EFFECTS OF ACCELERATED REHABILITATION EXERCISE AFTER MBO ON ANKLE FUNCTION AND STRENGTH IN ANKLE INSTABILITY

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EFEITOS DO EXERCÍCIO DE REABILITAÇÃO ACELERADA DEPOIS DE TBM SOBRE A FUNÇÃO E A FORÇA NA INSTABILIDADE DO TORNOZELO

EFECTOS DEL EJERCICIO DE REHABILITACIÓN ACELERADA DESPUÉS DE TBM SOBRE LA FUNCIÓN Y LA FUERZA EN LA INESTABILIDAD DEL TOBILLO

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ABSTRACT

Background: Taekwondo athletes with lateral chronic ankle instability (LCAI) may experience difficulties with proprioception and ankle muscle strength. After surgery, a conventional rehabilitation exercise program can be ineffective, as it may not restore proprioception or muscle strength and, thus, result in minimal improvement. Objective: This study aimed to assess the effects of an ARE program following MBO on the proprioception, isokinetic strength, and endurance of ankle. Methods: Thirty athletes diagnosed with LCAI underwent MBO. They were divided into the ARE group (n=15) and the control group (CON, n=15). The ARE group performed early ARE exercises six times per week for 4 weeks. The parameters applied to test ankle muscle strength were angular speed of 30°/sec and 180°/sec (inversion: Inv. and eversion: Eve., respectively). Proprioception was measured as being able to sense a joint position of 15° of Inv. and 5° of Eve. Results: Significant differences were observed between the ARE and CON groups in ankle strength 30°/sec (Inv.: p<0.001, Eve.: p<0.001), 180°/sec (Inv.: p<0.001, Eve.: p<0.001), and proprioception at 15° (Inv.: p<0.001) and 5° (Eve.: p<0.001). Conclusions: We recorded significant short-term effects from early ARE in Taekwondo athletes with LCAI after MBO. The results provide reference data for the sports rehabilitator or ATC in evaluating the rehabilitation phase and informing patients about expectations after MBO in terms of performance status and the timing of return to sports. ***Level of evidence III; Therapeutic studies–Investigation of treatment outcomes - Case-control Study.***

Keywords: Rehabilitation exercise; Tae Kwon Do; Ankle.

RESUMO

Introdução: Os atletas de taekwondo com instabilidade lateral crônica do tornozelo (ILCT) podem apresentar dificuldades com propriocepção e força muscular do tornozelo. Depois da cirurgia, um programa de exercícios de reabilitação convencional pode ser ineficaz, porque a propriocepção ou a força muscular podem não se restaurar e, portanto, resultar em melhora mínima. Objetivos: Este estudo teve como objetivo avaliar os efeitos de um programa de ERA depois de TBM sobre a propriocepção, força isocinética e resistência do tornozelo. Métodos: Trinta atletas com diagnóstico de ILCT foram submetidos à TBM. Eles foram divididos em grupo ERA (n=15) e grupo controle CON (n = 15). O grupo ERA realizou exercícios ERA precoces seis vezes por semana durante 4 semanas. Os parâmetros aplicados para testar a força muscular do tornozelo foram velocidade angular de 30°/s e 180°/s (inversão: Inv e eversão: Eve, respectivamente). A propriocepção foi medida pela capacidade de sentir a posição articular de 15° de Inv e 5° de Eve Resultados: Foram observadas diferenças significativas entre os grupos ERA e CON na força do tornozelo 30°/s (Inv: p < 0,001, Eve: p < 0,001), 180°/s (Inv: p < 0,001, Eve: p < 0,001), e propriocepção a 15° (Inv: p < 0,001) e 5° (Eve: p < 0,001). Conclusões: Registramos efeitos de curto prazo significativos com ERA precoce em atletas de taekwondo com ILCT depois da TBM. Os resultados fornecem dados de referência para o reabilitador esportivo ou ATC (Certified athletic trainer) na avaliação da fase de reabilitação e informar os pacientes sobre as expectativas depois da TBM em termos de condições de desempenho e momento de retorno ao esporte. ***Nível de evidência III; Estudos terapêuticos – Investigação dos resultados do tratamento - Estudo de caso-controle.***

Descritores: *Exercício de reabilitação; Tae Kwon Do; Tornozelo.*

RESUMEN

Introducción: Los atletas de Tae Kwon Do con inestabilidad lateral crónica del tobillo (ILCT) pueden presentar dificultades con la propiocepción y la fuerza muscular del tobillo. Después de la cirugía, un programa convencional de ejercicios de rehabilitación puede ser ineficaz porque la propiocepción o la fuerza muscular pueden no restablecerse y, por tanto, dar lugar a una mejora mínima. Objetivos: Este estudio tuvo como objetivo evaluar los efectos de un programa de ERA después de TBM sobre la propiocepción, la fuerza isocinética y la resistencia del tobillo. Métodos: Treinta atletas diagnosticados con ILCT fueron sometidos a TBM. Se dividieron en grupo ERA (n=15) y grupo de control CON (n = 15).

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El grupo de ERA realizó ejercicios ERA precoces seis veces por semana durante 4 semanas. Los parámetros aplicados para probar la fuerza muscular del tobillo fueron la velocidad angular de 30°/s y 180°/s (inversión: Inv y eversión: Eve, respectivamente). La propiocepción se midió por la capacidad de sentir la posición articular de 15° de Inv y 5° de Eve. Resultados: Se observaron diferencias significativas entre los grupos ERA y CON en la fuerza del tobillo a 30°/s (Inv: p < 0,001, Eve: p < 0,001), 180°/s (Inv: p < 0,001, Eve: p < 0,001), y la propiocepción a 15° (Inv: p < 0,001) y 5° (Eve: p < 0,001). Conclusiones: Registramos efectos significativos a corto plazo con ERA precoz en atletas de Tae Kwon Do con ILCT después de TBM. Los resultados proporcionan datos de referencia para el rehabilitador deportivo o ATC (Certified athletic trainer) a la hora de evaluar la fase de rehabilitación e informar a los pacientes sobre las expectativas después de la TBM en cuanto a las condiciones de desempeño y el momento de retorno al deporte. ***Nivel de evidencia III; Estudios terapéuticos – Investigación de los resultados del tratamiento - Estudio de caso-control***

Descriptores: *Ejercicio de rehabilitación; Tae Kwon Do; Tobillo.*

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INTRODUCTION

Ankle injury occurs frequently in sports activities. The most common type of ankle injury is inversion ankle sprain; 80% of ankle sprain is caused by lateral ligament injury. Importantly, repeated ankle sprains may lead to instability.[1,2] Approximately 30% of ankle instability progresses to lateral chronic ankle instability (LCAI), which limits sports activities.[3,4] The treatment of lateral ankle sprain involves conservative methods of casting, bracing, medications, and rehabilitation exercises. Despite an adequate level of conservative treatment, LCAI is detected in many athletes, resulting in a long period of rehabilitation before returning to their sports.[5]

Taekwondo players are required to perform movements that require ankle dorsiflexion and plantarflexion frequently. This consequently leads to ankle instability with a high rate of re-injury.[6] When ankle instability occurs repeatedly, LCAI results, even after conservative treatment. Reduced ankle functions and stability may inevitably lead to surgical therapy.[7] The Open Brostr**ö**m Operation method has been used for ankle surgery since the 1960s.[8] At present, the Modified Brostr**ö**m Operation (MBO) using arthroscopy is preferred. Previous studies reported the MBO as an appropriate surgical method for the recovery of structural functions, with excellent results, especially for chronic lateral ankle instability.[9] The MBO approach strengthens the ligament by reinforcing the inferior extensor retinaculum.[10] This is the current standard method of treatment for patients with subjective or objective instability.[11]

During rehabilitation exercise, Taekwondo players with LCAI are most concerned about returning to their sports promptly. The duration of the postoperative rehabilitation exercise is a critical factor for the athletes.[5] Most recommended rehabilitation exercise programs following conventional surgery for LCAI focus on restoring stability and muscular strength through the recovery of coordination, balance, and muscle tone.[12] These programs may also highlight the importance of strengthening the peroneus and tibialis anterior muscles.[2] As the conventional method of surgery has changed and the MBO method is preferred for enhancing ankle stability, the rehabilitation approaches must also be modified accordingly. While the treatment of LCAI and swift return to sports may be achieved by the early recovery of kinesthesia and subsequent restoration of muscular strength in accelerated rehabilitation exercise (ARE), the current research interest has mainly been focused on the surgical method, with only a few studies on rehabilitation exercise.

This study aimed to suggest a suitable 4-weeks ARE program following MBO to assist Taekwondo players with LCAI to rapidly return to the sports field via the early recovery of muscular strength, muscular endurance, and kinesthesia. The importance of early ARE will also be discussed.

METHOD AND MATERIALS

Subjects

Thirty Taekwondo players with MBO for chronic ankle instability were recruited from the Bucheon SM Hospital and the Sports Science Centre (The Republic of Korea). They were classified into the 2 group: accelerated rehabilitation exercise group (ARE, n=15), and the control group (CON, n=15). All participants were informed of the experimental purpose and procedures and signed a consent form. After MBO surgery ankle were protected by immobilization for 1 week and an ankle brace for 1 week. At 2 weeks postoperatively, ARE program were started. The remaining CON group did not receive rehabilitation exercise intervention between tests and served as the control. The ankle muscle strength and proprioceptive sense was measured as isokinetic equipment. The baseline characteristics of the participants, including age, height, weight, invasion are shown in Table 1. This study was approved by the Institutional Review Board of Catholic Kwandong University (IRB No. CKU-21-02-0210).

Accelerated Rehabilitation Exercise Program

The ARE program used in this study was designed to be early and accelerated rehabilitation to use, and to combine ROM, proprioceptive sense and muscles strengthening exercise. The program is a modified and supplemented version of the rehabilitation exercise program used in studies by Pearce *et al.*,[13] White *et al.*,[14] Hall EA[15] and Park *et al.*[16] In the protocol, between each workout, there was a total of 90 min of ARE program done daily, six times a week for a span of 4 weeks, and the CON group didn't participate in any exercise program (Table 2).

Measurement of Isokinetic Strength

This study used an isokinetic equipment to measure the inversion (Inv.) and eversion (Eve.) of the ankle (Isoforce, SungDo MC Co., Seoul, Republic of Korea). The participants were placed in a supine position on the isokinetic measuring chair. Following this, the lateral Malleoulus bone was placed at the rotation of the measuring device by adjusting the slope and height of the chair. When the inversion and eversion was being measured, the femoral and precordial regions were fixed to prevent any additional effort being exerted through these areas. To prevent any adverse reaction to the isokinetic device, the participants measured after sufficient practice. The applied isokinetic protocol in the examination was 6 repetitions at the angular speed of 30°/sec and 12 repetitions at 180°/sec.

Table 1. Characteristics of subjects.

Trial (N=30)	Age	Height	Weight	Invasion
MBO (n=15)	25.15 ± 2.79	175.61 ± 3.01	79.07 ± 2.76	Rt.
CON (n=15)	24.84 ± 3.62	177.30 ± 2.69	85.84 ± 3.29	

Values are Mean ± SD, MBO: modified Brostrom operation group, CON: control group.

Table 2. ARE program.

Protocol			
Trial	**Exercise Type**	**1-2 weeks**	**3-4 weeks**
ROM Ex.	CPM (10min)	DF/PF, Inv./Eve.	DF/PF, Inv./Ev.e
Aerobic Ex.	Upper Cycle	15 min.	5 min.
	Lower Cycle	Não	10 min.
Isotonic Ex.	Ankle pump	from 2 weeks (10R×2S,OKC)	12R × 3S (OKC)
	Towel pulling(toe)	5R×10S	10R×5S
	Leg extension	10R×5S	15R × 5S
	Toe raises	10R × 5S	15R × 5S
Isometric Ex.	Ankle pump	12R × 3S (CKC)	12 × 3S (CKC)
	Towel stretch (DF/PF/Inv./Eve.)	5R × 10S	10R × 5S
Graston Technique	Achilles tendon/ Calf muscle	5 min.	5 min.
Isokinetic Ex.	Inv./Eve.	Non	5R × 12S

Measurement of Ankle Joint Position Senses(JPS)

The JPS test was calibrated before isokinetic equipment measurement. JPS of ankle were tested: 15° of inversion and 5° of eversion. The participant's dominant foot was placed in the manufacturer's ankle attachment and positioned in the test position with the knee flexed at 45° and the hip flexed at 70°.[17] The participants practiced to prevent errors (before starting the experimental test, allowed 2 practice trials). The participants were blindfolded to ensure elimination of visual clues. The subject was again asked to push on a stop button when he thought the test position was reached.

Statistical analysis

All statistical analyses were performed with SPSS version 22.0 for Window (SPSS, Inc., Chicago, IL, USA), and the mean and standard deviation of each variable were obtained using descriptive statistics. The one sample Kolmogorov-Smirnov test and Shapiro-Wilk test was conducted to normality test. The equal variance test was conducted using Levene's equal variance F test. The parametric test was conducted, as it satisfied the statistical significance level. Repeated-measures analysis tests were conducted to assess the differences between the pre- and post-tests and relationships between the groups on the ARE group's performance. Statistical significance was accepted for *p*-values <0.05.

RESULTS

Change of Isokinetic muscle strength

Table 3 show the changes in isokinetic muscle power. When the muscle power was measured in MBO with lateral chronic instability using the angular speed of 30°/sec of isokinetic equipment, comparing post ARE with pre ARE, the ARE group and the CON group showed a significant difference depending on the interaction(Group X Time) in Inv.(p<0.001, F=30.718) and Eve.(p<0.001, F=28.887).

Change of Isokinetic muscle strength(endurance)

The ankle Inv. and Eve. isometric strength of the angular speed of 180°/sec was measured in using the isokinetic equipment. The result was shown in Table 4. The ARE group and CON group showed significant difference in Inv.(p<0.001, F=118.438) and Eve.(p<0.001, F=16.911).

Change of Proprioceptive sense

Table 5 shows the results of the proprioceptive sense. There was a significant difference in Inv. 15° of proprioceptive sense between the ARE group and CON groups(p<0.001, F=74.491). The ankle Eve. 5° of proprioceptive sense was showed significant difference in ARE group and Con group(p<0.001, F=242.311).

Table 3. Change of Isokinetic muscle power before and after ARE (30o/sec).

Trial				Pre-exercise	Post-exercise	Interaction (Group X Time)	
						F	P
30°/sec (peak torque %body)	Inv.	In	MBO	26.92 ± 15.28	53.84 ± 30.49	30.718	0.000**
			CON	31.92 ± 13.21	33.69 ± 12.46		
	Eve.	In	MBO	26.69 ± 14.57	52.53 ± 27.55	28.887	0.000**
			CON	31.92 ± 14.92	34.07 ± 17.62		

Values are Mean ± SD, Inv.: inversion, Eve.: Eversion; In: invasion; *p < .05, **p < .01.

Table 4. Change of Isokinetic muscle endurance before and after ARE (180o/sec).

Trial				Pre-exercise	Post-exercise	Interaction (Group X Time)	
						F	P
180°/sec (peak torque %body)	Inv.	In	MBO	28.15 ± 09.14	68.46 ± 13.50	118.438	0.000**
			CON	32.69±14.12	33.46±15.18		
	Eve.	In	MBO	21.46 ± 05.56	43.23 ± 18.02	16.911	0.000**
			CON	23.38 ± 04.59	25.46 ± 05.45		

Values are Mean ± SD, Inv.: inversion, Eve.: Eversion; In: invasion; *p < .05, **p < .01.

Table 5. Change of Proprioceptive sense before and after ARE.

Trial			Pre-exercise	Post-exercise	Interaction (Group X Time)	
					F	P
Inv. (15°)	In	MBO	10.36 ± 1.06	13.87 ± 0.32	74.491	0.000**
		CON	12.80 ± 0.72	13.19 ± 0.62		
Eve. (5°)	In	MBO	1.49 ± 0.49	3.67 ± 0.42	242.311	0.000**
		CON	2.56 ± 0.66	2.64 ± 0.69		

Values are Mean ± SD, Inv.: inversion, Eve.: Eversion; In: invasion; *p < .05, **p < .01.

DISCUSSION

Lateral chronic ankle instability (LCAI) is a frequent injury in athletes. Over 40% of athletes after an ankle sprain report the feeling of the ankle giving way even in the absence of passive mechanical restriction.[18] Thus, the debate on the method of treatment (surgical vs. conservative) has continued. Recent advancements in surgical techniques and the high probability of re-injury and progression to LCAI caused by the lack of suitable rehabilitation exercise and management during conservative treatment support a surgical treatment approach.[5] Hence, for athletes, surgery is the preferred recommendation at present. However, as it has been pointed out that surgery may cause problems,[19] such as a rapid fall in the ankle function or muscular atrophy,[20,21] the importance of postoperative accelerated rehabilitation exercise has been highlighted.[5,20]

In recent years, the MBO method of treating ankle instability surgically has been widely used. Generally, the MBO requires three suture anchors, one inserted at the anterior talofibular ligament(ATFL), one at the calcaneofibular ligament(CFL), and one at an area close to the ATFL for the strengthening of the ligament.[22] After surgery, the force of fixation is achieved based on the strengthened ligament of the ankle joint. The conservative postoperative treatment often leads to a limited range of motion(ROM) of the ankle joint, reduced muscular strength, and reduced kinesthesia.[23] The latter two are the most common causes for an extended delay in returning to sports among athletes.[21,22,23] Thus, an early postoperative ARE program must be provided to the athletes. The recovery program to enhance muscular strength and kinesthetic should be different according to operation types and technique.

In this study, a 4-week early ARE program was applied after one weeks of postoperative immobilization. The eversion and inversion muscular strength and muscular endurance were monitored, and a significant increase was observed in the ARE group compared to the CON group. The current rehabilitation method for the early recovery of muscular strength after ankle surgery involves no weight loading for 2 weeks,

with the immobilization of the ankle in a slight dorsiflexion state.[2,12] Subsequently, 50% weight loading is permitted.[2] The subsequent 4-6 weeks rely on ankle strengthening exercises, where 100% weight loading is allowed 6 weeks after surgery, with additional exercises to strengthen the Achilles tendon and a jump exercise after 10 weeks.[2,8] Such rehabilitation methods antagonize the current surgical approach by increasing the immobilization period. Thus, reducing ankle function and patient prognosis.[6] Aydogan *et al.*[23] reported that a long immobilization period results in reduced ankle function and decreased muscular strength because the MBO involves the retinaculum augmentation reinforcing the ATFL and CFL to increase inversion stiffness. Also suggested the early introduction of ARE to enhance muscular strength. In line with this and based on an effective muscle strengthening method recommended in previous studies,[24] this study applied a program combining early isometric exercises and mid to late isokinetic exercises of low and high speeds.[26,27] While the agonist muscles for the ankle inversion and eversion are categorized into the peroneal muscle and tibialis posterior muscle, the former is characteristically weaker than the latter structurally.[28] The most important function of the peroneal muscle is its role in ankle eversion, but it also has a regulatory function to prevent hyperinversion upon ankle inversion.[29] Moreover, as the peroneal muscle acts to protect the ligament and joint upon ankle inversion, the strength and function recovery leads to an improved control during ankle eversion and inversion.[27,28,29] Based on this, the 30°/sec inversion and eversion improvements in the isokinetic muscular strength in this study were thought to be the result of the early ARE program. Our results also concurred with previous studies. Thus, an early ARE is predicted to contribute to the rapid enhancement of muscular strength and functional restoration in the athletes after the MBO. Moreover, the 180°/sec inversion and eversion improvements in isokinetic muscular endurance in the ARE group were statistically significant. In contrast, a previous study reported that as muscular endurance decreased, the angular speed increased and that a fall in muscular endurance due to accumulated fatigue from a long period of exercising,[30,31] thus implying that there may be another cause for the reduced muscular endurance. Hobara *et al.*[32] showed a rise in muscular endurance at high and low speeds during a fast-motion exercise. This study demonstrated that an increase in muscular endurance may be attributed to an increased muscular strength at low speed, which leads to the retention of the increased muscular strength at high speed; this finding is supported by numerous previous studies.[30,31,32] The results in our study suggest a possibility that the rapid application of the ARE may assist in the early return to sports for Taekwondo players by enhancing muscular endurance.

The perception of joint motion and body position is influenced by a multitude of senses. Of these, proprioception takes a critical role in neuromotor control and governs the somatosensory afferent based on kinesthesia and JPS.[33,34] The proprioceptive sensory information received by mechanical receptors of the muscles, tendons, and ligaments also affect the musculoskeletal system and play a part in dynamic joint stability.[35] However, if the efficient relay of such information is prevented by an abnormal structure surrounding the joint upon surgery or disease, the reduced proprioceptive function increases the probability of reduced control in posture, motor ability, and the ability to respond to perturbation.[36] In general, the visual, vestibular, and somatosensory data have regulatory mechanisms to determine variations in postural balance based on the center of gravity, as well as the characteristics of the position and supporting planes. However, for the maintenance of balance in motion, the proprioceptive sensory information is prioritized among all somatosensory data for the control of muscular length, muscular tone, and neurons.[35,36,37] In this study, the 4-weeks ARE program significantly improved proprioception in the ARE group compared with the CON group. The result may be due to the dysfunction being transient after surgery, as Taekwondo uses the repetition of numerous characteristic motions through leaps and single foot rotations and movements involving more advanced physical function of the ankle than other sports. Ankle training in the ARE program promoted recovery via repeated performance and rapid adaptation. Our results concurred with previous studies that reported on high levels of proprioception recovery and adaptation ability for athletes involved in sports that require numerous motions of physical improved muscular strength.[36,37] From the first to the fourth week of exercise, muscular strength improvements mostly depend on neurological factors (neurons, glial cells, etc.).[38] The improvement was stalled when the effects of such factors are delayed.[35,38] For this, if the postoperative brace takes up a long time, the myoneural facilitation is delayed, the somatosensory expression is reduced, and the retune for the processing of somatosensory input and output as required in balance control in the central nervous system are decreased.[39] In this study, early ARE after the MBO was shown to promote muscular strength improvement, with subsequent effects on the improvement of proprioception. For Taekwondo athletes with LCAI, an early rehabilitation exercise program after the MBO, to enable the athletes to resume their sports at the earliest time possible, is essential. As a result, provided reference information for sports rehabilitator or ATC to evaluate rehabilitation exercise results and inform athletes about what they should expect after MBO in terms of performance status and timing of return to sports.

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