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Influence of Eight Weeks of Plyometric Training on the Speed and Flexibility of Adolescent Girls

Abstract

This research aimed to study the effect of eight weeks of plyometric training on the speed and flexibility of adolescent girls who play Wushu. To this end, 20 girls (age: 11 ± 3.5 years, weight: 46 ± 19 kg, height: 117 ± 53 cm) were selected as examinees and randomly divided into experimental and control groups. In the meantime, the control group only did normal wushu exercises, whereas the experimental group did normal wushu exercises along with plyometric ones (including jumps and hops) for eight weeks and three sessions each week with a set time of 30 to 45 minutes. Speed and flexibility were estimated using setup tests, 30-meter sprints, and Sargent jump and flexibility tests before and after the end of the training course. Correlated and independent t-tests at a 0.05 significance level were used to analyze the data. The results indicated that the speed and flexibility of wushu athletes increased significantly after eight weeks of plyometric training. Furthermore, a significant difference was observed between the experimental and control groups. In addition, wushu athletes can use plyometric exercises to improve speed and flexibility.

Keywords: *wushu athletes, plyometric exercises, speed, flexibility*

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Introduction

Nowadays, the importance of bodybuilding exercises is quite obvious, and coaches seek to bring their athletes to the highest level of preparation and success by selecting the best bodybuilding techniques. An athlete with no physical fitness cannot execute the technique and tactics desired by the coach. The mixture of strength and speed, also known as "power," is among the critical factors of physical fitness, which plays an essential part in most sports. The progress of sports science allows coaches and researchers to determine the effective factors in enhancing the performance of sports skills and diminish the factors that hinder sports performance so that athletes can reach the pinnacle of the championship with the least amount of energy and time (Sheeran, 2006).

A Myriad of studies on various training methods reveals that the efficiency of the muscular system and neuro-muscular factors can be improved and expanded due to physical exercises. However, there may be discrepancies of opinion in the pathway of performing the work. Among these, one can cite the type of muscle contractions, training techniques, number of training sessions, etc. These differences of opinion disclose the unknowns of sports and supply the basis for study to find the best training method (Bompa, translated by Rajabi et al., 2003).

Among the essential factors for every athlete's quantitative and qualitative progress is the application of training methods related to the field of sports and based on scientific principles (Pirani, 1993).

Plyometric exercises, which refer to a special kind of sports activity in which explosive moves contribute, are one of these methods. These motions are crucial for building up the muscle tension needed for the primary motion. In other words, the chief key and the critical element are explosive movements. Plyometric exercises form the ~~most profitable relationship~~ between speed and strength and finally show themselves as explosive power. These exercises contain a series of muscle activities along with jumping ones in which the stretching feedback of a muscle is used. These reflexes occur when the muscles tighten immediately after being stretched. Stretching in advance, followed by rapid contraction, causes more movement power (Sandgol, 1993).

Ross Paul Hames and colleagues made the case in 1980 that combining plyometric and weight training increases physical performance. In 2002, Hidroshet et al. looked at the results of an eight-week plyometric training program. They found that after exercising, the joint's sensory and motor states improved (cited by Kalvandi et al., 2018).

In 2013, Kalali Junqani et al. performed a study titled "Effect of 8 weeks of resistance-plyometric exercises on the number of changes in bone mineral density of 20 elite football players who did not have any injuries or bone fractures in the last year". Eight weeks of resistance-plyometric exercises resulted in a substantial difference in the bone density of the waist and thighs, according to the findings. According to these findings, they recommended using resistance-plyometric exercises to improve bone mineral density among soccer players. The balance of 60 male student-athletes was tested by Sadeghi et al. in 2018 after six weeks of plyometric strength and combined training (plyometric strength). The outcomes showed that strength, plyometric, and combined training yield a substantial increase in the reach distance of subjects in all eight directions of SEBT. They also revealed that the combination of strength-plyometric training and plyometric exercise improves dynamic balance in subjects compared to strength training. In 2009, Sedano et al. investigated how plyometric exercises affected female soccer players' body composition, explosive strength,

and ball speed. They concluded that after six weeks of training, vertical jump, and after 12 weeks, ball speed increased, but body composition did not change. In 2009, Bishop et al. examined the impacts of plyometric training on the execution of the start movement of young swimmers. They reported that 22 young swimmers were able to acquire the necessary increase in the tested performance indicators after eight weeks of training. They concluded that the appropriate volume of water and the proper implementation of plyometric exercises significantly affect the improvement of swimmers' start movement.

The research results in plyometrics demonstrate that plyometric training methods blend speed and strength in sports performance and have great potential to improve the athlete's speed. Plyometric training, if used with scientific methods, provides effective capabilities to the athletes so that they can start the execution of the movement and skill faster, change the direction suddenly, and change the acceleration of the movement in the briefest possible time. Therefore, the researcher intends to use plyometric workouts in this study (Zali, 1999).

In recent years, the impacts of plyometric training on athletes have been examined extensively, but few have focused on Wushu. Therefore, this study assessed the possible growth in speed and flexibility of female gymnasts by executing a selected plyometric exercise program. By doing the exercise, we are looking for an answer to the question, "Do eight weeks of plyometric training affect the biomechanical variables (speed, flexibility) of female athletes?"

It is desired that the outcomes of the research can help coaches and athletes improve their training with full knowledge. It is also hoped that it will have a positive effect on raising their awareness level and skill quality and can be used by other organizations, including physical training organizations, championship sports bases, academics, and all sports centers, to realize the goals and infrastructure of championship sports, they are active in various sports fields.

Materials and methods

This study is applied research, and the research design was conducted as a pre-and post-test on teenage girls (9-14 years old) in Isfahan city. The statistical population was randomly chosen from the available sample of a group of 20 female wushu athletes from the city of Isfahan who volunteered to partake in the test. Furthermore, their previous injuries and injuries were investigated by distributing the questionnaire. The subjects were randomly put into 2 groups of 10 people: control and plyometric.

In coordination with Isfahan wushu trainers, the researcher explains the goal and steps of the research to the wushu practitioners during a meeting (a wushu practitioner is someone who regularly performs 3 sessions of wushu exercises per week in the last 2 years). Eventually, 20 people without any heart problems or any history of dangerous diseases were selected among the wushu athletes willing to participate in the study. After filling out the consent form by their parents, they were randomly divided into two experimental and control groups. The researcher and his associates attended the training session with the required equipment to complete the tests on the specified day. First, the questionnaire was completed by the subjects to obtain personal information. Next, to familiarize the subjects with the tests, all the steps of the test implementation and how to perform each of the tests were explained and implemented by the researcher. Then, after warming up the body properly and doing stretching and easing exercises, a pre-test was conducted to estimate the speed of the 30-meter distance test and the flexibility board to measure flexibility. Pre-test and post-test were taken from both groups.

A medical scale with an accuracy of 0.1 kg was used to estimate the subjects' weight. First, the subjects were asked to take off their shoes and present themselves for weighting with only a shirt and sports shorts.

$$V_{(m.s)} = \frac{30}{t_2 - t_1}$$

Flexibility: The flexibility board test was used to assess flexibility.

The schedule of a training session

The exercise schedule of eight weeks of special training for the experimental group was as follows. The control group performed normal exercises. The experimental groups also performed plyometric workouts for 35-45 minutes, including 10 minutes of warm-up, 20 minutes of special training in 3 sets and 3 sessions per week, and 5 minutes of returning to the initial state. All the exercises and tests were done in Isfahan city, and after eight weeks of training, both groups were examined on the test's balance, speed, and flexibility, and the results were registered in the relevant form.

The chosen plyometric exercise program was designed in eleven movements based on the overload principle. Each movement was performed in 3 cycles with 10 fixed repetitions each all week. There is a one-minute rest between every two stages.

Table 1. Selected plyometric training based on the overload principle

The first week	Double leg speed jump	Single leg speed jump	Squat jump	Knee Tuck Jump							

second week	Double leg spot hops	Single leg spot hops	Squat jump	Knee Tuck Jump	Spread legs forward, jump						
The third week	Double leg spot hops	Single leg spot hops	Squat jump	Knee Tuck Jump	Spread legs forward, jump	Scissor jump					
forth week	Double leg spot hops	Single leg spot hops	Squat jump	Knee Tuck Jump	Spread legs forward, jump	Scissor jump	Single leg jump				
The fifth week	Double leg spot hops	Single leg spot hops	Squat jump	Knee Tuck Jump	Spread legs forward, jump	Scissor jump	Single leg jump	Double leg forward hop			
The sixth week	Double leg spot hops	Single leg spot hops	Squat jump	Knee Tuck Jump	Spread legs forward, jump	Scissor jump	Single leg jump	Double leg forward hop	Single leg forward hop		
The seventh week	Double leg spot hops	Single leg spot hops	Squat jump	Knee Tuck Jump	Spread legs forward, jump	Scissor jump	Single leg jump	Double leg forward hop	Single leg forward hop	lateral Heiden	
The eighth week	Double leg spot hops	Single leg spot hops	Squat jump	Knee Tuck Jump	Spread legs forward, jump	Scissor jump	Single leg jump	Double leg forward hop	Single leg forward hop	lateral Heiden	Double leg hurdle jump

The data was eventually described using the central (mean) and dispersion (standard deviation) indicators, and statistical diagrams were created. The data's normality was verified using the chypron test, and the hypotheses were tested using the covariance test. Prior to performing the covariance test in the inferential section, the assumptions were examined.

Findings

The statistical description of biomechanical variables in experimental and control groups

Table 2. Regarding the average of the groups

Group	Time	Statistical parameter	Speed (m/s)	Flexibility (Cm)
Test	Pre-test	Average	4.45	18.60
		The standard deviation	0.480	4.01
		Minimum	3.61	10.0
		Maximum	5.03	24.0
	Post-test	Average	5.74	22.70
		The standard deviation	0.598	4.22
		Minimum	4.61	18.00
		Maximum	6.63	30.00
Control	Pre-test	Average	4.16	18.50
		The standard deviation	0.566	4.08
		Minimum	3.17	10.00
		Maximum	5.03	24.00
	Post-test	Average	4.45	18.68
		The standard deviation	0.480	3.97
		Minimum	3.61	10.00
		Maximum	5.03	24.00

The experimental group's pre-test and post-test results for the components of speed, flexibility, sitting, and power are shown in Table 2. As can be seen, the post-test and pre-test scores have a significant difference in both variables, and the scores in the post-test have a growth compared to the pre-test. This difference is due to intervention. This Table also contains the

pre-test and post-test scores of the control group in the components of speed, flexibility, sitting, and strength. As can be seen, the post-test and pre-test scores do not have significant differences.

Data normality test

In this section, the normality of the data according to the distribution of bells was investigated through the Shapiro test and the Smirnoff column graph. The results are listed in Table (3).

$$H_0 = sig > 0/05$$

$$H_1 = sig \leq 0/05$$

Table 3. Summary of Shapiro and Kolmogorov Smirnov test

Biomechanical variables	Shapiro test		Kolmogorov Smirnov test	
	Significance level	Coefficient	Significance level	k-s
Speed pre-test	0.166	0.932	0.139	0.168
Flexibility pre-test	0.100	0.920	0.200	0.147
Speed post-test	0.678	0.966	0.200	0.138
Flexibility post-test	0.669	0.966	0.200	0.123

Shapiro and Smirnov Kolmongraph test for all variables in pre-test and post-test scores is not significant at the alpha level of 0.05, and the significance level is higher than 0.05. The extracted result indicates the normality of the distribution of scores.

Homogeneity of variance of groups

Homogeneity of variances was also examined using Levine's test, and its results are listed in Table (4). The significance level of F in all biomechanical variables is higher than 0.05. In other words, the equality of error variance of dependent variables is established according to groups.

Table 4. The results of Levin's test to check the homogeneity of error variance

Biomechanical variables	F	Significance level	hypothesis Degree of freedom	Error degree of freedom
Speed	0.316	0.581	1	18
flexibility	2.74	0.115	1	18

Hypothesis test

The first hypothesis: Eight weeks of plyometric training affects the speed of teenage and active girls.

To test this hypothesis, the covariance test was used. First, the assumptions of the test were checked. Then, because of the effect of the pre-test scores, the covariance test, and the adjusted average were used to adjust the scores.

Table 5. Factor covariance test related to the effect of intergroup factors

Source of changes	sum of squares	df	Mean of squares	F	Significance level	Eta symbol
INTERCEPT	2.661	1	2.661	10.49	0.005	0.382
pre-exam	0.984	1	0.984	3.88	0.050	0.186
Groups	6.302	1	6.302	24.85	0.001	0.594
error	4.310	17	0.254			
Total	533.13	20				

Table (5) indicates that the speed pre-test scores are significant at the alpha level of 0.05. By performing the covariance test and adjusting the pre-test scores, the effect of the group (exercise) was calculated. The speed variable indicated a significant difference between the control and experimental groups, and F is significant at the alpha level of 0.05 in the

results. The value of this effect is equal to 0.594. That is, 59.4% of the changes related to speed in the two groups are related to the effect of plyometric training. The difference and significance of the two groups by follow-up test are demonstrated below.

Table 6. Follow-up test related to the effect of plyometric training on speed

Groups	Adjusted mean	groups (treatment)		Difference of means	Significance level
		I	J		
Test	5.68	Test	Control	1.167*	0.001
Control	4.51	Control	Test	-1.167*	0.001

Table 6"s findings demonstrate that the experimental group's average for the speed variable is greater than the control group's average. This result shows the effect of plyometric training on the speed of teenage girls.

Second hypothesis: Eight weeks of plyometric training affects the flexibility of young and active girls.

The covariance test was used to test this hypothesis. First, the assumptions of the test were checked, and then, due to the effect of the pre-test scores, the covariance test and the adjusted mean were used to adjust the scores.

Table 7. Factor covariance test related to the effect of intergroup factors

Source of changes	sum of squares	df	Mean of squares	F	Significance level	Eta symbol
INTERCEPT	13.913	1	13.913	3.53	0.077	0.172
pre-test	235.515	1	235.515	59.81	0.001	0.779
Groups	77.07	1	77.07	19.57	0.001	0.535
error	66.93	17	3.937			
Total	8946.26	20				

The flexibility pre-test scores are significant at the alpha level of 0.05, according to Table 7's data. By performing the covariance test and adjusting the pre-test scores, the effect of the group (exercise) was calculated. According to the exercise's results, there is a substantial difference between the experimental and control groups with regard to the variable of flexibility. In addition, F is significant at the alpha level of 0.05, and the effect value is equal to 0.535. That is, 53.5% of the changes related to flexibility in the two groups are related to the effect of plyometric training. The difference and significance of the two groups by follow-up test are shown below.

Table 8. Follow-up test related to the effectiveness of plyometric training on the flexibility of teenage girls

Groups	Adjusted mean	groups (treatment)		Difference of means	Significance level
		I	J		
Test	22.6865	Test	Control	3.927*	0.001
Control	18.72	Control	Test	-3.927*	0.001

The outcomes of Table (8) indicate that in the case of the speed variable, the average of the experimental group is higher than the control. This result demonstrates the effect of plyometric training on the flexibility of teenage girls.

Discussion

This research aimed to study the effect of eight weeks of selected plyometric training on female wushu athletes' specific biomechanical variables (speed, flexibility).

The results demonstrated that the speed improved after the training period, and the difference was significant. This finding aligns with Roozbahani's (2005) "Investigation of the effect of plyometric exercises on the speed of execution of common techniques in 16 champion male taekwondo athletes." He figured that the exercises significantly affected speeding up the common foot kicks in taekwondo athletes. The present research result about the speed test is inconsistent with the studies of Markovic et al. (2007), who did not notice a

significant improvement in the speed factor by studying different forms of plyometric training. Part of these differences may be because of the difference in the preparation level of the subjects; according to the completed studies, the higher the level of physical fitness of a person, the less the change in physical fitness factors following exercise sessions. Furthermore, in the studies that did not note a significant increase in speed following plyometric exercises, either elite athlete subjects were used, or the pressure of plyometric exercise may be lower than that of specific workouts in the desired domain.

Plus, the findings indicated that eight weeks of plyometric training affects the flexibility of teenage girls who are wushu athletes.

It was observed that "flexibility" also improved after the course, and the distinction was significant. This finding is in line with the results of Shiravieh (2004), who acknowledges that the increase in leg power, flexibility, and agility of the players in the experimental group is more than the control group. Flexibility is closely related to strength, speed, and skill (Gayini and Rajabi, 2004). Probably due to plyometric exercises, muscle strength and speed have increased. As a result, the flexibility of the subjects increases. In Wushu, all physical fitness factors play a significant role in the player's performance. Today, the importance of bodybuilding exercises is no secret, and coaches seek to bring their athletes to the highest level of preparation and success by choosing the best bodybuilding methods. In different studies, the effect of plyometric exercises with different protocols on the indicators of physical fitness and body composition of different subjects has been studied. In numerous sports, plyometric exercises are employed to boost speed and explosive performance. In general, plyometric exercises perform powerful muscle contractions in response to a workload or dynamic and rapid stretching of the involved muscles (James et al., 2007).

Performing plyometric exercises, taking into account the age, gender, sports history of people, and their sports aptitude, brings the following results (Moeini, 1995):

1. Applying and activating a large number of motor units to apply a strong contraction;
2. Plyometric exercises give the muscles elasticity and flexibility to avert muscle fibers from tearing during impulsive stretching;
3. The use of fast contraction fibers, particularly fibers that are fast glycolysis;
4. Increasing muscle glycogen storage;
5. Increasing the enzyme activity of glycolysis;
6. Increasing myoglobin content;
7. Increase in muscle ATP-PC reserves;
8. Selective bulking of fast-twitch muscle fibers;
9. Changes in the spatial shape of muscle mitochondria under the muscle cell membrane.

Muscle spindles and tendon Golgi organs are part of the manic proprioceptor system located inside the ligaments, muscles, tendons, and joints. They are sensitive to stretch, tension, pressure, and provide information about the force and tension applied to the muscle. Both types of receptors stated (muscle spindles and tendon Golgi organ) are involved in plyometric workouts. However, muscle spindles seem more essential, and both sensory receptors work reflexively (Moeini, 1995).

Plyometric exercises can be used to develop the explosive power of athletes. In this regard, Chu and Kratchel concluded in their study that executing movements and skills at high speed requires using appropriate exercises, especially plyometric and combined ones (Moghadam 1997).

The effects that plyometric exercises can have on the neuro-muscular system and physical capabilities such as strength, speed, and especially power include stretch reflex, shortening of introverted and extroverted contraction time, which increases the elastic force of muscles during introverted contraction, the adaptation of the nervous motor system, recruitment of more motor units, increased stress on muscle activity (both during the introverted and extroverted contraction phase), and the conversion of muscle strength and speed into explosive power (Myler et al., 1984, Thayer, 1984).

Conclusion

Based on the current research results, plyometric exercises affect biomechanical factors. In general, most studies have reported the improvement of physical fitness factors following plyometric exercises. Plyometric exercises' inherent characteristic is the strength and speed to produce power. Wushu is a sport with movement characteristics such as power, agility, speed, and muscular endurance. Therefore, athletes in this field can benefit from such exercises. Finally, future researchers are suggested to conduct research parallel to the present study for different fields.

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Conflict of interest

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