

Review

The Effect of Low Extremity Plyometric Training on Back Muscle Power of High School Throwing Event Athletes

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Abstract. [Purpose] The physical strength elements required for athletic throwing events include muscle strength, swiftness, agility, speed, flexibility, and physical balance. Although plyometric training and weight training are implemented as representative training methods for improving swiftness and agility, most studies of it have been conducted with players of other sports. [Subjects] The study subjects were 10 throwing event athletes attending K physical education high school. The subjects were randomly assigned to a control group of five subjects and an experimental group of five subjects. To analyze the body composition, an Inbody 3.0 instrument (Biospace, Korea) was used as experimental equipment to measure heights, weight, body fat percentages, and muscle masses and a Biodex system 4.0 (BIODEX, USA) was used to measure isokinetic muscle-joint and lumbar muscle strengths. The plyometric training consisted of 15 techniques out of the training methods introduced in the 'Power up plyometric training'. The plyometric program was implemented without any training load three times per week during day-break exercises for the experimental group. The number of times and the number of sets were changed over time as follows: three sets of 10 times in the 1st–4th weeks, three sets of 15 times in the 5th–8th weeks, and five sets of 15 times in the 9th–12th weeks. [Results] According to the ANCOVA results of lumbar extensor muscle strength at 60°/sec, the overall reliability of the model was significant. According to the ANCOVA results of lumbar flexor muscle strength at 60°/sec, the overall reliability of the model was significant. [Conclusion] Plyometric training positively affected high school throwing event athletes. To summarize the study findings, the application of plyometric training with high intensity and loads improved the results of athletes who perform highly intensive exercises at normal times.

Key words: Plyometric, Lumbar extensor, Throwing athletic

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INTRODUCTION

The purpose of all sports training is the maximization of the physical and mental elements required to perform exercises or play games. Therefore, the application of specialized and specific training suitable for sports is important. In particular, the acquisition of maximum muscle strength and power is an essential element of all sports. Plyometric training is widely used as a method of developing explosive power capacity in those sports that require jumping ability such as athletics, basketball, and volleyball¹⁾.

Most sports require various kinds of fast and slow muscle strength and speed²⁾. Although typical training methods for increasing the muscle strength of athletes include weight

training, such as resistance exercises and plyometric training³⁾, the power necessary for explosive jumping refers to the power exhibited in dynamic states⁴⁾.

Plyometric training is a type of muscle strength exercise that can improve basic physical strength and it has been extensively studied for the improvement of exercise performance ability. It is an explosive and repetitive rebounding load type exercise that uses the muscles' stretch reflexes and stretch-shortening cycles to develop lower extremity muscles^{5, 6)}. Stretch reflexes are used to promote motor unit mobilization in order to reduce differences between speeds and muscle strength⁷⁾.

In athletics, diverse efforts have been made to try and enhance records through active studies and the development of training methods. With increasing interest in athletics, the importance of athletics scientification has been recognized. Desired records in athletics cannot be achieved only with natural movements and efforts, but also require more reasonable and scientific training content and methods⁸⁾. The physical strength elements required for athletic throwing events include muscle strength, swiftness, agility,

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Table 1. Training activities

Activity	Program period (week)					
	1-4		5-8		9-12	
	rep	set	rep	set	rep	set
1. Lateral jump with both feet	10	3	15	3	15	5
2. Jumping and kicking up the heel	10	3	15	3	15	5
3. Squat jump	10	3	15	3	15	5
4. Power skipping	10	3	15	3	15	5
5. Jumping with both feet and grabbing the ankles	10	3	15	3	15	5
6. Star jump	10	3	15	3	15	5
7. Jumping and touching the toes	10	3	15	3	15	5
8. Standing scissors jump	10	3	15	3	15	5
9. Consecutive scissors jump	10	3	15	3	15	5
10. Lateral jump with one foot	10	3	15	3	15	5
11. Jump and dead run	10	3	15	3	15	5
12. Running up the stairs with one foot	10	3	15	3	15	5
13. Running up the stairs with both feet	10	3	15	3	15	5
14. Running up the stairs aside	10	3	15	3	15	5
15. Running fast and light	10	3	15	3	15	5

speed, flexibility, and physical balance. Although plyometric training and weight training are implemented as representative training methods for improving swiftness and agility, most studies of it have been conducted with players of other sports.

Therefore, the purpose of the present study was to identify the effects of lower extremity plyometric training for 12 weeks, performed by high school throwing event athletes, on isokinetic lower extremity muscle strength and lumbar muscle strength in order to develop more efficient training methods.

SUBJECTS AND METHODS

The study subjects were 10 throwing event athletes attending K physical education high school. The subjects were randomly assigned to a control group of five subjects and an experimental group of five subjects. The experimental group performed 12 weeks of lower extremity plyometric training in addition to general physical strength training programs implemented during school hours. The control group performed training other than lower extremity plyometric training. The control group ($n=5$) was 17.60 ± 0.54 years old in age, $1.74.58\pm 4.60$ cm in height, and 73.22 ± 9.90 kg in weight, and had $14.52\pm 5.67\%$ body fat, and kg lean body mass 32.92 ± 4.81 . The plyometric training group was 17.60 ± 0.89 years old in age, 173.58 ± 7.78 cm in height, and 77.22 ± 11.66 kg in weight, and had $15.34\pm 6.30\%$ body fat, and 35.16 ± 26.85 kg LBM.

To analyze the body composition, an Inbody 3.0 instrument (Biospace, Korea) was used as experimental equipment to measure the subjects' heights, weight, body fat percentages, and muscle masses and a Biodex system 4.0 (BIODEX, USA) was used to measure isokinetic muscle-joint and lumbar muscle strengths.

The plyometric training consisted of 15 techniques out of

the training methods introduced in the 'Power up plyometric training'⁹⁾. The details are as presented in Table 1. The plyometric program was implemented without any training load three times per week during daybreak exercises performed by the experimental group. The number of times and the number of sets were changed over time as follows: three sets of 10 times in the 1st-4th weeks, three sets of 15 times in the 5th-8th weeks, and five sets of 15 times in the 9th-12th weeks.

To measure kinetic lumbar muscle strength, a Biodex System 4.0 was used to measure average power. When stabilized after warm-up exercises, the subject's body regions other than the lumbar region were fixed using adjustable pads so that they would not be subject to external force during extension and flexion movements. The lower extremities and the chest were fixed using straps to restrict the actions of the other muscles. The rotation axis of the joint being tested was aligned with the rotation axis of the dynamometer, and the subjects were encouraged to exert maximum efforts. The average power of flexion and extension was calculated from the values of 4 repeated measurements of lumbar extension and flexion at $60^\circ/\text{sec}$.

The data obtained were processed using the SAS ver 9.12 statistics program. The means and standard deviations of the two groups were calculated. To examine differences between the groups and between measurement time points, the results of the prior test were set as covariates and analyses of covariance (ANCOVA) were conducted. Post hoc tests of differences between the groups were conducted using the least squares mean (LSM) method only when the assumption that the gradients of regression lines were statistically the same within the groups was established, and improvement rate independent t-tests were conducted to examine differences in records between athletes of different items. The statistical significant level was chosen as $\alpha < 0.05$.

All the subjects understood the purpose of this study and

Table 2. Least mean square (LSM) of lumbar extensor muscle strength at 60°/sec and comparison of differences between the groups (Nm)

Group	pre_M±SD	post_M±SD	MEAN	SD
Control group	327.22±58.41	274.62±49.95	280.57	14.38
Experimental group	341.84±81.96	382.58±77.65	376.62	14.38

*p<0.01

Table 3. Least mean square (LSM) of lumbar flexor muscle strength at 60°/sec and comparison of differences between the groups (Nm)

Group	pre_M±SD	post_M±SD	MEAN	SD
Control group	170.12±44.75	153.94±20.24	153.37	9.28
Experimental group	167.44±45.25	185.68±32.45	186.24	9.28

*p<0.01

provided their written informed consent prior to their participation in the study in accordance with the ethical standards of the Declaration of Helsinki.

RESULTS

According to the ANCOVA results of lumbar extensor muscle strength at 60°/sec, the overall reliability of the model was significant ($F=27.28$ $p<0.001$). In the results of the prior test, the common gradient of regression straight lines of lumbar extensor muscle strength at 60°/sec was significant within each treatment, indicating that the initial value of the ANCOVA did not significantly affect actions after the treatment ($F=26.19$ $p<0.001$). The main effect, i.e., the differences between the groups resulting from the experimental treatment, was significant ($F=22.15$, $p<0.002$).

In the lumbar extensor muscle strength at 60°/sec, the standard deviation of the control group decreased from 327.22±58.41 Nm in the prior test to 274.62±49.95 Nm in the post-treatment test, and the standard deviation of the experimental group improved from 341.84±81.96 Nm in the prior test to 382.58±77.65 Nm in the post-treatment test (Table 2).

The LSMs of both groups were compared and the results shown in (Table 2) indicated that there were differences when seen based on two-tailed tests ($p<0.002$). However, one-tailed tests were appropriate in the present study, and the significance level was eventually shown to be 0.001 ($0.002 \times 1/2$), indicating that the lumbar extensor muscle strength at 60°/sec was significantly different between the two groups.

According to the ANCOVA results of lumbar flexor muscle strength at 60°/sec, the overall reliability of the model was significant ($F=6.21$ $p<0.02$). The common gradient of linear regression of lumbar flexor muscle strength at 60°/sec was significant within each treatment, indicating that the initial value of the ANCOVA did not significantly affect post-treatment actions ($F=6.58$ $p<0.003$). The main effect, i.e., the differences between the groups made by the experimental treatment, was significant ($F=6.26$, $p<0.004$).

In the lumbar flexor muscle strength at 60°/sec, the standard deviation of the control group decreased from

170.12±44.75 Nm in the pre-test to 153.94±20.24 Nm in the post-test and the standard deviation of the experimental group improved from 167.44±45.25 Nm in the pre-test to 185.68±32.45 Nm in the post-test (Table 3).

The LSMs of both groups were compared and the results (Table 5) indicate that there were differences based on two-tailed tests ($p<0.004$). However, one-tailed tests were appropriate for the present study, and the significance level was eventually shown to be 0.002 ($0.004 \times 1/2$), indicating that the lumbar flexor muscle strength at 60°/sec was significantly different between the two groups.

DISCUSSION

Since measurement of peak torque is very accurate and is highly reproducible, all isokinetic contractile force values can be standardized and utilized as reference data. Many researchers have reported on isokinetic muscle functions⁹.

In the present study, lumbar flexor/extensor muscle strength at 60°/sec in two-tailed tests showed significant differences between the two groups ($p<0.01$). This result is consistent with those of Youm and colleagues¹⁰, who reported that after implementing abs and back training, the expression ratio of abdominal and lumbar muscle strengths significantly increased (14.53%), and also with those of Brittenham¹¹, who reported that abdominal/lumbar training evenly developed abdominal, spinal, and gluteal muscles conferring positive effects on power expression. The differences in isokinetic muscle strength centered on the waist between sports activities are similar to as the results of a previous study which indicated that the major reason is the development of the muscles around the waist¹².

Although plyometric training mainly jumping consist of exercises, appropriate levels of stimulation are required for back muscle strength to increase lower extremity muscle strength. Ju¹³ reported that plyometric training was correlated with the improvement of lumbar joint flexor/extensor muscle strength.

Standaert and colleagues¹⁴ reported that when posture swayed due to lumbar stabilization exercises, the transversus abdominis muscle (TrA) was activated and that muscle activity was reduced when lumbar stability was deficient or

there was a problem in motor control. Gresswell and colleagues¹⁵⁾ reported that functional activities caused changes in intra-abdominal pressure and that the TrA was activated before the Erector Spinae Muscle was activated when loads were imposed on the spine.

Maffiuletti et al.¹⁶⁾ reported that four weeks of plyometric training performed by 10 female volleyball players improved lower extremity muscle strength by 20%. Although most studies of plyometric training examined the degree of improvement of lower extremity muscle strength, the present study revealed good results from an examination of lumbar flexor/extensor muscle strength. We consider that the increase in core muscle strength improved the athletes' motor abilities.

Plyometric training positively affected the performance of high school throwing event athletes. To summarize the study findings, the application of plyometric training with high intensity and loads improved the performance of athletes who perform highly intensive exercises at normal times.

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