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Effects of Closed-Sling Exercise on Muscle Activity and Balance; Football Club Player with Chronic Ankle Instability

The purpose of this study was to investigate the effects of sling exercise on muscle activity and balance on football players with chronic ankle instability. Eight subjects performed Biodex and sling exercises for four weeks and compared the muscle activity and balance ability of the uninjured and injured feet. Stable and unstable foot % MVIC did not change significantly after treatment in all muscles. The total balance ability was not significantly different between the two groups, however, increased only in the unstable side. The anterior/posterior balance ability also represented no significant difference between the groups and was significantly improved only in the unstable side. The medial/lateral balance ability was not significantly different between the groups and was significantly improved only in the unstable side. This study suggests that sling exercise contributes to improving % MVIC, total balance ability, anterior/posterior balance ability, and medial/lateral balance ability of the unstable side.

Key words: *Proprioception, Ankle injury, Chronic ankle instability*

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INTRODUCTION

Sling exercise is one of the methods to treat injuries of the musculoskeletal and nervous system by hanging the rope on the ceiling and using open kinematic chain or closed kinematic chain method [1]. Closed kinematic chain exercise is useful for rehabilitation of muscular skeletal injury since appropriate proprioceptors are stimulated by movement.

The Koreans spend the time to exercise in sports clubs has been increased from 49.2% in 2000 to 54.8% in 2014 [2]. These exercises often contribute to lateral ankle sprains [3]. Ankle sprains occur mainly during jumping and cutting and account for 15-45% of all sports injuries. Physical contact contributes to the injury of the ankle, especially in soccer players with inversion trauma [4].

These soccer players are extremely competitive; they have a lot of physical contacts which lead to injuries during games. These injuries are due to tackles, sharp turns, and sudden stops [5]. Eighty-five percent of ankle sprains occur when the athletes are constantly abusing the tissues of the ankle by performing inversion and internal rotation while the feet are plantar flexed. These acute injuries can occur after overuse and eventually lead to chronic injury [6]. For this reason, thirty-three percent of these patients received rehabilitation treatment for dysbasia [7].

The main reason for chronic ankle instability is that the lateral ankle ligament is more vulnerable than the inner ankle ligament [8]. Additionally, The tibialis anterior and peroneus longus contribute to the control of inversion and plantar flexion, and instability occurs when these muscles become weak [9]. One of the other reason is a reduction in the sensitivity of the proprioceptors. These reductions delay the reaction time of peroneus, quadriceps and biceps femoris during sudden ankle sprain [10].

The degree of injury of ankle sprain is determined by the damage of the anterior tibiofibular ligament, the calcaneofibular ligament, and the posterior talofibular ligament [11]. Chronic ankle instability (CAI) can be repeated over time [12] due to decreased strength of the tibialis anterior and peroneus longus and the function of the proprioceptors [13]. CAI can be caused by two or more factors such as mechanical

instability and functional instability [14]. Mechanical ankle instability is defined as the movement of the ankle beyond the limit of physiological movement. Laxity is often used analogously to mechanical instability. Functional instability is defined as the subjective feeling of giving-way and ankle instability or recurrent, symptomatic ankle sprains (or both) due to proprioceptor and neuromuscular deficits [15].

The leading causes of functional instability are insufficiencies of proprioceptors, neuromuscular control, postural control, and strength [3].

As one of the rehabilitation methods for such damage, neuromuscular and sensorimotor training improves postural control, increase static and dynamic balance, and decreases the injury recurrence in subjects with acute ankle sprains, FAI, and CAI [16]. The persistent weakness of the peroneal muscle is the primary cause of the ankle sprain, resulting in increased muscle length and muscular atrophy [17]. Previous studies of functional CAI, ankle joint, and ankle muscle suggest that strengthening of the peroneal 18) and tibial muscles [19] is necessary to prevent and treat the ankle sprain.

Causes of mechanical ankle instability are tilting of the talar bone and positive signs in the anterior drawer sign [20]. On the other hand, functional ankle instability is determined based on ROM, and limitations of anterior tibial muscle, long peroneal muscle, lateral ligament, and motility and shrinkage of soft-tissues around the ankle joint. Subjects with functional ankle instability will experience continual ankle strains and injuries, and the subjective feeling of giving-way of the ankle.

The leading cause of the CAI is because lateral side ligaments are much weaker than medial side ligaments [8]. Besides, the reduction of proprioceptors decreases the ability to balance worsen the CAI [21]. Thus, when the proprioceptors around the joint are normal, the ankle stability is maintained, and re-injury can be prevented [16].

Through balance training, they can enhance their strong senses and postures as well as proprioceptors function [22]. One of the methods to prevent the CAI is increasing the strength of peroneal muscle by exercising the muscles around the ankle. These strengthening exercises increase ankle stability [7], balance ability and body posture, proprioceptors [22].

For these reasons, this study investigated the effect of sling exercise on the ankle joint muscles of soccer players.

METHODS

Subjects

Eight soccer players (ages 25-45) participating in the experiment were diagnosed with CAI by CT or MRI. The study included those who performed well and were well treated, and those who were within three months of recent injury. Participants with a history of ankle surgery, reduced balance and edema were excluded (Table 1).

Table 1. General characteristic of subjects

General characters	Mena±SD
Age (yrs)	36.50±2.12
Height (cm)	175.50±3.54
Weight (kg)	77.50±7.78

Measurement Muscle activity

In this study, surface EMG (Korea, WEMG-8 (LAXTHA)) and Ag-Ag/CI single-time-use rectangular electrode (bioprotech EMG single electrode, electrode T246H by Bioprotech, Republic of Korea) was used to measure muscle activity.

The size of the electrode is 15mm × 15mm, and the distance between the electrodes is 2cm. The signal of EMG was 1024Hz, and the sampling rate signal was also recorded for full-wave rectification. The data was saved using TeleScan 3.2 program (Korea, WEMG-8 (LAXTHA)), and the range of the signal is 10-400 Hz, and filtering is performed. Also, in order to filter out the background noise, it was notch-filtered by using 60Hz.

The area where the electrodes were attached was shaved and wiped with alcohol. For measuring the muscle activity, the middle area of the center where the muscle activity is the highest was attached to the electrode parallel to the muscular fiber. The ground electrode was attached to lateral condyle. The electrodes were attached on the Tibialis anterior, peroneus longus, and lateral gastrocnemius.

In order to get the average for muscle activity, the amplitudes that were collected three times were converted to the valid value for the analysis. The reference value of MVIC is measured based on each muscle's maximum muscle activity for three seconds [23]. Three measurements were recorded for the average.

Biodex Balance System

This study used Biodex Balance System (USA, BIODEX) for measuring the static balance and dynamic balance. This machine can move sideways, forward and backward to catch the target in the circular 60cm diameter footplate. It also displays console for the feedback and can sense the motion, analyze data, and has a print function. This machine can analyze both static and dynamic balancing also, digitalize the data of the participants' dynamic balance ability (anterior/posterior and lateral/medial). Static and dynamic balances were measured using the Biodex Balance System (Dynamic Limit of Stability Protocol). This measurement is done by standing with two feet (affected side/ non-ring side) on the moving platform and keeping the balance when subjects were crossing nine targets. When the participants are performing this, the time that individuals pass through all nine targets is recorded, and there are Level 1 through 8, 8 meaning the lowest level and 1 meaning the highest level. The individuals stop moving at each target for 3 seconds [24]. These indicate that the longer the time that individuals perform their tasks, the lower their static balance ability. This was conducted once without any practice. Data are recorded three times during the 4week functional rehabilitation treatment: the initial start, 2week rehabilitation treatment, and 4week rehabilitation treatment. In order to avoid any error, the location of the feet and the position of each were recorded [25].

Sling

This study used P-T-S Sling System (Korea, MARPE). Subjects were fixed with straps on neck, chest, waist, knee, and ankle in the supine position. The subject was then raised without touch the bed by the P-T-S system. Then, the ankle joint was , and the tibialis anterior was resisted. After 1 minute of rest, the peroneus muscle was allowed to resist movement with ankle eversion. After resting for 1 minute, the ankle joint was plantar-flexed and resistance exercise was performed on gastrocnemius. Three sets (one set: three times for 10 seconds) were performed one time at a time and performed twice a week. The experimental period is four weeks.

Data processing

The Kolmogorov-Smirnov test was performed to determine the normal distribution of each variation. Descriptive statistics were used to analyze the general characteristics of the subjects.

Paired T-test was performed to verify the difference between before and after exercise on unstable side with ankle instability. Independent sample t-test (T-test) was performed for comparison between groups; unstable side and stable side. The statistical program was analyzed using SPSS 20.0 for Windows. The significance level was .05.

RESULTS

Change of the %MVIC in each muscle

Within the group, the maximum muscle activity was standardized and used to calculate the %MVIC value to analyze the changes in maximum contractile force. There were no statistically significant changes in %MVIC value before and after the sling exercises for 3 seconds on all of the stable and unstable muscles ($p>.05$)(Table 2).

Table 2. Change of the %MVIC in each muscle (unit: %MVIC)

Muscle	Side	Pre	Post	p
GL	Stable	44.26±14.62	46.80±18.86	.566
	Instable	34.98±12.86	43.90±10.82	.649
PL	Stable	66.73±13.66	67.81±21.48	.298
	Instable	60.08±16.71	65.89±19.50	.731
TA	Stable	131.41±30.86	126.25±24.86	.887
	Instable	123.74±25.49	132.26±19.55	.285

The values were expressed as the mean±SD, GL : Gastronemius Latelal, PL : Peroneus Longus, TA : Tibialis Anterior

Change of total balance ability

The total balance ability of the unstable side was significantly improved (p<.05), however, the improvement was insignificant on the stable side. In the comparison between the groups, there was no significant difference between the stable side and the unstable side (p>.05)(Table 3).

Table 3. Change of total balance ability (unit: cm)

Side	Pre	Post	p
Stable	3.53±0.19	3.45±0.17	.75
Instable	7.28±0.12	3.50±0.15	.000*
p	.000*	.63	

The values were expressed as the mean±SD . *p<.05

Change of the anterior/posterior balance ability

In the within-group change, the stability of the unstable side decreased significantly while the stability of the stable side increased insignificantly (p <.05). There was no significant difference between the stable side and unstable side after intervention (p>.05)(Table 4).

Table 4. Change of the anterior/posterior balance ability (unit: cm)

Side	Pre	Post	p
Stable	2.13±0.19	2.17±0.16	.435
Instable	5.43±0.13	2.24±0.14	.000*
p	.000*	.62	

The values were expressed as the mean±SD, *p<05

Change of medial/lateral balance ability

Medial/lateral balance ability of unstable was significantly improved (p<.05), however those of stable side was decreased slightly. The medial/lateral balance between stable and unstable was not significantly different between groups. (p>.05)(Table 5).

Table 5. Change of medial/lateral balance ability (unit: cm)

Side	Pre	Post	p
Stable	2.13±0.19	2.17±0.16	.435
Instable	5.43±0.13	2.24±0.14	.000*
p	.000*	.62	

The values were expressed as the mean±SD, *p<05

DISCUSSION

The purpose of this study was to investigate the effects of sling exercise on muscle activity and balance on football players with chronic ankle instability using the sling and isometric balance exercises.

The hyperextension of the fibular ligament and its reduced use can cause muscle atrophy, resulting in functional ankle instability [14]. As a treatment method for this, strengthening of the fibular and tibialis muscles is essential [15, 16]. Static and dynamic stability of the ankle joint can be maintained when the muscular strength around the ankle joint and the natural receptive senses are normal, thereby preventing reinjury [13]. Open chain exercise has been used to strengthen ankle joint muscles [26], however closed chain muscle strengthening exercises are increasing in recent years. Foot closed chain exercises (CKC) are physical exercises carried out where the foot is fixed in the ground and cannot move. In particular, the closed chain exercise performed on the sling is the most significant advantage that the patient can exercise in the most comfortable position. Therefore, in this study, we investigated the effect of closed chain motion on the sling on the dynamic balance and muscle activity of the tibialis anterior, peroneus longus, and lateral gastrocnemius.

In the study, the %MVIC of the sling exercise group increased slightly in the tibialis anterior and lateral gastrocnemius, however, change of %MVIC were not statistically significant. This result is similar to the results of other studies in which there is no significant difference in effectiveness between the balanced training group and the ankle joint exercise group using the sling. Although the subjects of this study had chronic ankle instability, the sling exercise did not affect the muscle activity increase because the muscle strength was higher than that of the ordinary person.

Balance is the ability to maintain the stability of the trunk plays an essential role in all movements. Balance ability is generally classified as static balance and dynamic balance. Static equilibrium is the ability to maintain equilibrium in a stationary state, and the dynamic equilibrium is the ability to maintain equilibrium in a moving state. In particular, the dynamic balance is involved in the interaction of various states, including all movements of daily life such as walking.

In this study, the total balance ability of the unstable side, the balance ability before and after, and the left and right balance ability were significantly improved. The results of this study are similar to the

results of a 4week ankle joint sling exercise program with significant effects on ankle strength and chronic ankle instability and it is similar to the study that slings exercise is effective in balancing flexion and ankle dorsiflexion of female.

There could have been some margin of error to this study because the sample size is small and some participants were still exercising when they were recommended to rest. Furthermore, Aoyama et al [27] reported that the ankle instability caused more use of the knee and hip muscles than the surrounding muscles of the ankle. Therefore, in the next study, it is necessary to analyze the muscles around the knee and hip joint.

CONCLUSION

These results represented that Sling exercise had a therapeutic effect on functional ankle instability, improving the stability of the muscles around the ankle joints, improving the stability of the muscles around the ankle joints, and the ability to proprioceptive of the ankle.

That is, it is anticipated that this method can be presented as an effective rehabilitation method for the stability of the ankle joint and prevention of recurrence of the ankle joint.

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