

Effects of 8 Weeks' Specific Physical Training on the Rotator Cuff Muscle Strength and Technique of Javelin Throwers

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Abstract. [Purpose] For maximum efficiency and to prevent injury during javelin throwing, it is critical to maintain muscle balance and coordination of the rotator cuff and the glenohumeral joint. In this study, we investigated the change in the rotator cuff muscle strength, throw distance and technique of javelin throwers after they had performed a specific physical training that combined elements of weight training, function movement screen training, and core training. [Subjects] Ten javelin throwers participated in this study: six university athletes in the experimental group and four national-level athletes in the control group. [Methods] The experimental group performed 8 weeks of the specific physical training. To evaluate the effects of the training, measurements were performed before and after the training for the experimental group. Measurements comprised anthropometry, isokinetic muscle strength measurements, the function movement screen test, and movement analysis. [Results] After the specific physical training, the function movement screen score and external and internal rotator muscle strength showed statistically significant increases. Among kinematic factors, only pull distance showed improvement after training. [Conclusion] Eight weeks of specific physical training for dynamic stabilizer muscles enhanced the rotator cuff muscle strength, core stability, throw distance, and flexibility of javelin throwers. These results suggest that specific physical training can be useful for preventing shoulder injuries and improving the performance for javelin throwers.

Key words: Javelin, Specific physical training, Throw

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INTRODUCTION

Seventy-five percent of injuries in throwing sports occur in the glenohumeral region of the upper limb¹⁾. Athletes who perform overhand throwing motions are more susceptible to injuries than those who perform other throwing actions²⁾.

Shoulder rotation during a javelin throw typically involves large external rotation, whereas internal rotation is limited³⁾. The limited internal rotation of the rotator cuff induces tenseness in the posterior capsule, leading to an increase in anterior translation and shear force during glenohumeral flexion⁴⁾. Furthermore, repeated eccentric stress on the rotator cuff due to excessive external rotation can cause microtrauma of the tendon, resulting in injuries⁵⁾. Several studies have investigated the use of core training, balance training, and function movement screen (FMS) training to strengthen the rotator cuff in order to prevent these injuries^{6–10)}.

In analyzing javelin throwing techniques, optical equipment is often used to investigate the movements. The speed of javelin release, the velocity of the center of gravity during the approach, and the angle of the support leg have been shown to be closely associated with javelin throwing performance^{11, 12)}.

The balance and coordination of the rotator cuff during a javelin throw show maximum efficiency in terms of glenohumeral movement and safety³⁾. In addition, a muscular dynamic stabilizer is needed to prevent injuries in javelin throwers¹³⁾. Existing training methods for javelin throwers emphasize improvements in internal rotation; however, it has been shown that external rotation training is required to improve the muscular dynamic stabilizer¹⁴⁾. Accordingly, this study investigated the change in rotator cuff muscle strength, throw distance, and the technique of javelin throwers after specific physical training (SPT) that combined elements of weight training, FMS training, and core training.

SUBJECTS AND METHODS

The experimental group in this study consisted of four male university javelin throwers (age 22.0 ± 1.15 years, weight 81.0 ± 2.94 kg, height 182.0 ± 5.72 cm) and two fe-

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Table 1. The 8-week specific physical training program

Training	Training details	Intensity & frequency
Weight training	Power clean & press, Dead-lift, Push press, Power snatch, Lunge, Jerk, Clean pull up, Bent over row, Squat jump, External rotation	2–3 sets, 1–2 times per week
Javelin specific training	Isometric Javelin Contractions, Javelin Step-Ups, Bungee Hip-Snaps, Cross-overs up Stairs, Bounding	3–4 sets, 3–4 times per week
FMS training	Deep squat corrective exercise, Hurdle step corrective exercise, In-line lunge corrective exercise, Shoulder mobility corrective exercise, Active straight leg raise corrective exercise, Rotary stability corrective exercise, Team core exercise	3 sets, 3 times per week

Table 2. Rotator cuff isokinetic strength and FMS score before and after 8 weeks of SPT

Direction	Velocity (degree/sec)	Men values		Women values		Difference A-B	
		Pre	Post	Pre	Post	Pre	Post
Internal rotation	240/240	58.50 (9.33)	63.00 (6.00)	45.00 (4.24)	46.50 (6.36)	8.670 (10.67)	5.170 (10.66)
	400/400	51.75 (4.50)	66.75 (6.65)	48.00 (4.24)	60.00 (4.24)	12.75 (5.28)	–1.250 (7.45)*
External rotation	240/240	21.75 (5.12)	32.25 (3.77)	12.00 (4.24)	19.50 (2.12)	5.500 (5.86)	–4.000 (6.23)*
	400/400	20.25 (2.87)	27.00 (2.45)	13.50 (2.12)	19.50 (2.12)	4.250 (3.93)	–2.250 (4.08)*
FMS score (points)		15.50 (1.00)	16.25 (1.71)	15.00 (0.00)	17.50 (0.71)	0.300 (1.07)	–1.030 (1.37)*

Isokinetic muscle strength measurement unit: torque/%BW, FMS score unit: point (0.5 point scale).

*: $p < 0.05$, A: comparison group, B: experimental group

male athletes (age 22.0 ± 1.41 years, weight 72.5 ± 6.36 kg, height 166.5 ± 4.95 cm). The control group consisted of two male national-level javelin throwers (age 26.0 ± 4.24 years, weight 92.0 ± 11.31 kg, height 183.0 ± 7.07 cm) and two female athletes (age 26.5 ± 1.41 years, weight 70.5 ± 2.83 kg, height 167.5 ± 6.36 cm). Before the start of the measurements, the participants were given a full explanation of the research purpose and experimental procedure, and signed Institutional Review Board consent forms to comply with the ethical principles of the Declaration of Helsinki (1975, revised 1983).

Measurements were made three times. In the experimental group, measurements were made once before and once after the training, whereas the control group was measured once to obtain comparison data. On the day of measurement, body measurements, isokinetic muscle strength tests, and FMS tests were done in the morning, and javelin throwing techniques were filmed at the track in the afternoon.

All participants were asked to come to the Exercise Physiology Laboratory at Korea National Sport University on the day of the study. They performed 20 min of warm-up after body measurements had been made with a body composition analyzer (Jawon Medical, Gyeongsan, Korea). The strength of the rotator cuff muscle was measured by using a HUMAC NORM Extremity System (CSMI, Stoughton, MA, USA) for isokinetic muscle strength measurements, and the raw data were divided by each participant's individual weight. The muscle strength and specific characteristics of the javelin throwers were recorded during isokinetic measurements, and the means were calculated of five measurements of internal and external rotation at angular velocities of 240 degree/sec and 400 degree/sec¹⁴.

FMS measurements were carried out to assess the improvement level in participants' functional movement¹⁵. To

increase the internal validity of the FMS test scores, two evaluators performed two measurements each and the average score was used in the analysis.

Twelve infrared cameras (Oqus 500; Qualisys, Gothenburg, Sweden) were used for kinematic analysis, and a total of 49 reflective markers were placed on the javelin and 13 body parts for the filming. The raw data were converted to a C3D format and used for post processing with Visual3D ver. 4.91.0 (C-motion Inc., Germantown, MD, USA). The raw data of the reflective markers contained vibrations of the skin occurring during the javelin throwing motion and background noise, and they were smoothed by using a Butterworth lowpass filter (10 Hz) before analysis¹⁶. A cluster coordinate system model provided by Visual3D was used for the analysis of factors. This allowed the sequential calculation of displacement, velocity, angle, and angular velocity based on the coordinates of the body parts measured at equal time intervals¹⁷.

The training program was performed by the experimental group for 8 weeks. The SPT was specifically designed for javelin throwers as a type of non-periodization training, combining weight training, FMS training, and core training^{9, 18}. The specifics of the program are listed in Table 1.

All calculated data were analyzed using SPSS ver. 17.0 (SPSS Inc., Chicago, IL, USA). The results are reported as means (SD). As a normal distribution could not be assumed because of the small sample size, Wilcoxon signed-rank test, a non-parametric technique, was used. Significance was accepted for value of $p < 0.05$.

RESULTS

Table 2 lists the rotator cuff isokinetic strengths and FMS scores of before and after the 8 weeks SPT program.

Table 3. Kinematic analysis before and after 8 weeks of SPT

Variables	Men values		Women values		Difference A-B	
	Pre	Post	Pre	Post	Pre	Post
Record (m)	57.70 (1.32)	62.50 (2.96)	42.45 (0.64)	44.30 (0.99)	9.600 (1.10)	5.800 (2.64)*
Pull time (sec)	0.153 (0.01)	0.159 (0.01)	0.163 (0.01)	0.185 (0.01)	-0.007 (0.02)	-0.018 (0.03)*
Pull distance (% height)	97.16 (7.63)	99.91 (3.93)	91.71 (5.12)	103.4 (0.50)	-2.174 (10.0)	-7.905 (4.37)*
Release height (% height)	99.36 (3.15)	96.21 (1.36)	103.6 (0.34)	101.4 (0.57)	-4.973 (3.32)	-2.159 (2.03)
Release velocity (m/sec)	23.88 (0.50)	23.32 (0.73)	19.86 (0.39)	20.18 (0.02)	0.737 (1.13)	1.002 (0.82)
Approach velocity (m/sec)	5.516 (0.25)	5.679 (0.37)	4.479 (0.08)	4.446 (0.02)	0.140 (0.26)	0.043 (0.39)
Mean throw velocity of throwing phase (m/sec)	11.64 (0.63)	11.51 (0.16)	9.153 (0.02)	9.112 (0.07)	0.939 (1.79)	1.045 (1.68)
Knee flexion angle (degree)	-10.34 (16.5)	-3.910 (13.4)	66.01 (20.7)	63.25 (12.0)	48.56 (1.34)	34.76 (0.92)
ROM of trunk rotation angle (degree)	103.1 (6.81)	96.88 (6.18)	119.9 (1.33)	130.5 (1.25)	-16.48 (9.69)	-15.76 (17.6)

*: $p < 0.05$, A: comparison group, B: experimental group

No significant change was found in the internal rotation measurements of isokinetic muscle strength at the angular velocity of 240 degree/sec. However, at the angular velocity of 400 degree/sec, a statistically significant increase in muscle strength was observed after SPT (male athletes before: 51.75 ± 4.50 vs. after: 66.75 ± 6.65 , female athletes before: 48.00 ± 4.24 vs. after: 60.00 ± 4.24 , $p < 0.05$). No statistically significant differences were found in the external rotation measurements of isokinetic muscle strength at both the angular velocity of 240 degree/sec and 400 degree/sec. A statistically significant increase in the FMS score was observed after SPT (male athletes before: 15.50 ± 1.00 vs. after: 16.25 ± 1.71 , female athletes before: 15.00 ± 0.00 vs. after: 17.50 ± 0.71 , $p < 0.05$).

Table 3 lists the throwing performances and kinematic factors before and after SPT. The male athletes' throw distance increased from 54.70 ± 1.32 m before SPT to 62.50 ± 2.96 m after SPT, and the female athletes' throw distance increased from 42.45 ± 0.64 m to 44.30 ± 0.99 m, and both improvements were statistically significant ($p < 0.05$). The pull time increased from 0.153 ± 0.01 sec to 0.159 ± 0.01 sec in male athletes, and from 0.163 ± 0.01 sec to 0.185 ± 0.01 sec in female athletes, and both improvements were statistically significant ($p < 0.05$). The pull distance increased from $97.16 \pm 7.63\%$ height to $99.91 \pm 3.93\%$ height in male athletes, and from $97.71 \pm 5.12\%$ height to $103.4 \pm 0.50\%$ height in female athletes, and both improvements were statistically significant ($p < 0.05$). However, no statistically significant change was observed in release height, release velocity, approach velocity, knee flexion angle, and range of motion of the trunk rotation angle.

DISCUSSION

This study assessed the changes in rotator cuff strength, throw performance, and technique after a training program specifically designed for javelin throwers. The angular velocity of overhand throwing motions such as javelin throws

can reach 6,500–7,000 degree/sec, leading to a higher risk of injury compared to other throwing motions^{2, 19, 20}. However, an increase in throw velocity is required to improve javelin throw performance^{12, 20}. To achieve this, training programs aiming to increase the internal rotator muscle strength of the rotator cuff were used in the past²¹. However, in recent years, a sport-specific SPT program that combines core training, balance training, and FMS training in addition to the traditional weight training has been used^{6–8, 10}. The 8 weeks SPT performed in this study increased the external rotator muscle strength of the rotator cuff at 200 degree/sec and 400 degree/sec isokinetic angular velocities ($p < 0.05$). Furthermore, an increase in internal rotator muscle strength was also observed at the 400 degree/sec isokinetic angular velocity, showing that SPT has very positive effects.

Functional movement is required to enhance muscular strength, flexibility, coordination, balance, and movement efficiency, and improvements in these factors are crucial for improving performance^{13, 14}. Studies that have used training programs to improve functional movement have reported its positive effects on FMS score, agility, flexibility, and injury prevention, but have reported no effect on muscle strength⁹. However, a mixed training system was used in this study, and improvements in both rotator cuff strength and functional movement were observed ($p < 0.05$).

The results of this study show that the implementation of the training program increased the athletes' throw distance by 3.8 m, and helped to improve their performance ($p < 0.05$). Previous studies of javelin throwing techniques have shown that shorter pull times and longer pull distances have positive correlations with throw distance¹². Pull time was increased by 0.11 sec ($p < 0.05$) and pull distance by 5.7% height ($p < 0.05$) in this study, however, only increases in pull distance have been reported in previous studies. The decrease in total time dedicated to technique training during the course of SPT is thought to have had a large effect on these results, and we recommend that technique training should not be neglected in similar future studies of javelin

throwers.

In summary, 8 weeks of SPT, for improving the muscular dynamic stabilizer, enhanced the rotator cuff strength, core stability, throw distance, and flexibility of javelin throwers. Thus, the SPT performed in this study is expected to be a useful tool for injury prevention and performance improvement of javelin throwers.

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