic performance, but also includes multidimensional performance in sports such as skills, physical quality, and psychological quality [4]. Therefore, sports performance is often improved by different training methods. Understanding and mastering different training methods can help guide athletes to train correctly and scientifically [5]. Athletes' training methods often involve several aspects such as flexibility, speed, strength, coordination, sensitivity, endurance, etc., which are also indicators of physical qualities, and these qualities have a close intrinsic connection with each other, which are mutually reinforcing and constraining [6-9]. Among them, flexibility refers to the range of motion and activity of human joints and joint systems, that is, the elasticity and stretching ability of bones, ligaments, muscles and other tissues constituting the joints, and the core training methods are in the form of static

*lwbxxy123@163.com

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and dynamic stretching [10, 11]. And strength training is a systematic exercise to enhance muscle strength and endurance with the help of resistance exercise methods such as dumbbells, fitness equipment or self-weighted movements [12].

Flexibility training and strength training, as common programs in athletic training, involve all types of athletes and have an impact on the athletic performance of their athletes. Kaya [13] emphasized that prolonged proprioceptive neuromuscular facilitated stretching training to maximize human movement can improve athletic performance and that performance may have long-term effects. Singh [14] explored the flexibility and athleticism of student-athletes under a stretching intervention training program, and the experiment found that the training intervention helped to improve student athleticism, thus indirectly promoting athletic performance. Blazeovich et al [15] tested that performing static stretching exercises and dynamic stretching exercises for 5-30 seconds did not affect athletes' performance in sports such as sprinting, jumping, or change of direction, but it is possible to perform better when stretching is used as a warm-up exercise. Hsu et al [16] compared the effects of warm-up exercises such as static and dynamic stretching on the competitive performance of elite table tennis players, and dynamic stretching significantly improved flexibility, strength, ball speed, and agility, which led to improved competitive performance. Li et al [17] argued that active static stretching is difficult to form a warm-up alone, and that it is important to incorporate factors such as stretch duration, dynamic stretching combined or not, stretch intensity, and post-warm-up intervals into the design of active static stretching training protocols as a way to help optimize exercise performance.

A comparative experiment by Beattie et al [18] found that 40 weeks of strength training significantly improved the performance indices of competitive distance runners, i.e., maximal strength, reactive strength, reactive lactate clearance, and maximal anaerobic metabolic oxygen consumption. Burnie et al [19] stated that non-specific strength training can increase muscle size and strength in athletes, often in conjunction with movement training such as antagonistic sports to change the coordination between muscles, thus translating muscle strength into athletic performance. Whereas Chaabene et al [20] suggested that strength training that emphasizes centrifugal muscle action be used for muscle training to decelerate and stabilize the body in order to improve athlete-specific performance, but this study is only a theoretical result. Wilson et al [21] focused on the effects of strength training with and without training feedback on athletic performance, emotional state, motivation, and competitive awareness in athletes, and strength training with real-time quantitative sexual feedback improved performance levels. Panagoulis et al [22] showed that a comprehensive 8-week neuromuscular strength training session during the season positively improved the competitive performance of early adolescent soccer players, proving it to be an effective training method. Gäbler et al [23] used a systematic review and meta-analysis to show that concurrent periodization of strength and endurance training can help to improve athletic performance in children and adolescents, with more significant performance in adolescents. In summary, short-term flexibility training may have a negative or no effect on sports performance, while long-term flexibility training may help to improve sports performance, but it is necessary to consider a variety of factors and design a reasonable training program in conjunction with other training. Appropriate strength training may help to improve athletic performance, but no studies have been conducted to investigate athletic performance under the synergy of flexibility and routine training.

In this paper, the athletes were randomly divided into experimental group and control group, and the experimental training cycle and training program were clarified. Functional screening and athletic performance were selected as test indicators, and SPSS26.0 was used to conduct repeated measures ANOVA and independent samples t-test. Through the comparison between the pre and post-test groups of athletic performance indexes to confirm that the initial state of

the two groups is the same, and analyze the post-test data to explore the effect of the synergistic approach of flexibility and strength training on athletes' athletic performance. The interaction effect of time and group was revealed with the help of repeated measures ANOVA. Independent samples t-tests were used to compare the differences in functional screening scores between the experimental and control groups, and to test the value of the synergistic approach of flexibility and strength training in optimizing athletes' movement patterns.

2 Subject and methodology of the study

2.1 Subjects of study

The study of synergistic training of flexibility and strength to improve athletes' sports performance is the object of this paper, and 20 male freestyle wrestlers from the Heavy Athletic Training Division of Province A were investigated.

2.2 Experimental methods

2.2.1 Subjects and Groups

There were 20 athletes in the men's freestyle wrestling team of the Heavy Athletics Training Division of Province A, and these conforming athletes were graded at level 2 and above. Before the experiment was carried out, the 20 athletes were randomly grouped in order of standing, with 10 in the experimental group and 10 in the control group. All these 20 athletes participated in the whole experiment voluntarily and understood the purpose of the experiment. The subjects were free of heart disease, respiratory disease and concussion, and had no major sports injuries in the last two months. The information of the subjects in the experimental and control groups is shown in Table 1. The P-value of the experimental group and the control group in terms of age, height, weight and years of training is greater than 0.05, which can indicate that there is no significant difference between the experimental group and the control group of athletes in terms of age, height, weight and years of training, so that the experiment can be carried out.

Table 1: Experimental subject information

	Age	Height/cm	Weight/kg	Years of training
Experimental group	18.27±1.36	179.38±6.12	65.17±7.98	6.90±1.04
Control group	18.42±1.79	179.02±5.74	63.21±8.02	6.60±1.48
T	-0.15	0.36	1.96	0.30
P	0.76	0.53	0.31	0.12

2.2.2 Duration of the experiment and place of training

Schedule: March 2024-May 2024

Training place: Wrestling gym of A Province Heavy Athletics Training Division, Physical fitness gym of A Province Heavy Athletics Training Division

Testing location: University B Laboratory Building, Province A Heavy Athletics Training Division Wrestling Gym, University B Athletic Field

2.2.3 Division of experimental phases

The training phases and schedule are shown in Table 2. Two tests were conducted before and after the unfolding of the experimental intervention for the experimental and control groups, with the pre-test and post-test divided over 2 days each, and 1 day each for the indoor program

and the outdoor program. The experimental group was then subjected to 10 consecutive weeks of flexibility and strength training, twice a week, on Wednesday and Saturday afternoons, for 100 minutes each time. The control group trained according to the daily schedule of the freestyle wrestling team of the Weight Athletics Training Division of Province A. The training time was the same as that of the experimental group. The training program of both groups was divided into two phases, the first 5 weeks was the basic application phase, and the second 5 weeks was the enhancement and improvement phase. The two groups kept the same training time and content, such as tactical training, morning exercise training, etc. In addition, the warm-up was also the same as the experimental group. In addition, the warm-up for both groups is also the same.

Table 2: Training phase and time schedule

Training phase division	Training time	Number of training sessions	Training duration
Pre-test (2024.3.1~2024.3.2)	2 days	/	/
Basic adaptation stage	5 weeks	Every Wednesday and Saturday	100 minutes
Enhancement stage	5 weeks	Every Wednesday and Saturday	100 minutes
Post-test (2024.5.12~2024.5.13)	2 days	/	/

2.2.4 Selection of experimental indicators and test methods

In order to be able to ensure that the training is carried out normally, the testing process should not be too cumbersome, and should not affect the normal training but also meet the needs of the characteristics of the freestyle wrestling program, according to these conditions, this experimental study designed relatively simple and easy to operate test items.

(1) Seven movements for functional screening: deep squat, hurdle step, linear lunge, shoulder flexibility, straight leg active lift, trunk stabilization push-up, and twist/rotation stability. Scoring was based on conventional scoring criteria, with a score of 2 if 3 points of any requirement could not be obtained, a score of 1 if 2 points of any requirement could not be obtained, and a score of 0 if the athlete felt pain in a particular part of the body at any time during the test. Through the screening of the 7 movement patterns, diagnose the quality of the functional movements of each movement chain in the main movement links of the human body, determine the movement disorder or wrong movement patterns existing in each movement link of the human body, and provide a reference basis for the development of the body's functional training program.

(2) Six indicators of athletic performance: pull-up, vertical jump in place, standing long jump, 100-meter run, 400-meter run, and assisted running touch height. In this paper, according to the characteristics of the project, the elements included in the determination of sports performance are fast power, special sensitivity, explosive power, speed, core strength, flexibility, speed endurance and other test content.

2.2.5 Development of training programs

(1) Flexibility training program

Subjects were asked to complete the following training components: head stretching, trunk extension, foot climbing with both hands, lunge down, lunge side pressure, hip abduction, hip

extension, knee extension, knee flexion, and ankle stretching. 4~6 sets of each movement, 5~10 repetitions per set.

(2) Strength training program

Subjects were asked to complete the following training: deep squat, hip abduction, hip extension, seated knee extension, standing knee flexion, standing heel lift, single-leg stand, upper extremity elastic band chest push, upper extremity elastic band pull down, elastic band seated rowing. 4 sets of each movement, 5~10 reps per set.

During the training process, fingertip oximeter was used to monitor the subjects' exercise heart rate, and at the same time, combined with the subjects' subjective physical feeling, the training intensity of the two groups was controlled at a similar level.

2.3 Mathematical and statistical methods

Statistical software SPSS version 27.2 and EXCEL were used to organize and analyze the data obtained from the tests, and the Kolmogorov-Smirnov test was used to test the normal distribution of the variables, and if the data conformed to the normal distribution, Levene's test was used to verify the chi-squaredness, and if the data conformed to the chi-squaredness test, a one-way analysis of variance with post-hoc multiple comparisons was performed LSD test. If the data did not conform to normal distribution, independent or paired samples t-tests were performed using nonparametric tests. Correlation analysis was performed to analyze the exercise performance of the experimental group after flexibility and strength training interventions. All variables were expressed as mean and standard deviation. $P < 0.05$ for significant difference and $P < 0.01$ for highly significant difference were used to analyze the results of the test data.

3 Findings and analysis

3.1 Analysis of pre-test scores for specific indicators of athletic performance

The performance data of the members of the experimental group (numbered A1~A10) and the control group (numbered B1~B10) before the experiment for each of the sports performance special index test indexes are shown in Tables 3 and 4, respectively. The pre-test mean values of the experimental group in the six events of pull-up, vertical jump in place, standing long jump, 100m run, 400m run, and assisted touch were 15.60 ± 1.07 times, 57.00 ± 5.23 cm, 2.79 ± 0.05 m, 10.87 ± 0.60 s, 49.83 ± 0.32 s, and 63.20 ± 4.08 cm, respectively. The control group in the six events of the pre-test means were 15.70 ± 1.16 times, 56.90 ± 4.77 cm, 2.78 ± 0.05 m, 10.70 ± 0.33 s, 49.87 ± 0.64 s, and 63.70 ± 4.40 cm.

Table 3: Scores of each test index in the experimental group (N=10)

	Pull-up (times)	Vertical jump in place (cm)	Standing long jump (m)	100 m run (s)	400 m run (s)	Run-up touch high (cm)
A1	14	48	2.76	11.48	49.57	66
A2	16	62	2.74	10.36	50.03	62
A3	15	57	2.82	10.75	49.35	60
A4	17	60	2.79	11.19	49.84	59
A5	16	59	2.71	11.38	50.14	71
A6	15	63	2.74	11.74	49.83	60
A7	16	61	2.83	11.23	49.55	68
A8	16	58	2.81	10.25	49.97	63
A9	14	52	2.85	10.07	49.62	59
A10	17	50	2.85	10.28	50.43	64
Mean value \pm SD	15.60 \pm 1.07	57.00 \pm 5.23	2.79 \pm 0.05	10.87 \pm 0.60	49.83 \pm 0.32	63.20 \pm 4.08

Table 4: Score data of each test index in control group (N=10)

	Pull-up (times)	Vertical jump in place (cm)	Standing long jump (m)	100 m run (s)	400 m run (s)	Run-up touch high (cm)
B1	17	62	2.74	10.93	49.82	59
B2	14	60	2.76	10.25	50.06	68
B3	15	63	2.73	10.67	49.77	62
B4	16	55	2.84	11.14	49.32	57
B5	16	52	2.85	10.96	51.03	64
B6	17	61	2.78	10.63	49.29	68
B7	15	58	2.76	11.09	50.66	64
B8	14	52	2.83	10.23	50.32	70
B9	16	49	2.71	10.62	49.14	66
B10	17	57	2.75	10.45	49.28	59
Mean value \pm SD	15.70 \pm 1.16	56.90 \pm 4.77	2.78 \pm 0.05	10.70 \pm 0.33	49.87 \pm 0.64	63.70 \pm 4.40

Before the experiment on the two groups of subjects of each test index scores using SPSS26.0 software for data testing and analysis, resulting in the experimental group, the control group of intergroup variability comparative analysis of the results shown in Table 5. The p-values of the six tested indicators were 0.209, 0.357, 0.572, 0.433, 0.514, and 0.402, which were all greater than 0.05. It can be seen that there is no significant difference between the test scores of the strength indicators of the two groups of subjects before the beginning of the experiment, and it can also be shown that the scores of the special group of indicators of sports performance of the two groups of subjects are at a level before the experiment.

Table 5: Results of comparative analysis of differences between groups

		Pull-up (times)	Vertical jump in place (cm)	Standing long jump (m)	100 m run (s)	400 m run (s)	Run-up touch high (cm)
Mean value±SD	Experimental group	15.60±1.07	57.00±5.23	2.79±0.05	10.87±0.60	49.83±0.32	63.20±4.08
	Control group	15.70±1.16	56.90±4.77	2.78±0.05	10.70±0.33	49.87±0.64	63.70±4.40
T		-0.742	1.183	0.486	-0.804	-0.947	-0.835
P		0.209	0.357	0.572	0.433	0.514	0.402

3.2 Analysis of post-test scores for specific indicators of athletic performance

Comparison of the data on the pre and post-test scores of the members of the experimental and control groups for each of the sports performance-specific indicator test metrics is shown in Table 6. The observation of the mean values with the change of time shows that there is no difference between the pre-test groups in the mean values of the six test indexes, while the post-test of these six test indexes does have a significant difference, and the difference between the six test indexes of the experimental group and the control group in the post-test amounted to 2.6 repetitions, 7.05 repetitions, 0.06m, 0.29s, 0.57s, and 7.2cm, respectively. Analysis of variance (ANOVA) with 0.05 as the level of significance test showed a statistically significant difference between the two groups ($p < 0.001$) and a statistically significant interaction effect of group and time ($p < 0.001$). This means, one, that the separate between-group effect (group) was statistically significant: it indicates that the imposition of the intervention of the independent variable, i.e., the synergistic practice of flexibility and strength, affected the dependent variable of the athletes' specific skill indicators. Secondly, the interaction effect was statistically significant: it indicated that the experimental and control group subjects improved their mean scores on the six indicators differently as the pre and post subtest times increased.

Table 6: Comparison of pre - and post-test performance data of each group

	Group	Pre-test	Post-test
Pull-up (times)	Experimental group	15.60±1.07	19.80±0.98
	Control group	15.70±1.16	17.20±1.12
Vertical jump in place (cm)	Experimental group	57.00±5.23	64.55±4.67
	Control group	56.90±4.77	57.50±4.92
Standing long jump (m)	Experimental group	2.79±0.05	2.86±0.04
	Control group	2.78±0.05	2.80±0.07
100 m run (s)	Experimental group	10.87±0.60	10.33±0.41
	Control group	10.70±0.33	10.62±0.56
400 m run (s)	Experimental group	49.83±0.32	49.15±0.28
	Control group	49.87±0.64	49.72±0.46
Run-up touch high (cm)	Experimental group	63.20±4.08	71.40±3.87
	Control group	63.70±4.40	64.20±3.92

Comparisons and changes in the means of the six test metrics in the pre- and post-tests are shown in Figure 1. The interaction effect was significant, as was the main effect of the independent variable time (pre-test vs. post-test). The change in time caused significant changes in the observed data on all 6 test indicators in the experimental group, but relatively did not cause the same significant changes at the level of the control group. This suggests that changes

in the pre-test and post-test do not cause changes in the 6 test indicators in all cases, but depend on the level of the independent variable group, i.e., the difference in the methodology used in the training intervention causes differences in this indicator in the athletes. As can be seen graphically, the slopes of the straight lines of the experimental and control groups are also different, with the experimental group showing a greater improvement in the improvement of the pull-up level, as its straight line slope is steeper.

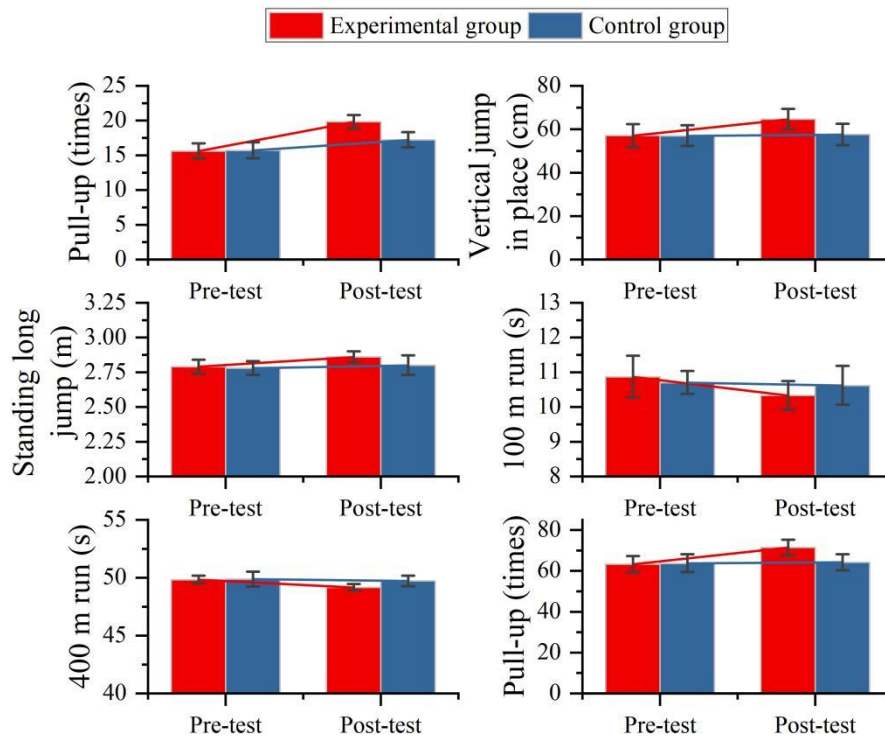


Figure 1: Comparison of the means of the test indexes before and after the test

The results of the repeated measures ANOVA for the experimental and control groups on the specialized skill indicators are shown in Table 7. Summarizing the data analysis, the repeated measures ANOVA revealed significant variation within the group from pre-test to post-test. In the pull-up program, the mean square of the between-group variance was 16.376 with a degree of freedom of 1, reflecting the inherent differences in the ability enhancement of the program by different training methods. The mean square of temporal variation was as high as 501.867, with significant temporal changes in the pull-up level itself as the training cycle progressed. The interaction mean square was 49.026, meaning that the training method and the time factor jointly influenced the magnitude of progress. The group, time, and interaction mean squares for the in situ vertical jump were 10.455, 162.573, and 39.058, respectively, reflecting the sensitivity of the vertical explosive category to the combination of training cycle and method. In the standing long jump, the mean squares of intergroup, time, and interaction were 13.582, 205.372, and 49.033, respectively, which were both affected by the training methods and showed regular improvement with time. The speed events also showed not only significant differences in training methods, but also between-group differences in fatigue recovery and ability adaptation in the time dimension, and the interaction was stronger in the long distance (400 meters), with an interaction mean square of 60.864. Assisted running touch height as a composite indicator, $F=19.407$, $p=0.001$, and time as well as the time*treatment factor had $p<0.05$, which shows that there are statistically significant differences in the indicators measured at different times.

Table 7: Results of repeated measures ANOVA

	Sources of variation		df	MS	F
Pull-up	Between groups	Training methods/groups	1	16.376	1.186
		Error	16	11.435	
	Within groups	Time	1	501.867	98.386***
		Time × group	1	49.026	10.487***
		Error	16	3.988	
Vertical jump in place	Between groups	Training methods/groups	1	10.455	0.701
		Error	16	20.107	
	Within groups	Time	1	162.573	50.433**
		Time × group	1	39.058	10.912**
		Error	16	2.984	
Standing long jump	Between groups	Training methods/groups	1	54.276	5.018*
		Error	16	13.582	
	Within groups	Time	1	205.372	18.444**
		Time × group	1	49.033	5.037*
		Error	16	10.563	
100 m run	Between groups	Training methods/groups	1	15.371	1.864
		Error	16	13.018	
	Within groups	Time	1	392.583	98.345**
		Time × group	1	48.376	13.556**
		Error	16	5.225	
400 m run	Between groups	Training methods/groups	1	17.038	0.692
		Error	16	22.646	
	Within groups	Time	1	201.473	48.038**
		Time × group	1	60.864	9.337**
		Error	16	3.017	
Run-up touch high	Between groups	Training methods/groups	1	60.028	6.174*
		Error	16	17.336	
	Within groups	Time	1	75.373	19.407**
		Time × group	1	50.082	4.935*
		Error	16	13.477	

3.3 Changes in Functional Screening Indicator Scores and Analysis

The seven functional movement screening indexes were numbered as X1~X7, and the results of the pre- and post-test data comparison of the functional movement screening in the experimental group are shown in Figure 2. The mean values of the seven functional movement screening indexes were increased by 0.5, 0.7, 0.7, 0.7, 0.8, 0.7, 0.9, 0.7, among which, the deep squat, straight-line lunge, shoulder mobility, trunk stabilization push-ups, and twisting/rotating stability items had significant differences in $P < 0.05$. 0.05, there was a significant difference between the pre- and post-test scores.

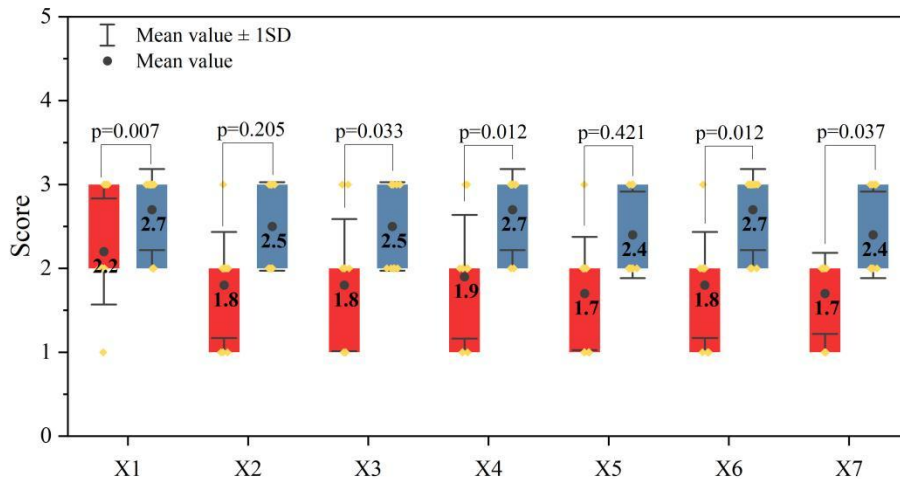


Figure 2: Comparison results of test data before and after action screening

The results of the pre- and post-test data comparison of the functional movement screening in the control group are shown in Figure 3. The mean values of the seven functional movement screening indexes increased by 0.3, 0.3, 0.4, 0.3, 0.2, 0.3, 0.2, and 0.2, respectively, with $P > 0.05$ for all items, and there was no significant difference in the pre- and post-test scores.

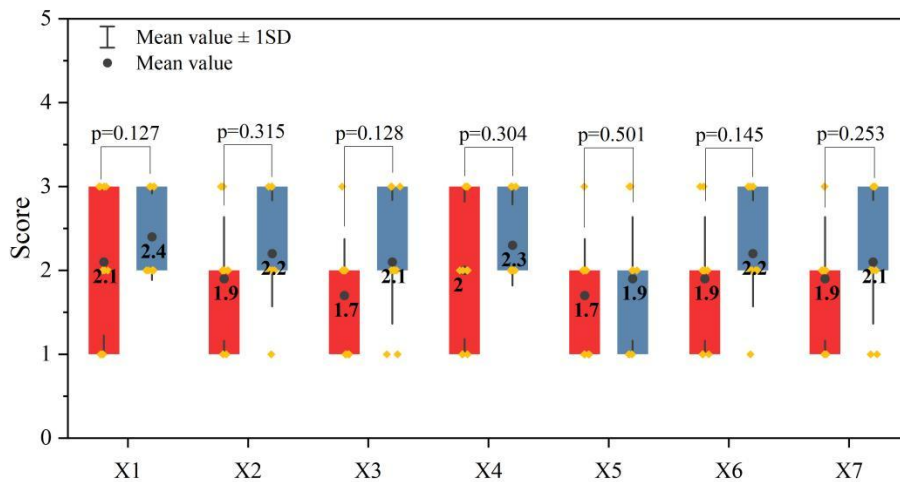


Figure 3: Comparison results of test data before and after action screening

Experimental and control groups after 10 weeks of training. A functional screening posttest was administered. The results of the independent samples t-test for the posttest scores of the experimental and control groups are shown in Table 8. The mean post-test score of the experimental group was 17.9 ± 1.36 and the mean post-test score of the control group was 15.2 ± 1.62 . $p = 0.014 < 0.05$, then the scores were considered to be significantly different between the experimental and control groups.

Table 8: Independent sample t-test results

Group	Mean value \pm SD	The 95% confidence interval for the difference		t	df	Sig.
		Lower limit	Upper limit			
Experimental group	17.9 \pm 1.36	.20462	2.67561	2.097	18	.014
Control group	15.2 \pm 1.62					

4 Conclusion

This paper takes 20 male freestyle wrestlers from province A as the experimental subjects, and analyzes the effect of synergistic training of flexibility and strength in improving the athletic performance of male freestyle wrestlers through experimental comparison.

(1) The interaction effects of time and group were associated with different training methods. The synergistic method of flexibility and strength training adopted by the experimental group had an effect on all six indexes, and the athletes' specialized motor skills were improved to a certain extent, while the control group, which adopted the daily training method, was not obvious before and after the experiment. The experimental group showed the greatest improvement in pull-up level improvement, with a 26.9% improvement in the post-test over the pre-test.

(2) The intergroup variation of strength events was moderate but the time variation was prominent, and the time mean square of pull-ups reached 501.867. The intergroup and interaction variations of jumping events were more obvious, and the intergroup and interaction mean squares of standing long jump were 13.582 and 49.033, respectively. The intergroup variance of speed events was higher in the 400-meter run, with the intergroup mean square reaching 17.038, and the time variance increasing with distance. Assisted running touch height as a combination of flexibility and strength, the three categories of variation are relatively balanced.

(3) After 10 weeks of training, the movement screening scores of the experimental group reached a significant improvement, while the conventional training methods did not significantly improve the improvement in terms of improving the completion and quality of completion of movements, indicating that the synergistic training of flexibility and strength is beneficial to improving the completion of functional movements.

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