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Original Article

Development of an efficient rehabilitation exercise program for functional recovery in chronic ankle instability

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Abstract. [Purpose] The aim of the present study was to construct an integrated rehabilitation exercise program to prevent chronic pain and improve motor ability in cases of ankle injury and re-injury. [Subjects and Methods] Twenty-six male soccer players who required functional strength exercises due to repeated ankle injury were the subjects. A 12-week rehabilitation exercise program was constructed with the aim of improving muscle strength in the ankle and dynamic coordination of the lower limb. Muscle strength and dynamic coordination were evaluated using the Y Balance Test, and isokinetic muscle strength of ankle dorsiflexion, plantarflexion, inversion, and eversion were measured before and after the 12-week program. [Results] Following 12 weeks of rehabilitation exercise, there were statistically significant improvements in the ratios of dorsiflexor strength to plantarflexor strength, eversion strength, and inversion strength on the left side. The other variables showed no significant changes. [Conclusion] The rehabilitation exercise program for chronic ankle instability helped to reduce pain, and to restore normal joint range of motion, muscle strength and endurance, and functional ability. Active protocols to improve complex functions need to be developed to complement these results.

Key words: Chronic ankle joint, Isokinetic, Y Balance Test

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INTRODUCTION

Ankle sprains are one of the most common injuries caused by physical activity during sports or activities of daily living[1–3]. They usually occur during dynamic movement, and over 50% of all ankle injuries involve ligament damage[4]. Chronic ankle instability (CAI) is defined as a subjective feeling of the ankle giving way, which results from a pattern of instability involving an initial ankle sprain followed by repeated ankle sprains[5]. CAI can be defined as the state caused by the experience of multiple ankle sprains, with instability resulting from restricted joint range of motion (ROM) and limited movement[6]. In addition, stability of the ankle can have a positive effect on standing balance, and even influence the stability of such movements as walking and jumping[7].

CAI can occur as a result of inappropriate treatment following an initial injury and pain in the lateral part of the ankle joint is reported to be the most common cause[5, 8, 9]. Due to instability and discomfort during sudden changes of direction or stopping actions, patients with CAI report reduced balance control. Therefore, when ankle injury occurs, the mechanical receptors in the joint become damaged, leading to functional instability[10]. Although the precise mechanisms of functional ankle instability have not been elucidated, the condition presents with ligament damage, reduced muscle strength, delayed muscle response time, and proprioceptive deficits in the ankle[11–13]. Ankle injuries can be divided into acute and chronic injuries. In the case of CAI, because dynamic movement is restricted and balance and gait abilities are impaired, conservative

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Table 1. Rehabilitation exercise program

		Program	Intensity	Time
Warm up		· Walking and cycling	· No pain	10
Main Exercise (12 weeks)	1 (1–2 week) [Initial]	· ROM exercise of the ankle joint focused on PF/DF & In/Ev	· No pain · RPE 11–13 · Circuit Ex. · Increase Ex. · Repetition Ex.	60
	2 (3–10 week) [Improvement]	· ROM exercise of the ankle joint · Band exercise (red & green bands) · Weight (focused on the lower extremity)		
	3 (11–12 week) [Maintenance]	· Plyometric & PNF training focused on PF/DF & In/Ev		
Cool down		· Static stretching (mat exercise)	· No pain	10

treatment via rehabilitation exercise is thought to be important[5, 8, 14, 15].

The aim of active conservative treatment after an exercise-related injury is to promote functional recovery to a level equivalent to or better than the pre-injury level, through the use of appropriate treatments and exercises, thereby enabling the patient to return to the field or to daily life. Hence, this study aimed to construct an integrated rehabilitation exercise program that could improve functional measures, such as muscle strength and dynamic coordination, in order to prevent chronic pain and improve functional impairment caused by ankle injury or re-injury.

SUBJECTS AND METHODS

The study subjects were 26 male soccer players who required functional strength exercises due to repeated ankle injuries. The subjects had a mean age of 23.2 ± 1.4 years, a mean height of 179.8 ± 4.8 cm, and a mean body weight of 75.4 ± 6.0 kg. All the subjects understood the purpose of this study and provided their written informed consent prior to participation in this in the study in accordance with the ethical principles of the Declaration of Helsinki.

Rehabilitation exercise was performed for a total of 12 weeks, two sessions per week, 80 minutes per session, with the aim of alleviating CAI, strengthening in this by muscles of the ankle and the dynamic coordination of the lower limb. The rehabilitation exercise program consisted of three phases: the initial exercise phase (weeks 1–2), the functional improvement phase (weeks 3–10), and the functional maintenance phase (weeks 11–12) (Table 1). The program focused on joint ROM for dorsiflexion (DF), plantarflexion (PF), internal rotation, and external rotation in order to strengthen the muscles of the ankle. These exercises were combined with band training, weight training, plyometrics, and exercises to improve proprioception in order to develop stable, coordinated, functional ability. Measurements were performed before and after participation in the 12-week program in order to evaluate the degree of improvement in muscle strength and dynamic coordination. The Humac Norm Testing & Rehabilitation System (Computer Sports Medicine, Inc., Stoughton, MA, USA) was used to measure the isometric muscle strength of the ankle, considering the functional movements of DF, PF, inversion (IN), and eversion (EV). Joint ROM was defined as the maximal range of pain-free movement. The torque of the joint was aligned with the rotation axis of the dynamometer, and the axis of movement was aligned with the anatomical position of the joint. Measurements were made of each subject, and were converted into a digital format using a computer program. In order to evaluate ankle muscle strength, peak torque (Nm) and the ipsilateral muscle strength ratio (%) of DF, PF, IN, and EV were measured 30°/s.

The Y Balance Test (Functional Movement Systems, Chatham, VA, USA), which was developed to improve dynamic coordination, was used in this study. This test not only allows subjects to gain stability, but also contributes to gradual improvement in muscle strength and flexibility. The Y Balance Test is a method of testing lower limb muscle strength and coordinated functions in dynamic stability, and was adapted from the Star Excursion Balance Test, using three directions instead of eight[16]. The three directions are equiangular at 120° intervals. The subject stands on one leg at the center, and the maximum distance that he/she can stretch the other leg is measured for each of the three directions. Here, the three directions corresponded to the anterior, posteromedial, and posterolateral axes. Three measurements were made of each leg, and the average of these measurements was used in the analysis.

Means and SDs were calculated for all the measured data. The paired-sample t-test was used to compare isometric muscle strength and dynamic coordination before and after the 12-week program. Data were analyzed using SPSS version 23.0 (SPSS Inc., Chicago, IL, USA), and values of $p<0.05$ were considered statistically significant.

RESULTS

Following 12 weeks of rehabilitation exercise, there were statistically significant improvements in bilateral PF strength, the ipsilateral muscle strength ratio, isometric IN strength, and isometric EV strength ($p<0.05$). There were no significant differences in the other variables.

Table 2. Isokinetic strength at 30°/sec (Nm)

			Pre-test	Post-test
Peak Torque (Nm)	PF	R	98.4 ± 25.5	107.8 ± 28.1
		L	105.4 ± 25.9	114.8 ± 28.1
	DF	R	22.2 ± 5.0	34.5 ± 5.8***
		L	37.7 ± 5.0	46.0 ± 5.9***
Ratio (%)		R	21.7 ± 7.0	38.1 ± 15.0***
		L	34.5 ± 8.9	46.8 ± 15.9***

Values are Mean ± SD. PF: planterflexion; DF: dorsiflexor, R: right; L: left.
***p<0.001

Table 3. Isokinetic strength at 30°/sec (Nm)

			Pre-test	Post-test
Peak Torque (Nm)	In	R	42.3 ± 9.7	43.7 ± 12.4
		L	54.3 ± 9.9	62.2 ± 12.9**
	Ev	R	27.1 ± 4.3	30.3 ± 7.9*
		L	34.6 ± 4.5	40.8 ± 7.7***
Ratio (%)		R	67.2 ± 18.1	73.4 ± 21.3
		L	65.8 ± 14.9	67.9 ± 16.0

Values are Mean ± SD. PF: planterflexion; DF: dorsiflexor, R: right; L: left.
*p<0.05, **p<0.01, ***p<0.001

DISCUSSION

Over 70% of patients who experience ankle sprains report additional symptoms resembling CAI, such as re-injury or functional abnormalities[17]. Moreover, CAI has been reported to be associated with several important functional impairments, such as reduced muscle strength and proprioception, as well as loss of both neuromuscular and postural control[5]. It is presumed that CAI is caused by complex functional deterioration, including reduced proprioception and weakening of the ankle evertors[18]. It has also been reported that proprioceptive and muscle strengthening exercises are important for the rehabilitation of ankle instability[6, 9, 19, 20].

In this study, isometric muscle strength was compared between before and after participation in the 12-week rehabilitation exercise program aimed at alleviating CAI. The results show there were significant improvements in DF and PF strength, as well as in the ipsilateral muscle strength ratio, demonstrating an overall improvement in ankle muscle strength (p<0.001). These results are consistent with those of a previous study, which evaluated eight weeks of strategic resistance training performed by 22 subjects diagnosed with functional ankle injury[21]. In another study of the strength, balance, and functional ability of functionally unstable ankles[22], significant differences in PF strength at 30°/s, 60°/s, and 120°/s, and in peak isometric PF force at 30°/s were reported (Table 2). These findings indicate that it is likely that improvement in ankle muscle strength improves functional stability and prevents injury.

Compared with the general population, soccer players show reduced evertor muscle strength and stiff invertor muscles due to repeated training, overuse, and soft tissue damage[2]. These differences lead to a tendency of the IN angle to be larger than in typical individuals, which has been reported to cause CAI due to weakening of the lateral muscles, and development of a supination foot deformity[23]. The results of the present study show the exercise program increased IN and EV strength, and there were significant increases in right EV (p<0.05), left EV (p<0.001), and left IN (p<0.01) (Table 3). Similarly, a meta-analysis of the relationship between ankle instability and balance impairment demonstrated that weakening of the ankle evertors was associated with functional ankle instability[24]. It is our opinion the the significant increases in EV and IN strength after exercise in this study were due to the active rehabilitation exercise preventing weakening of the evertor muscles. Additionally, the significant difference in EV strength is essential for the athletic performance of soccer players. Our finding is consistent with previous studies reporting that continual strengthening of the evertors helps to protect against injury by preventing damage to the lateral ankle ligament and reducing tibial slope[25, 26]. Generally, when evaluating isometric strength, lower limb muscle strength and the balance ratio are used to evaluate the isometric strength of individual muscles, and to predict the relative risk of certain injuries[27].

When standing erect, ankle stability can have a positive effect on standing balance, and even influence the stability of such movements as walking and jumping[7, 28]. In this study, the Y Balance Test was used as an index of functional balance ability. The Y balance test uses three directions of the Star Excursion Balance Test and it has been shown in previous studies

Table 4. Functional ability as measured by the Y balance test (cm)

		Pre-test	Post-test
Right	A	61.8 ± 4.4	62.0 ± 5.7
	PM	95.7 ± 8.7	97.6 ± 10.9
	PL	106.8 ± 8.9	106.9 ± 7.1
Left	A	63.5 ± 5.8	63.8 ± 4.2
	PM	99.1 ± 8.8	100.5 ± 10.9
	PL	110.6 ± 6.9	111.3 ± 9.0

Values are Mean ± SD. A: Anterior; PM: posteromedial; PL: posterolateral

to have a high reliability (Cronbach's α=0.91) in assessments of patients with CAI[29]. In a previous study of functional ROM in CAI[8], improvements from 75.06 ± 5.19% to 78.71 ± 4.97% in the anterior direction, 93.3 ± 10.37% to 97.47 ± 11.20% in the posteromedial direction, and 85.92 ± 11.97% to 93.09 ± 12.96% in the posterolateral direction were reported, but they were not statistically significant. However, a comparison 1 week later showed results, which were consistent with those of our present study (Table 4). The results cited above indicate there was improved functional balance ability, including muscle strength, flexibility, and proprioception in the lower limb, after only 1 week of repeated training. Therefore, in order to improve function in the major joints of the lower limb, namely, the knee and ankle, participation in an exercise program that can improve muscle strength, flexibility, and proprioception is essential.

Active protocols that can reduce pain, and restore normal joint ROM, muscle strength and endurance, and functional ability will need to be developed.

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