

# DYNAMICS OF MUSCLE STRENGTH IMPROVEMENT DURING ISOKINETIC REHABILITATION OF THE ATHLETES WITH ACL RUPTURE AND CHONDROMALACIA PATELLAE

Natasa Desnica Bakrac, MD, Cybex Rehabilitation Center, Vocarska 106, 10000 Zagreb  
Croatia

## Abstract

**Background.** 1) To assess quantitatively dynamics and extent of the increase in muscle strength during isokinetic rehabilitation and 2) to examine how it relates to improvements in subjective symptoms.

**Methods.** Experimental design: Daily measurements of muscle strength; detailed testing at the beginning and at the end of rehabilitation. Setting: Cybex rehabilitation center, Zagreb. Subjects: 44 athletes (31M, 13F, age 16-35), three injury-defined groups. Interventions: All subjects underwent isokinetic rehabilitation on Cybex Orthotron KT2 device, using individually designed protocols (extension and flexion exercises, concentric muscle contractions; 15 treatments). Measurements: Subjective (change in symptoms) and objective (monitoring of daily progress and detailed testing on diagnostic device).

**Results.** All patients have shown considerable improvement. Subjective assessment: pain and swelling diminished greatly; knee stability and personal feeling of muscle strength increased. Objective evaluation: muscle strength has improved in average 141 % (SD=110) in ACL-reconstructed group, 144 % (SD=130) for chondromalacia patellae group and 150 % (SD=74) for ACL-non-reconstructed group, comparing to strength at the beginning. Dynamic status tested on Cybex Otrhotron diagnostic device prior and after rehabilitation strongly correlated with final progress monitored on the rehabilitation device.

**Conclusions:** Isokinetic rehabilitation has proven to be very fast and effective method in treating knee injuries of athletes. Both objective and subjective criteria have shown significant increase in muscle strength and alleviation of clinical symptoms. The

improvement of muscle strength was on the average 149 % (SD=101), which is about 10% daily for 15 treatments. The greatest progress, 19% per day, occurred during first five days. The athletes were able to return to their sport activities in very short time.

Key words: isokinetic rehabilitation, ACL rupture, chondromalacia patellae, muscle strength, athletes, knee injuries

## *INTRODUCTION*

Isokinetic rehabilitation is a particularly suitable method for treatment of wide range of different knee injuries [1,2]. In isokinetic exercises, constant speed of motion is chosen on the basis of specific goals of rehabilitation (1-300°/sec – dynamic speed), while the resistance is accommodating [3]. In such rehabilitation, damaged joints are protected during the exercise, since the resistance adapts automatically, throughout the whole range of motion, according to the muscle strength, pain, fatigue, *etc.* Thus, even heavily injured athletes, and early postoperative patients could be treated. Isokinetic resistance enables exercising in the functional speed, to develop strength and endurance of the muscles [4], and to train the neuromuscular system to the speeds required for the dynamical functions of the extremities. Furthermore, it is very important to establish the balance between the antagonistic muscles [5], since there are many reports showing strong correlation between the strength imbalance and the incidence of injury [6,7,8]. In this paper we report on the isokinetic rehabilitation of the athletes with most common injuries of the knee: anterior cruciate ligament (ACL) rupture (non-reconstructed and reconstructed) and chondromalacia patellae.

## *SUBJECTS*

In our study we have included forty-four athletes, aged 16 – 35, and have divided them in three groups. First group consisted of 20 subjects diagnosed with ACL rupture (ACL group), 14 males and 6 females. In the second group we had 8

subjects with ACL rupture which have received reconstruction (RECON group), 6 males and 2 females. In the third group there were 16 subjects diagnosed with chondromalacia patellae (CHONDRO group), 11 males and 5 females. All of them underwent isokinetic rehabilitation on the Cybex Orthotron KT2 device, using individually designed protocols. These protocols had been adjusted throughout the treatment, taking into account progress from one phase to the other, increase of measured muscle strength, subjective complaints, efficiencies at different speeds, and other relevant factors. Extension and flexion of the knees were exercised, using concentric muscle contraction. On the average, 15 treatments were performed, in duration of 30 minutes each. Athletes from ACL and RECON groups have exercised with the addition of the so-called Johnson's device. That device ensures knee stability even during the most strenuous exercise, preventing anterior shear of the tibia.

## MEASUREMENTS

The result of isokinetic rehabilitation was assessed through subjective and objective parameters. The subjective criterion included pain, swelling, instability, and personal feeling of muscle strength. Two types of objective measurements were employed: a) progress of maximal muscle strength (peak torque) of quadriceps and hamstrings was monitored every day during the rehabilitation, for all subjects b) prior to and after the rehabilitation, detailed dynamic status of the upper leg muscles was taken for both injured and healthy contralateral leg, for some patients. This status included peak torque, work per repetition, range of motion and fatigue index.

## RESULTS AND DISCUSSION

All patients in the selected groups have shown considerable improvement, both in subjective and objective measurements. The subjective assessment is presented in Table 1. In the CHONDRO group, pain was the biggest problem. However, after the end of rehabilitation, over 80 % of the athletes were pain-free. This finding is not surprising since muscle atrophy was found to correlate to the degree of pain [9]. In addition, in more than half of the patients with swelling, this symptom disappeared by the end of the treatment. In the ACL group all patients had problems with knee stability, but at the end of the treatment, 50 % felt stable. In the RECON group, both pain and swelling have subsided considerably. Stability, which was reasonably good in the beginning, improved even further. This agrees well with the reports that strengthening of the quadriceps muscles leads to an increase in joint stability [9,10]. All patients in all three groups felt great improvement in personal feeling of muscle strength.

Objective evaluation explained very well the subjective appraisal. The results obtained following statistical analysis of the data have shown that the muscle strength has greatly increased in all treated athletes.

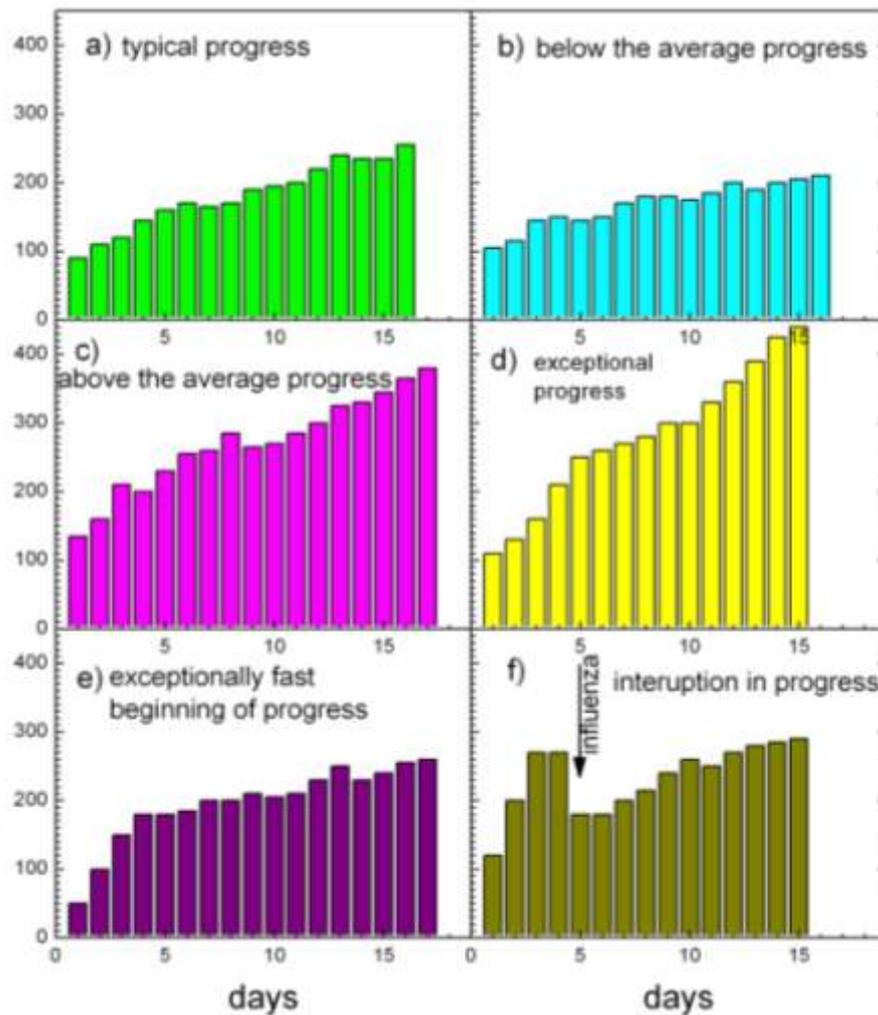


Figure 1

Figure 1 shows the increase in muscle strength with each day of rehabilitation, for several selected patients. Figures 1a and 1b represent athletes with typical and below the average progress, respectively. Figures 1c and 1d represent athletes that have shown above the average and an exceptional progress. In Figure 1e one can see a subject who has shown remarkably big improvement in the beginning of the rehabilitation, with a slower improvement in the later stages. Figure 1f represents an athlete that had to stop his rehabilitation for a week due to a heavy flu. He had trouble resuming his muscle strengthening in the same manner like he did before his illness, probably due to the weakness of the whole organism.

Regardless of the considerable individual variations, when we look at the mean values of the daily increase (shown in percents) we can see a continuous big improvement in all 3 groups (Figure 2). At the end of the rehabilitation, muscle strength has improved in average 144 % (SD=130) for the CHONDRO group, 150 % (SD=74) for the ACL group, and 141 % (SD=110) for the RECON group, comparing to the strength at the beginning of the rehabilitation. No significant difference in the

average improvements of muscle strength was found between male and female subjects. When we look the mean value of the muscle strength improvement for all examined subjects together, the increase in quadriceps and hamstring muscle strength of the impaired leg was on the average 149 % (SD=101), comparing to the strength at the beginning of the rehabilitation. In extreme cases the increase was up to 5 times (from 52 to 270 Nm). The most dramatic improvement occurred in athletes whose muscle strength was the weakest at the beginning of the treatment (either due to the severity of the injury, or long period of immobilization, or earlier lengthy, unsuccessful “classical” rehabilitation). For all athletes the progress was most pronounced during the first five days of isokinetic treatment, on the average 19% per day, followed by a steady growth of muscle strength. This rapid increase in muscle strength, especially in the early stages of isokinetic rehabilitation, is probably due to a more efficient motor unit (motor nerve plus it’s attached muscle fibers) utilization [11], as well as increased muscle contractile activity [12], rather than the muscle hypertrophy. The goal was to reach the strength of the healthy leg within 10 %, for which, on the average, 15 treatments were sufficient.

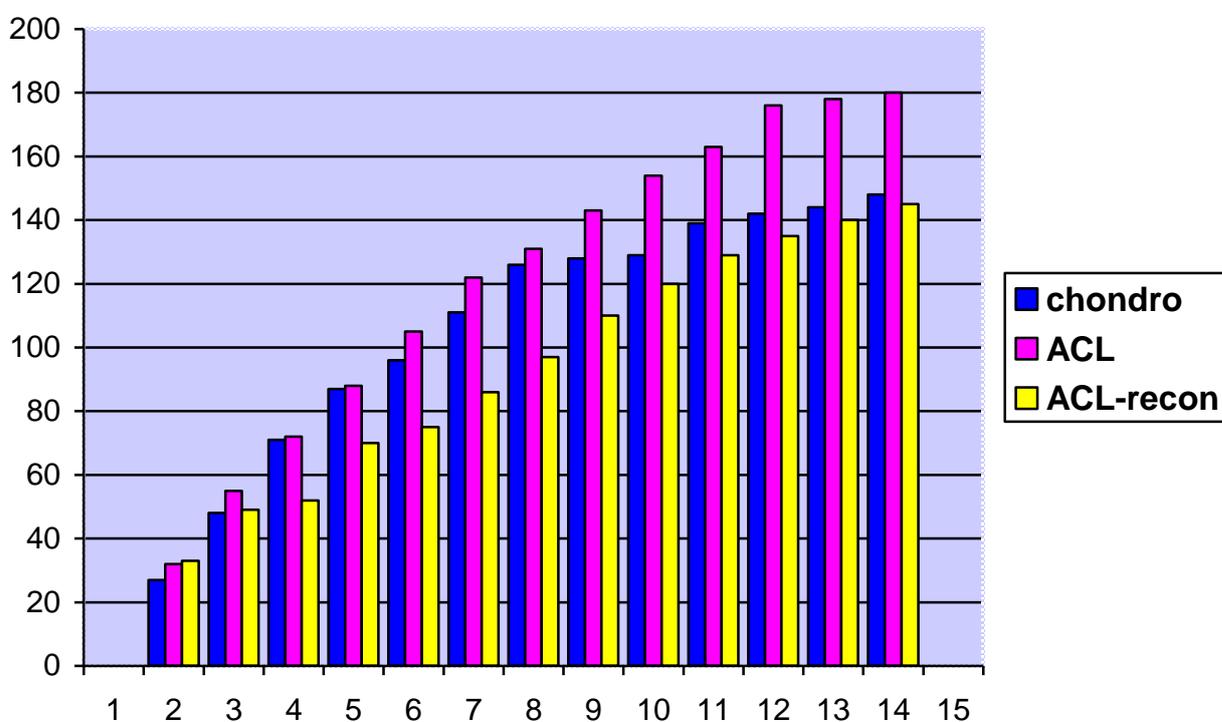


Figure 2

Detailed dynamic status was performed on the Cybex Orthotron diagnostic device prior and after the rehabilitation, for some patients. Such isometric testing can reliably quantify knee extension and flexion strength [13]. An example of such testing, belonging to a patient suffering from advanced chondromalacia, whose daily progress was shown in Figure 1e, is shown in Figure 3 and Table 2. Test1 refers to testing prior to the isokinetic rehabilitation and Test2 was taken after the rehabilitation was completed. The upper row of Figure 3 shows the difference in peak torque in Tests1 (dotted line) and Test2 (full line), for the right, injured leg (extension and flexion, respectively). In the lower row the same parameters are measured for healthy (left) leg. It is interesting to compare the increase of peak torque (Figure 3), which is the most important measure of the success of the rehabilitation, with the increase of the muscle strength (Figure 1e). It is clear that simple measuring of the muscle strength improvement, which we monitored daily during exercise on the Orthotron rehabilitation device itself, gives quite a good estimate of the final peak torque even without using additional and much more expensive tests, for which the Orthotron diagnostic device is needed. Uninvolved leg was also measured at the beginning of the rehabilitation. Namely, it was demonstrated that the healthy leg could be used as a reference guide for the outcome of the rehabilitation [14], regardless of whether this leg is the dominant or non-dominant one.

When we look at the low speed (60 deg/sec) test results (Table 2), the improvement in peak torque for injured leg was 477% in extension and 144% for flexion. Healthy leg was exercised only during the rest periods for impaired leg, and still it has improved 35 % in extension and 48% in flexion. In the high speed (180deg/sec) testing (Table 2), during Test1 injured (right) leg was not able to perform a given task since it couldn't have achieved a speed of 180 deg/sec. It is often the case that in the early stages of function restoration athletes are not able to exert tension at fast speeds [15]. After the rehabilitation (Test2) peak torque of the injured leg has surpassed the starting value of the healthy leg (137 Nm compared to the 125 Nm). Furthermore, the work per repetition and fatigue index have greatly improved in Test 2, so that in low speed testing work per repetition has improved from 18 to 194 Joules. All of these improvements were achieved in just 17 treatments, in 23 days.

The athletes from all the groups were able to return to their sports in very short time. CHONDRO group athletes were able to resume their sport activities within a month (typically after 3 weeks). Athletes who had an ACL reconstruction were able to return to active training within two months, starting at a somewhat slower pace, and were back in full competition on the average within three months. That is quite early since usually most athletes return to sports activities typically after six months [1,16,17]. However our result is not singular since there are examples of athletes returning to competitive sports in just six weeks after ACL reconstruction surgery [18]. Some of the athletes in the non-reconstructed ACL group were able to return to their regular sport activity within a month, while the others were fully prepared for reconstruction, with a prospect of much quicker and fuller recovery.

## CONCLUSION

Isokinetic rehabilitation has proven to be a very fast and effective method in treating knee injuries of the athletes. Both objective and subjective criteria have shown a significant increase in muscle strength and an alleviation of clinical symptoms. The improvement of muscle strength was on the average 149 % (SD=101), which is about 10% daily during 15 treatments. The greatest progress occurred during first five days, on the average 19% per day. The athletes were able to return to their sport activities in very short time. Furthermore, for all the athletes the balance between antagonistic muscle groups was established, which predisposed them for fewer injuries in the future.

### Figure Captions

Figure 1. Dynamics of the daily increase of muscle strength for several characteristic cases, showing individual variations of progress of particular athletes during the isokinetic rehabilitation

Figure 2. Dynamics of the daily improvements of muscle strength in comparison to the muscle strength at the beginning of the isokinetic rehabilitation. Each part of the table refer to daily increase, expressed in %, averaged for the patients from the whole CHONDRO, ACL or RECON groups, respectively

Figure 3. Knee extension/flexion test results. Torque (Newton-Meters) is given as a function of the range of motion (Degrees). Dotted lines refer to Test1, performed at the beginning of isokinetic rehabilitation and full lines refer to Test2, performed after the rehabilitation was completed. Both the involved (right) and uninvolved (left) legs are tested. Some important numerical values of these tests are given in Table 2

### Table Captions

Table 1. Subjective assessment of symptoms for ACL, RECON, and CHONDRO groups. Changes in symptoms after 15 isokinetic treatments

Table 2. Numerical values of the diagnostic testing. Knee extension/flexion measured at low and high speed for the involved (right) and uninvolved (left) leg

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Figs. 1, 2 & 3

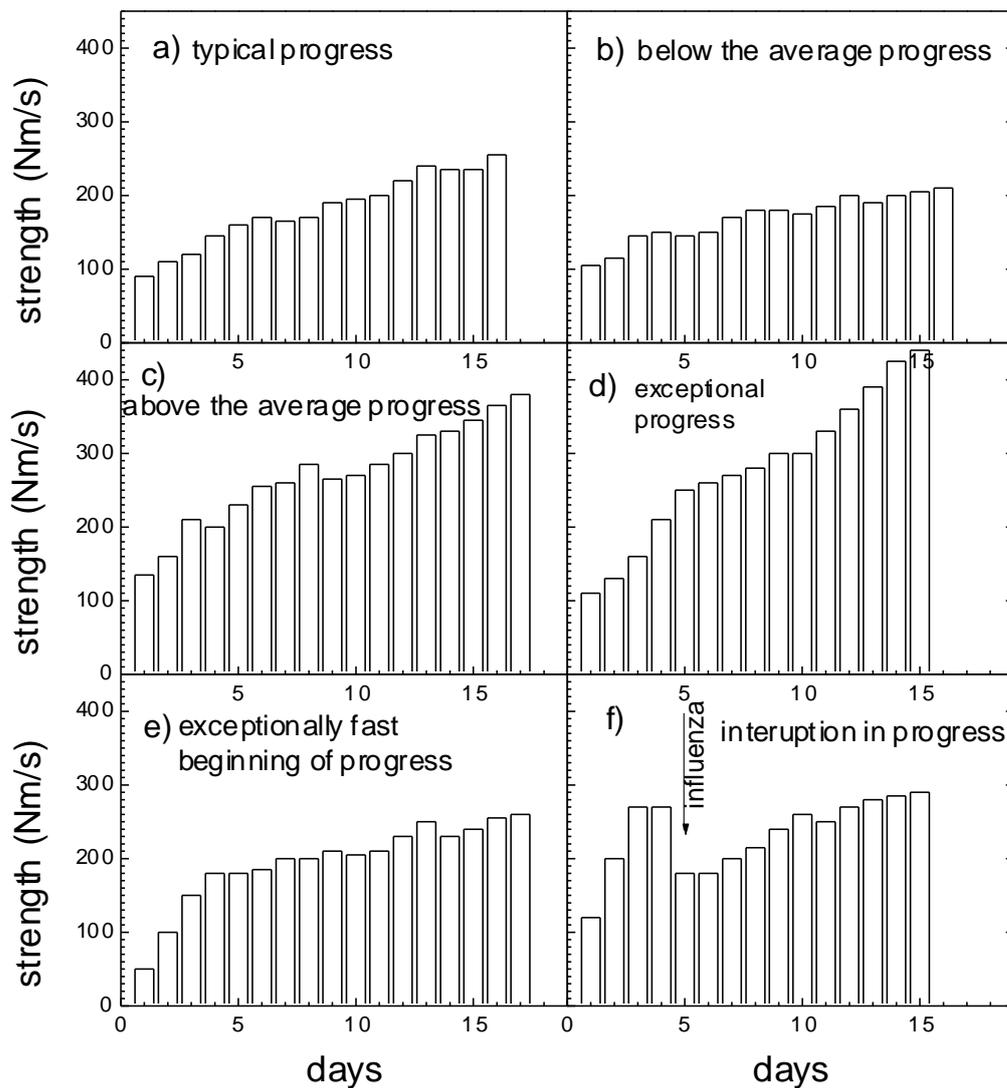


Figure 1

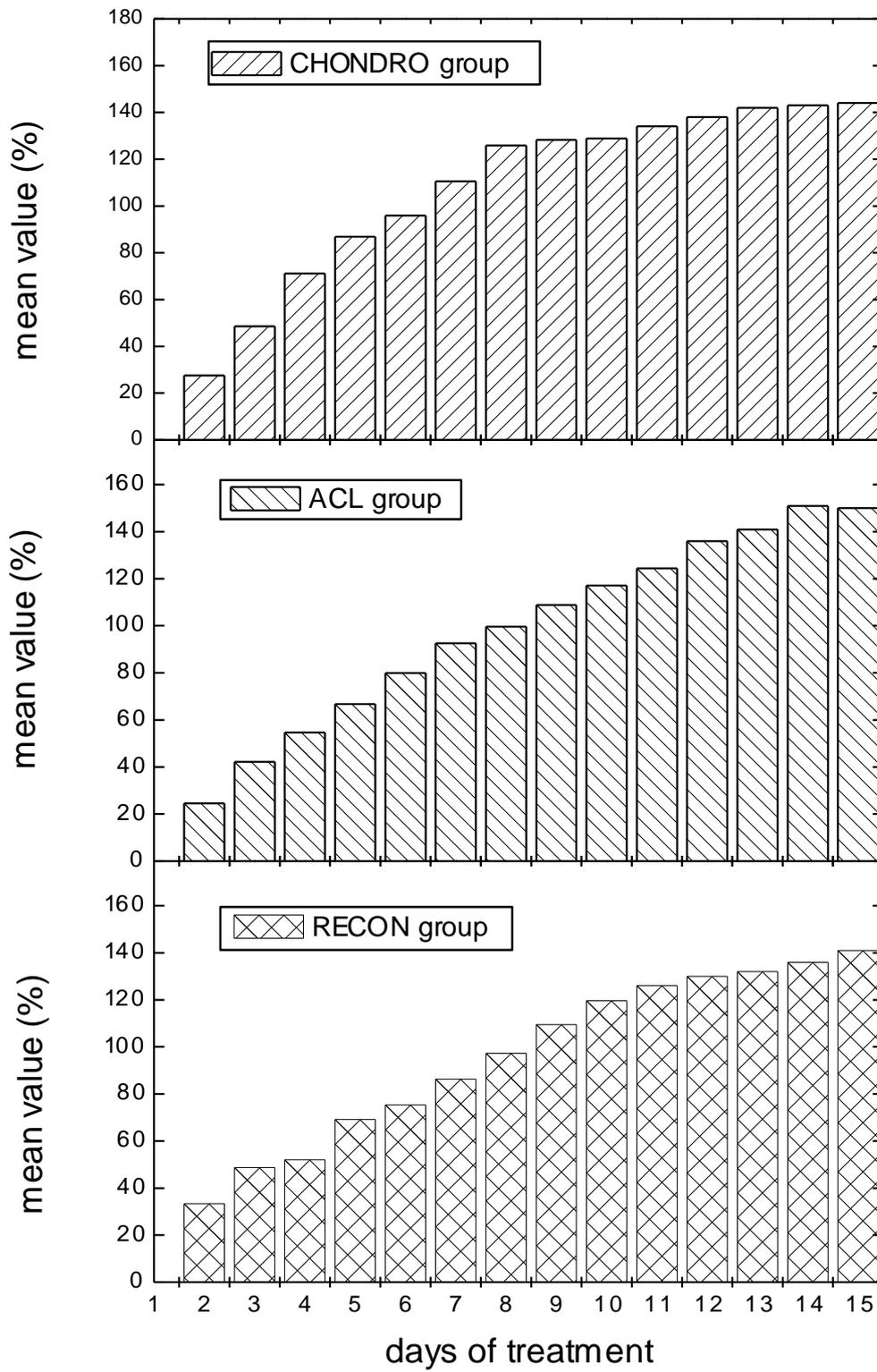
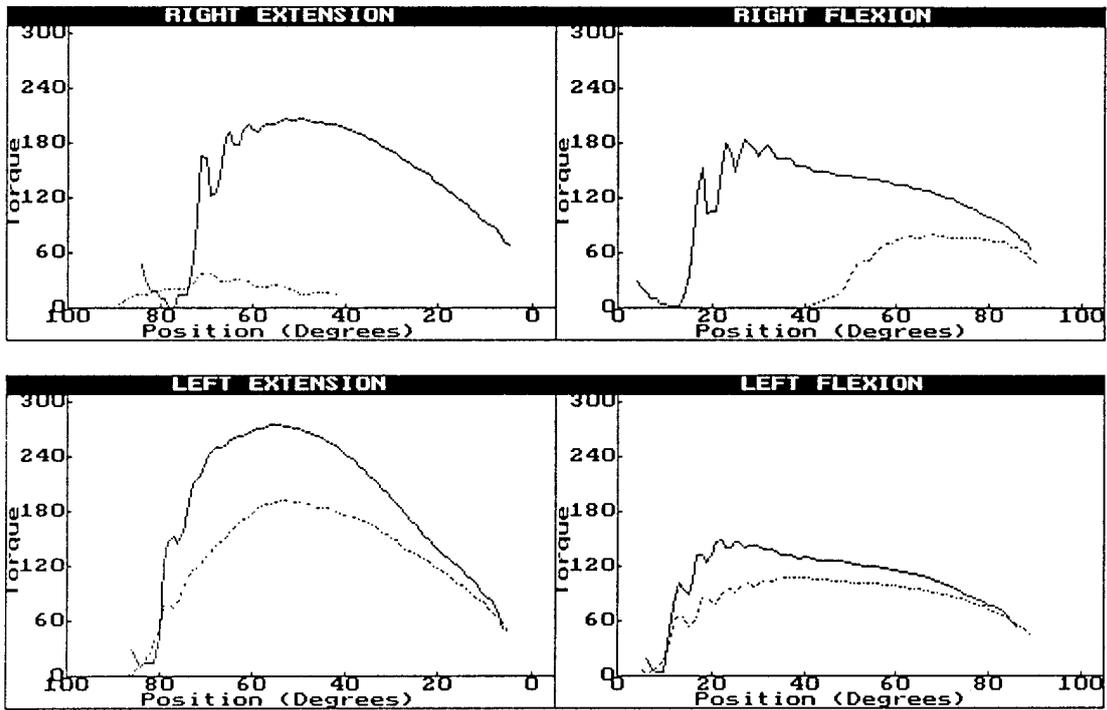


Figure 2



Comments :

Figure 3.

	EXTENSION			FLEXION		
	Test1	Test2	Change	Test1	Test2	Change
<b>LOW SPEED TEST RESULTS</b>						
Peak Torque (Newton-Meters)						
Right:	35	202	477 %	75	183	144 %
Left:	198	268	35 %	100	148	48 %
Work Per Repetition (Joules)						
Right:	18	194	978 %	46	152	230 %
Left:	188	251	34 %	113	141	25 %
Range of Motion (degrees)						
Right:	42	8	-34 °	91	88	-3 °
Left:	5	11	6 °	89	86	-3 °

<b>HIGH SPEED TEST RESULTS</b>						
Initial Peak Torque (Newton-Meters)						
Right:	0	137	0 %	0	137	0 %
Left:	125	172	38 %	87	103	18 %
Fatigue Index						
Right:	0	31	0 #	0	20	0 #
Left:	9	31	22 #	11	11	0 #
Total Work Done (Joules)						
Right:	0	1058	0 %	0	1056	0 %
Left:	1463	1793	23 %	948	1094	15 %

Table 1.