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Original Article

Effects of specific muscle imbalance improvement training on the balance ability in elite fencers

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Abstract. [Purpose] The lunge Motion that occurs frequently in fencing training and matches results in imbalance of the upper and lower limbs muscles. This research focuses on the improvement of the imbalance that occurs in the national team fencers of the Republic of Korea through specific muscle imbalance improvement training. [Subjects] The subjects of this research were limited to right-handed male fencers. Nine male, right-handed national fencing athletes were selected for this study (4 epee, 5 sabre; age 28.2 ± 2.2 years; height 182.3 ± 4.0 cm; weight 76.5 ± 8.2 kg; experience 12.4 ± 3.0 years). [Methods] The specific muscle imbalance improvement training program was performed for 12 weeks and Pre-Post tests were to evaluate its effect on the experimental group. Measurements comprised anthropometry, test of balance, and movement analysis. [Results] After the training program, mediolateral sway of the nondominant lower limb and the balance scale showed statistically significant improvement. [Conclusion] The specific muscle imbalance improvement training program used in this research was proven to be effective for improving the muscle imbalance of elite fencers.

Key words: Fencing, Muscle imbalance, Training

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INTRODUCTION

Swordsmanship can be traced back to ancient civilizations, and the inclusion of fencing in the first modern Olympic games (Athens 1896) secured its status as a major sport[1)]. In a fencing match, it is important to move swiftly and score while avoiding the opponents attack and guard[2)]. Therefore, fencers need to improve and maintain the speed of their moves, and do so through highly intensive training[3, 4)].

In a recent survey about fencing injuries, 92.8% of elite and advanced fencing athletes indicated that they experienced injuries and pain[5)]. The most injured location was the lower limb, and most athletes indicated that they had had a ligament sprain or muscle strain[6)]. Elite fencers also reported cases of tendon ruptures in the tibialis anterior[7)]. Injuries like these can be concluded as resulting from the dynamic and repetitive movements required in fencing matches, during which fencers move at high speeds[2, 8)]. Upon observance of a fencing match, it is easy to understand that the most used motion in attack is the lunge motion. The repetition of highly intensive and dynamic lunge motions during a fencing match can be an underlying cause of injury to the neuromuscular system due to impact from the ground. There were also many accounts of imbalanced movements that were combined with great power[9)]. When looking at the actions of the muscles around the knee during the fencing lunge, it can be observed that the forward knee extensor muscles will go through eccentric contraction action while the posterior muscles go through more powerful concentric contraction to slow down the body[10)]. This type of lunge motion, which occurs frequently during fencing matches and practices, is a cause of imbalanced upper and lower limbs[11)]. Therefore, a special program that focuses primarily on solving muscle imbalance is needed to prevent injuries in elite fencers. This research focuses on improving this imbalance of national fencing athletes through the use of specific muscle imbalance improvement training and observing the changes in maintenance of balance. It was hypothesized that (a) the training program would change the biomechanical characteristics and (b) it would change the balance scale score.

SUBJECTS AND METHODS

The participants in this research were 9 right-handed male national team fencers (4 epee, 5 sabre ; age 28.2 ± 2.2 years; height 182.3 ± 4.0 cm; weight 76.5 ± 8.2 kg; experience 12.4 ± 3.0 years) and one participant withdrew from the program due to injury. Participant was excluded immediately from experiments and exercises if they experienced symptoms of injuries or major loss of physical stamina. Before the start of the measurements, the participants were given a full explanation of the research purpose and experimental procedure, and they signed Institutional Review Board consent forms to comply with the ethical principles of the Declaration of

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Table 1. 12-week specific muscle imbalance improvement training program

Exercise type		Exercise content	
Exercise items	Flexibility training	- Increase of joint range through muscle isolation training - Joint rolling or moving to a beat: fingers, wrist, knees, ankle, toes	
	Pilates training	- Divided into exercises at a training center and during matches - 3 times a week, 90 minutes	
	Muscle balance training	- Divided into exercises in a weight room and during matches - Use of weight-training equipment, tubing, a foam pad, a BOSU etc. - Increased repetitions or sets if one side can not do it - 4 types for upper limb, 2–3 types for core, 4 types for lower limb Biceps Curl, arm-pushing, dumbbell raise, dumbbell pronation, core training (side bend, side setup, side lunge, leg raise), back extension, single leg extension, single leg curl, single leg press, single calf raise	
Exercise duration		12 weeks	
		While training	During matches
Exercise strength		60–75% 1RM BOSU ball, medicine ball	Tubing, foam Pad
Repetitions		10–15 times	10–15 times
Rest period		Mon, Thurs: 30 sec/set, 2–3 min/item Tue, Fri: circuit cycle 30sec/item, 2–3 min/set	
Exercise frequency		3 times a week	
Number of sets		3 sets (weak side − strong side − weak side)	
Time taken		Total 30–40 min - Before/after exercise stretching 10–20 min	
Period		12 weeks	

Helsinki (1975, revised 1983).

Before the participants arrived at the lab, the researchers placed and calibrated 12 infrared cameras (Motion Analysis Corporation, Santa Rosa, CA, USA) and 2 ground reaction force plates (Type9287BA, Kistler Instruments AG, Winterthur, Switzerland). The equipment was also heated for 30 minutes to prevent drift. A sampling rate of 200 Hz was used for the infrared cameras and the ground reaction force was set at 1,000 Hz.

To prevent injuries, warming up and stretching were performed 30 minutes before each Pre and Post measurements by the subjects. Then, reflective markers were attached to the major joints and segments of the subjects. They performed right and left one leg stands (ROLS and LOLS, respectively) for a minute each, deep squats (DS) and a balance scale test (BS). All motions were executed 3 times. After performing Pre-tests, specific muscle imbalance improvement training (SMIIT) program was applied, this included static, active and passive stretching, Pilates, core muscle strengthening, and lower limb strengthening. Post-test was conducted on subjects after participating in 2012 London Olympics with the same process and in the same environment.

In order to improve the flexibility component, the SMIIT program included joint rolling to increase the range of joint movement and moving according to a beat. The difficulty level was adjusted through the speed of the beat for each athlete. The muscle balance component of the SMIIT program included activities divided into exercises performed in a weight room and exercises that could be done anywhere such as during a match or training. In order to avoid muscular imbalance, subjects were informed to execute the training protocol properly. When necessary, the weights were lightened and repetition was increased from 10 to 15 times. The details of the SMIIT program are shown in Table 1.

Kinematic data were subjected to a labeling process and transformed into the c3d format, and then Visual3D ver. 4.91.0 (C-motion Inc., Germantown, MD, USA) was used to perform modelling and analysis[12]. The original data obtained with the reflective markers contained data from swaying of the skin and noise from the environment. This was solved by smoothing the data with a Butterworth low-pass filter (6 Hz)[13]. Data for 20 seconds of the ROLS and LOLS, each performed for 1 minute were used. The center of mass (COM) and center of pressure (COP) were standardized based on the height and shoe size of each athlete. The DS was divided into descent and ascent phases (phase 1 and phase 2, respectively) and normalized based on each athlete's shoe size. To measure the balance scale, balance measurement equipment (Biodex Balance System SD, Biodex Shirley, NY, USA) was used. The athletes raised both their arms while standing on the kinematic measurement equipment. Balance in anteroposterior and mediolateral directions was measured for a minute. There was no physical movement during this time. In measurement of the balance scale score with this equipment, the score is reduced when the body shifts off balance by more than the specified limit in a certain direction. The scores ranges from 0 to 6, and it is better if it is lower. After the means and standard deviations were calculated, the Wilcoxon signed-rank test was used to determine the significant differences between each of the variables. SPSS ver. 17.0 (SPSS, Inc., Chicago, IL, USA) was used for statistical analysis, and significance level was set at $p<0.05$.

Table 2. Result of balance test

Variables			Pre (n=9)		Post (n=8)	
			Mean	SD	Mean	SD
Dispersion of COM (cm/ht)	ROLS	AP	7.34	6.99	5.64	3.17
		ML	4.52	1.17	4.33	1.55
		SI	3.52	1.72	4.30	2.64
	LOLS	AP	7.27	9.48	4.24	2.71
		ML	5.32	3.54	4.59	1.25
		SI	2.28	1.48	2.17	1.26
Dispersion of COP (cm/fl)	ROLS	AP	11.84	8.64	6.85	1.30
		ML	8.46	2.78	6.64	1.96
	LOLS	AP	8.18	6.13	7.16	1.52
		ML	8.55	4.46	7.95*	1.52
Dispersion of COP of DS (cm/fl)	Phase 1	AP	5.66	3.23	5.51	0.97
		ML	14.76	7.18	9.95*	2.54
	Phase 2	AP	8.39	7.25	5.09	1.36
		ML	7.73	3.57	8.62	4.64
Balance scale (score)	ROLS	AP	2.71	1.60	1.90	1.11
		ML	1.96	0.92	1.55	0.85
	LOLS	AP	3.14	1.72	1.81*	0.92
		ML	2.55	1.23	1.75	0.93

ROLS: right one-leg stand; LOLS: left one-leg stand; AP: anteroposterior dispersion; ML: mediolateral dispersion; SL: superior-inferior dispersion
*$p<0.05$.

RESULTS

There were no statistically significant differences in the mediolateral, anteroposterior, and superior-inferior COM dispersion during the ROLS and LOLS. There were no statistically significant differences in the mediolateral, anteroposterior, and superior inferior COP dispersion during the ROLS, but there was a statistically significant difference in the mediolateral COP of the LOLS ($p<0.05$). There was statistically significant difference in the mediolateral, COP dispersion during phase 1 of the DS ($p<0.05$). But there was no such significance in phase 2. The results of the BS, which measures the ability to sustain kinematic balance for the right foot, showed no statistically significant difference, but the results of the BS for the left foot showed statistically significant difference in the anteroposterior direction ($p<0.05$).

These results indicate that there was less mediolateral sway in the LOLS and DS. Also, the anteroposterior sway of the left foot in the BS was improved (Table 2).

DISCUSSION

This research was performed to develop and execute a SMIIT program to improve the imbalance of upper and lower limbs muscles of fencing athletes. In the case of fencing, there is a high probability of injuries, but there are not many case studies based on prospective studies and related research[5–7]. Roi and Bianchedi (2008) defined the three important factors in fencing injury prevention as participants, equipment and facilities, and administration of competitions[6]. In this research, the main objective was to improve physical imbalance of the participants through physical conditioning.

Tsoiakis and Katsikas (2006) applied combined physical conditioning to fencers over a long period of time, but there were no statistically significant changes in assessments of countermovement jump or the squat[14]. But there was significant change in the neuromuscular performance of countermovement jump, as shown by the contact time. Rippetoe (2000) also argued that explosive multijoint, core strength, and resistance exercises were necessary for effective strength and conditioning of fencing athletes[15]. Based on prior research, the present research, taking into account the normal exercises executed by national athletes, used flexibility, Pilates, and muscle balance exercises for 12 weeks to improve imbalance[16, 17]. According to the results of this research, there was less mediolateral movement of the nondominant leg during the LOLS after the program than before the program. There was also less mediolateral movement in the descent phase of the DS, as well as an increase in the score of BS, which measures balance stability. The results show that imbalances were reduced through lower limb muscle strengthening. Research done improvement of equipment and facilities for prevention of fencing injuries suggested design of new fencing shoes to lower the impulse based on measurement of the impulse with existing fencing shoes, running shoes, and squash shoes[18]. Greenhalgh et al. (2013) reported that a metal carpet fencing piste (made from woven metal) overlaid on the wooden sprung court surface, which is good at absorbing impacts should be used to decrease the effect of impact shock on the shin due to overuse[2]. In order to decrease the danger of injuries in fencing, a multi-dimensional approach should be used that focuses on improving conditioning.

In summary, the comparison of Pre-Post Test of SMIIT program revealed that there was less mediolateral swaying in the nondominant leg as well as an increase in the score of the balance scale, which measures the ability to sustain balance. This proved that balance was improved through improvement of lower limb balance.

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