Effect of Early Use of Gradual Increase of Pain Free Weight Bearing Capacity on Range of Motion and Strength after Acute Inversion Ankle Sprain

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ABSTRACT

Inversion ankle sprain with its very high occurrence rate has constituted a real problem and challenge to the rehabilitation team. This investigation was designed to assess the effect of early use of a newly designed two weeks unloading endurance program including bilateral squat, heel rise, walking, running, unilateral squat, and stretching on range of motion and strength after acute grade II inversion ankle sprain. Forty-five patients with unilateral acute grade II ankle inversion sprain were included in the study. The ranges of ankle motions were measured using isokinetic dynamometer after completion of the program and were compared to the unaffected side. The results showed that the range of motion of dorsiflexion improved by 21%, the planterflexion by 2%, the inversion by 21%, and the eversion by 69%. The strength of the involved side dorsiflexors increased by 14%, the planterflexors by 24%, the invertors by 96%, and the evertors by 34%. The improvements in the tested parameters were statistically significant. All subjects returned to normal functional activities and pain free walking. The program was proven to be short and effective.

***Key words**: Ankle, Range of motion, Inversion ankle sprain, Ankle rehabilitation, Unloading.*

INTRODUCTION

Inversion ankle sprains are between the highly occurring orthopaedic, and sports injuries, and usually hinder athletic performance[2,27]. Eighty five percent of sprains involve plantarflexion and supination. In 65% of sprains, the anterior talofibular ligament is injured. With more violent inversion force about 20% of these sprains involve damage to both the anterior talofibular and the calcaneofibular ligaments. The calcaneofibular and the posterior talofibular ligaments are seldom ruptured alone[23].

Sprains of the ankle have been classified into three grades:

Grade I injury (mild) involves stretching of the ligament without microscopic tearing, mild swelling and tenderness with no mechanical instability.

Grade II injury (moderate) involves a microscopic tear of the ligament with moderate pain, swelling, and tenderness, but no instability of the joint.

Grade III injury (sever) involves a complete rupture of the ligaments with sever swelling and tenderness, and joint instability[23]

The management of damaged ligaments is one of the most difficult and challenging clinical problems in orthopaedics. The routinely used rehabilitation programs include immobilization either in a cast or using a bandage for 6 weeks, then a gradual non-weight bearing to a complete weight bearing exercise program[7,8,10,18]. Immobilization proves to be detrimental to the healing process as well as to the overall strength of the bone-ligament-bone complex[24].

Recently the physical therapy rehabilitation has been redirected towards functional training during lower extremity weight bearing activities[16,17,25]. It has been obvious that patients after long immobilization; especially athletes lose their functional abilities and skills. One area of particular clinical interest is the effect of motion and activity levels following injury on function. It is now known that endurance exercise can enhance collagen synthesis, and increase the tensile strength of ligaments[4,14,21]. The rate of return to normal structural and mechanical properties in a healing ligament is dependent on the rate and intensity of stress and can therefore be controlled by the level of physical activity[3,5,14,20,22]. The recovery of the mechanical properties of the healing ligament is slower than that of the structural properties. Properties of the ligament substance can completely recover following short-term remobilization, but full recovery of the ligament-bone junction is incomplete after a few weeks and may require many months or years[24].

Ligaments are active biological structures; correlations with morphology, biochemistry, and physiology provide an appreciation of their complexity and functional abilities. Although limited by metabolic activity and blood supply, they are able to respond to changes in joint loading and movement[6,20]. The treatment approach used in this study incorporates the mechanical reduction of gravity with pain-free lower extremity weight bearing positions[11]. The purpose of this study was to evaluate the effect of conservative functional rehabilitation program designed for grade II acute inversion ankle sprain on enhancing the healing process in early stage of rehabilitation, and on increasing the functional pain-free weight bearing capacity (increasing range of motion, and muscular strength and endurance).

MATERIALS AND METHODS

Subjects

Forty-five subjects (31 males and 14 females) 19 to 37 years old (mean age, 27.7 years, standard deviation, 5.13 years) with confirmed unilateral grade II acute inversion ankle sprain voluntarily participated in the study. All subjects signed informed consent form. The unaffected side serves as control for the affected one in each subject. All subjects were from the orthopaedic outpatient clinic of Kasr-El-Aini university hospitals.

Instrumentation

a- A total Gym with variable inclined plane (the degree of inclination determined the percent of body weight force on the lower extremity) and a foot support. Engineering Fitness International, San Diego, California, USA.

b- Biodex unweighting system. Biodex Medical Systems, Inc., Brookhaven, R and D plaza, 20 Ramsay Road, Box 702, New York 11967-0702, USA.

c- Star Trac, TR1800 Treadmill. Star Trac, Unisen, Inc., Bolingbrook, IL 60440-5071, USA.

d- Musculoskeletal Evaluation Rehabilitation And Conditioning (MERAC) isokinetic dynamometer. Universal Gym Equipment, Inc., 72nd Avenue, SW, P.O.Box 1270, Cedar Rapids, Iowa, USA.

Procedures

A) Evaluation

Patients after confirmation of the diagnosis, acute grade II inversion ankle sprain, were subjected to initial physical therapy evaluation including measurement of active range of motion of dorsiflexion, plantarflexion, eversion, and inversion for both sides; and the maximum pain free voluntary isometric contractions of the dorsiflexors, plantarflexors, evertors, and invertors.

The active range of movement of the foot was measured using the MERAC universal digital goniometer relative to the neutral position of the foot. The mean of three successive measurements was calculated and recorded. Intratester reliability for goniometric ankle range of motion testing is high with intraclass correlation coefficients (ICCs) ranging from 0.64 to 0.92 in traumatic patients during clinical sitting[26].

The maximal pain free voluntary isometric contractions of the dorsiflexors, planterflexors, evertors, and invertors were measured by the use of the MERAC dynamometer using a standard testing protocol from sitting position. Both feet were tested; testing of the involved ankle was performed immediately after the testing of the noninvolved one. Three trials were carried out and the mean was calculated and recorded. The intrerrater reliability for the dynamometer has been reported to be excellent with an ICC of 0.94 for strength measurements[12,19].

The measurement procedures were conducted once more immediately after completion of the treatment program.

B) Treatment

All patients followed a management program for the acute lesion included rest, ice, compression, and elevation (RICE) for 72 hours.

The exercise program included the following: (1) Bilateral squat and heel rise using the total gym starting at 20% of body weight and ending at 75% of body weight, for 5 sets of 10 repetitions; (2) The biodex unweighting system was placed over the treadmill, the subject was attached via a thoracic harness to the vertical hanging traction wire, and overhead pulley. The patient did walk and run at 50% of body weight and graduated to 100% of body weight for 15 minuets each session; (3) The unweighting system was used once again without the treadmill. The subject did unilateral squats starting at 50% of body weight and ending at 100% of body weight, for 5 sets each for 30 repetitions; (4) To improve flexibility, the subject did static stretches of the gastrocnemius and soleus for 3 sets each for 20 seconds[15].

The incremental reduction of gravitational force was continued until the full weight bearing was possible and pain free. The patients received three sessions per week for two weeks. The exercise program (Table 1) was developed using the American College of Sports Medicine[1], guidelines for exercise prescription.

Table (1): The exercise treatment program.

Sessions	1	2	3	4	5	6
Activities						
Bilateral squat						
Sets	5	5	5	5	5	5
Repetitions	10	10	10	10	10	10
Rest period, min.	1	1	1	1	1	1
Body weight, %	20	45	55	60	70	75
Heel rise						
Sets	5	5	5	5	5	5
Repetitions	10	10	10	10	10	10
Rest period, min.	1	1	1	1	1	1
Body weight, %	20	45	55	60	70	75
Walk\Run						
Speed, m/s	2.2	3.13	3.35	4	4.1	4.5
Duration, min.	15	15	15	15	15	15
Body weight, %	50	60	70	80	90	100
Unilateral squat						
Sets	5	5	5	5	5	5
Repetitions	30	30	30	30	30	30
Rest period, min.	1	1	1	1	1	1
Body weight, %	50	60	75	85	95	105
Stretching						
Sets	3	3	3	3	3	3
Duration, sec.	20	20	20	20	20	20
Rest period, sec.	20	20	20	20	20	20

RESULTS

The pretreatment evaluation revealed a decrease in active range of the movements of dorsiflexion, plantarflexion, eversion, and inversion of the involved side compared to the uninvolved side. The evaluation revealed also, a decrease in the strength values of the maximum pain free isometric contraction of the dorsiflexors, plantarflexors, evertors, and invertors of the involved side compared to the uninvolved side. The results were presented as percentage of the involved side to the uninvolved side (table 2).

Table (2): Pretreatment mean of active range of motion, and isometric strength.

Tests	Involved		Uninvolved		Involved/uninvolved
	mean	SD	mean	SD	
Active range of motion (degrees)					
Dorsiflexion	11.30	3.40	15.85	2.50	71.29%
Plantarflexion	49.98	6.51	55.01	4.29	90.85%
Inversion	25.49	4.33	30.11	5.49	84.65%
Eversion	15.98	7.12	25.04	3.33	63.81%
Strength (N-m) *					
Dorsiflexors	19.86	7.91	29.66	3.45	66.99%
Plantarflexors	85.85	4.21	110.11	4.55	77.97%
Invertors	17.26	5.55	38.88	2.34	44.40%
Evertors	24.18	8.10	33.67	5.01	71.83%

*Newton/meters.

The posttreatment results were presented also, as percentage of the involve d side to the uninvolved side for range of motion, and pain free maximum isometric contraction (table 3).

Table (3): Posttreatment mean of active range of motion, and isometric strength.

Tests	Involved		Uninvolved		Involved/uninvolved
	mean	SD	mean	SD	
Active range of motion (degrees)					
Dorsiflexion	13.76	7.77	16.44	2.01	83.69%
Plantarflexion	51.33	6.65	55.22	4.67	92.95%
Inversion	30.99	7.89	31.43	3.32	98.60%
Eversion	27.01	9.12	28.61	5.15	94.40%
Strength (N-m) *					
Dorsiflexors	22.67	6.71	31.60	4.33	71.77%
Plantarflexors	106.67	6.01	125.90	3.65	84.73%
Invertors	33.96	4.11	40.98	2.39	82.88%
Evertors	32.53	8.76	35.99	3.49	90.39%

*Newton/meters.

The pre and post training measurements of range of movement and isometric strength were compared for the involved side using the paired t-test, differences were considered significant at $p \leq .05$ (table 4, and Figs. 1,and 2).

Table (4): Comparison between the pre and posttreatment mean of active range of motion, and isometric strength of the involved side.

Tests	pretreatment		posttreatment		P value
	mean	SD	mean	SD	
Active range of motion (degrees)					
Dorsiflexion	11.30	3.40	13.76	7.77	0.001**
Plantarflexion	49.98	6.51	51.33	6.65	0.001**
Inversion	25.49	4.33	30.99	7.89	0.001**
Eversion	15.98	7.12	27.01	9.12	0.001**
Strength (N-m)*					
Dorsiflexors	19.86	7.91	22.67	6.71	0.000**
Plantarflexors	85.85	4.21	106.67	6.01	0.000**
Invertors	17.26	5.55	33.96	4.11	0.000**
Evertors	24.18	8.10	32.53	8.76	0.000**

* Newton/meters. **Significant.

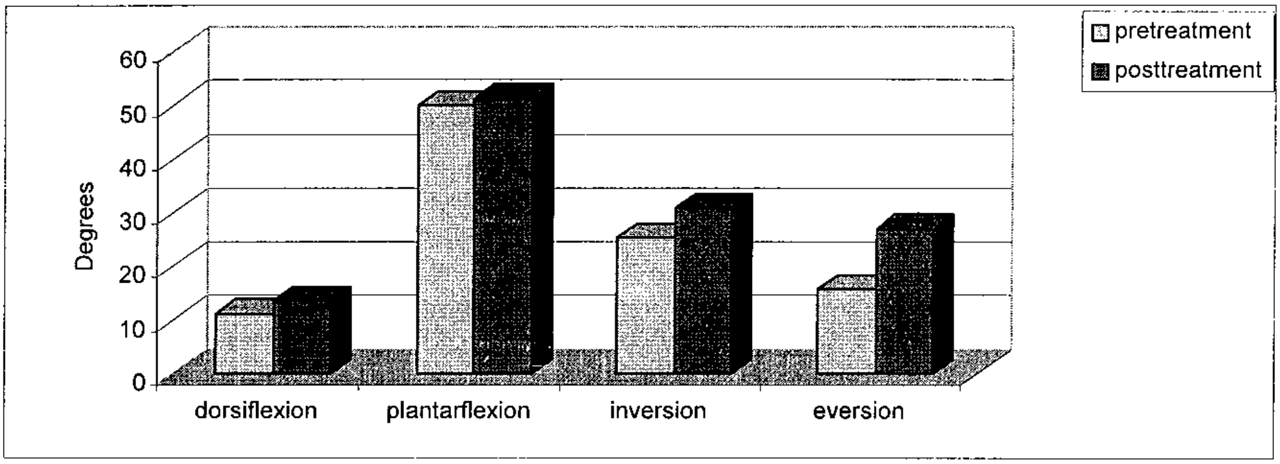

Fig. (1): The mean value of the pre and posttreatment range of movement of the involved side.

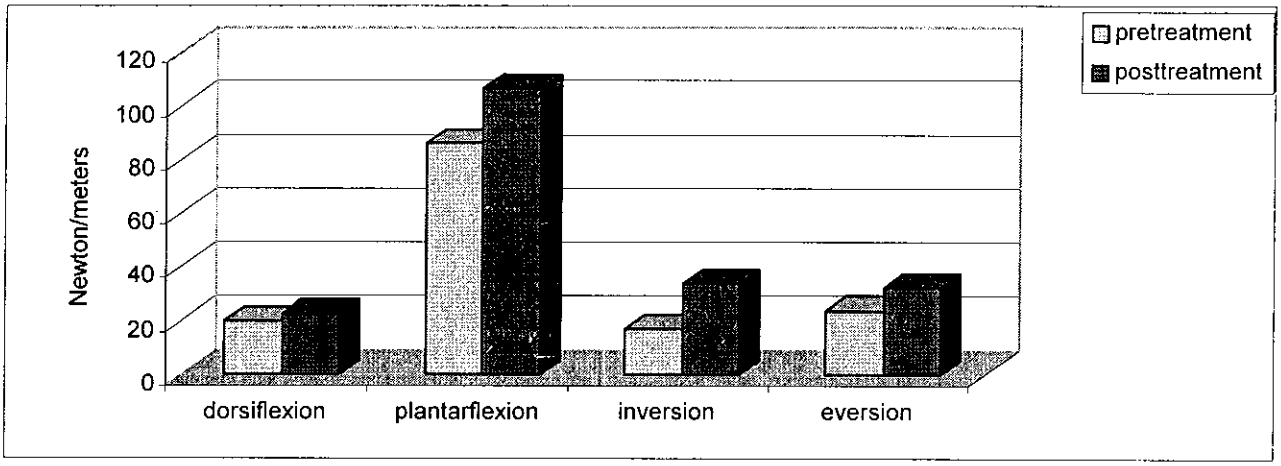

Fig. (2): The mean values of the pre and posttreatment isometric strength of the involved side.

The pre and post training measurements of range of movement and isometric strength were compared for the uninvolved side using the paired t-test, differences were considered significant at $p \leq .05$. All ranges and strength measurements were increased, but differences were found to be insignificant, except for the eversion range of movement and the planterflexors strength, p = 0.002, and 0.0001 respectively.

DISCUSSION

Tension to injured tendons and ligaments has been shown to improve healing through increasing fibroblast proliferation, migration, and collagen synthesis. It also, causes the collagen fibrils to align parallel to the line of force in short time[21].

The healing ligaments under tension have increased collagen content that is more longitudinally arranged, and have a decreased cellularity. The cross-links are low indicating active remodeling[22]. The longitudinal arrangement of the collagen fibrils was found to increase the biomechanical properties of the ligament[13].

The adverse effects of immobilization on ligament healing process and strength were proven[24], and the good results of early functional training during weight bearing activities of the lower extremity were established[16,17,25].

The introduction of the unweighting technique for gravity reduction during lower extremity weight bearing training[11],was used in this study to induce minimal and gradual increase of tension on the healing tissues. The system facilitated the application of especially designed functional rehabilitation program that emphasized the early restoration of range of motion, strength, and endurance.

The results of the study showed that the decreased range of motion of the ankle were significantly increased after treatment and became close to the uninvolved side range. It was interesting to see increase in the range of the uninvolved side especially the eversion range, this may indicate the presence of muscular weakness, limited range of motion, and may be longer reaction time.

The isometric muscular strength of the dorsiflexors, plantarflexors, invertors, and evertors of the involved side was significantly increased between 14% and 96% of the post-injury measured strength. The uninvolved side strength was increased between 5% and 14%. This was due to the mechanical reduction of gravitational force on the body while performing functional activities during weight bearing exercises allows exact control over the amount of stress to the lower extremities. The program could be used as part of designed preventive strategy.

The incremental gradual increase of weight bearing on lower extremities during training provided an easy tolerable transition to full weight bearing activities[11]. The effect of injury on duration of disability is related to functional limitations, which are dependent on behavioral factors such as motivation and confidence[9]. The suggested program of treatment provided both motivation and confidence, through the early intervention and the mechanical reduction of the gravitational force. Both factors increased the effectiveness and decreased the duration of the program.

The program was designed and proven to increase the healing and endurance of the soft tissues mainly ligaments, tendons, and muscles. Because of the low metabolic activity and vascularity of tendons and ligaments, the prescribed program included endurance exercises to facilitate tissue oxygenation and cardiovascular conditioning. All subjects returned to normal functional activities and pain free walking.

REFERANCES

1- American college of sports medicine.: Guidelines for graded exercise testing and exercise prescription. 2nd ed. Philadelphia: Lea and Febiger, 1980. pp 11-20, 137-151.

2- Boruta, P.M., Bishop, J.O., Braly, W.G., and Tullos, H.S. : Acute lateral ankle ligament injuries: A literature review. Foot Ankle. 11: 107-113,1990.

3- Cabaud, H.E.: Exercise effects on the strength of the rat anterior cruciate ligaments. Am J Sports Med, 8: 79-86, 1980.

4- Carlstedt, C., Nordin, M.: Biomechanics of tendons and ligaments. In: Nordin M, and Frankle V, Eds. Basic biomechanics of the musculoskeletal system. 2nd Ed. Philadelphia: Lea and Febiger, PP 59-87, 1989.

5- Clayton, M.L., Miles, J.S., and Abdulla, M.: Experimental investigations of ligamentous healing. Clin Orthop. 61: 146-153, 1968.

6- Cornwall, M.W.: Biomechanics of noncontractil tissue. Phys Ther. 64(12): 1869-1873, 1984.
7- Dettori, J.R., and Basmania, C.J.: Early ankle mobilization, part II: A one-year follow-up of acute, lateral ankle sprains (a randomized clinical trail). Milit Med. 159: 20-24, 1994.
8- Dettori, J.R., Rearson, B.D., Basmania, C.J., and Ledner, W.M.: Early ankle mobilization, part I: The immediate effect on acute, lateral ankle sprains (a randomized clinical trail). Milit Med. 159: 15-20, 1994.
9- Jette, A.M.: Physical disablement concepts for physical therapy research and practice. Phys Ther. 74: 380-386, 1994.
10- Kaikkonen, A., Kannus, P., and Jervinen, M.: Surgery versus functional treatment in ankle ligament tears. A prospective study. Clin Orthop. 326: 194-202, 1996.
11- Kern-Steiner, R., Washecheck, H.S., and Kelsey, D.D.: Strategy of Exercise prescription using an unloading technique for functional rehabilitation of an athlete with an inversion sprain. JOSPT. 29(5): 282-287, 1999.
12- Kwoh, C.K., Patrick, M.A., and Munin, M.C.: Inter-rater reliability for function and strength measurements in the acute care hospital after elective hip and knee arthroplasty. J Arthritis Care Res. 10: 128-134, 1997.
13- Liu, S.H., Rong, S-Y, AL-Shikh, R., and Lane, J.M.: Collagen in tendon, ligament, and bone healing. A current review. Clin Orthop. 318: 265-278, 1995.
14- Maffulli, N., and King, J.: Effects of physical activity on some components of the skeletal system. Sports Med. 13: 393-407, 1992.
15- Muir, L.W., Chesworth, B.M., and Vandervoort, A.A. : Effect of static calf stretching exercise on the resistive torque during passive ankle dorsiflexion in healthy subjects. JOSPT. 29(2): 106-115, 1999.
16- Nyland, J., Brosky, T., Currier, D., Nitz, A., and Caborn, D.: Review of the afferent neural system of the knee and its contribution to motor learning. JOSPT. 19: 2-11, 1994.
17- Palmitier, R., An, K., Scott, S., and Chao, E.: Kinetic chain exercise in knee rehabilitation. Sports Med. 11: 402-413, 1991.
18- Povacz, P., Unger, S.F., Miller, W.K., Tockner, R., and Resch, H.: A randomized prospective study of operative and non-operative treatment of injuries of the fibular collateral ligaments of the ankle. J Bone Joint Sur. 80-A(3): 345-351, 1998.
19- Timm, K.E., Gennrich, P., Burns, R., and Fyke, D.: The mechanical and physiological performance reliability of selected isokinetic dynamometers. Isokinetics and exercise Science. 2: 182-190, 1992.
20- Tipton, C., Mathes, R., Maynard, J., and Carey, R.: The influence of physical activity on ligaments and tendons. Med Sci Sports Exerc. 7: 165-175, 1975.
21- Tipton, C., Schild, R., and Tomanek, J.: Influence of physical activity on the strength of knee ligaments in rats. Am J Physiol. 212: 783-787, 1967.
22- Vailas, A.C., Tipton, C.M., Matthes, R.D., and Gant, M.: Physical activity and its influence on the repair process of medial collateral ligaments. Connect Tissue Res. 9: 25-31, 1981.
23- Wester, J., Jespersen, S., Nielsen, K., and Neumann, L.: Wobble board training after partial sprains of the lateral ligaments of the ankle: A prospective randomized study. JOSPT. 23(5): 332-335, 1996.
24- Woo, S. L-Y., Livesay, G.A., Runco, T.J., and Young, E.P.: structure and function of tendons and ligaments. In: Mow, Van C., and Hayes, W.C., Eds.: Basic orthopaedic biomechanics. 2nd ed. Philadelphia: Lippincott-Raven publishers, 1997. pp 209-251.
25- Worrell, T.W., Borchert, B., Erner, K., Fritz, J., and Leerar, P.: Effect of a lateral step-up exercise protocol on quadriceps and lower extremity performance. JOSPT. 18: 646-653, 1993.
26- Youdas, J.W., Bogard, C.L., and Suman, V.J.: Reliability of goniometric measurements and visual estimates of ankle joint active range of motion obtained in a clinical setting. Arch Phys Med Rehabil. 55: 1113-1118, 1974.

27- Zelisko, J.A., Noble, H.B., and Porter, M.: A professional basketball injuries. Am J Sports Med. 10: 297-299, 1982.

الملخص العربي

تأثير الاستخدام المبكر للزيادة التدريجية لطاقة التحميل بدون ألم على المدى الحركي والقوة بعد تمزق الأربطة الوحشية الحاد لمفصل الكاحل

تمـــزق أربطة مفصل الكاحل الوحشية كثيرة الحدوث وتعتبر مشكلة وتحدي لفريق التأهيل . ويشمل برنامج العلاج المعتاد التثبيت لمدة ستة أسابيع باستخدام جبيرة أو رباط ضاغط ، ويتبعه برنامج تمرينات بدون تحميل يتدرج حتى التحميل الكامل . كان من الواضح أن المصابين وخاصة الرياضيين بعد التثبيت الطويل يفقدون قدراتهم الوظيفية ومهاراتهم . من المعروف الآن تأثير تمرينات قوة التحمل على تحفيـــز إنـــتاج الكولاجين وزيادة قوة شد الأربطة . ويهدف هذا البحث لدراسة تأثير الاستخدام المبكر لبرنامج تمرينات يستخدم التخفيض المـــتدرج لـــتأثير الجاذبية الأرضية الميكانيكي أثناء تمرينات التحميل ولمدة أسبوعين بعد تمزق الأربطة الوحشية الحاد لمفصل الكاحل . اشترك في البحث خمسة وأربعون متطوعاً تتراوح أعمارهم بين 19 ، 37 عاماً ، منهم واحد وثلاثون من الذكور وأربعة عشر من الإناث . وقد تم تقييم المدى الحركي للمفصل والقوة العضلية باستخدام جهاز قياس القوة العضلية الثابت قبل بداية البرنامج ومرة أخرى بعد انتهائه مباشرة .

أشـــارت نتائج البحث إلى وجود زيادة في المدى الحركي للمفصل تتراوح بين 2% ، 69% ، وكذلك زيادة في قوة العضلات تتراوح بين 14% ، 96% . كانت الفروق معنوية بين أداء المفصل قبل وبعد العلاج مما يدل على تأثير برنامج التمرينات على تحسين الالتئام وزيادة المـــدى الحـــركي والقوة العضلية للمفصل المصاب . وأشارت النتائج كذلك إلى أن البرنامج مؤثر وقصير . وقد عاد جميع المرضى إلى نشاطاتهم الوظيفية العادية وإلى المشي بدون ألم .