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The Gulhane Anterior Cruciate Ligament Rehabilitation Protocol Following Anterior Cruciate Ligament Reconstruction Surgery

Ön Çapraz Bağ Tamir Operasyonu Sonrası Gülhane Ön Çapraz Bağ Rehabilitasyon Protokolü

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Summary

Objective: A well-planned post-operative rehabilitation protocol is as important to the final outcome after anterior cruciate ligament (ACL) reconstruction as the surgery itself. The aim of the present study was to investigate whether a comprehensive approach to acute post-operative rehabilitation -the Gulhane ACL Rehabilitation Protocol- significantly affected post-operative outcome in ACL reconstruction cases over a 13- week period.
Materials and Methods: This prospective clinical trial included 58 male patients who underwent unilateral, arthroscopically assisted ACL reconstruction with a bone-patellar tendon-bone graft. A KAT (Kinesthetic Ability Trainer) 2000 balance system was used to quantify balance performance of the lower extremities 2 days before surgery and 13 weeks post-surgery. Additionally, isokinetic tests were performed at the same time points, and knee and thigh (5 cm, 10 cm, and 15 cm above the patella) circle measurements were obtained in both legs 1, 6, and 13 weeks post-surgery.
Results: The mean age of the patients was 26.63 years. In all, 31 patients had right and 27 patients had left ACL reconstruction. There was significant improvement in dynamic balance scores from pre-op to post-op ($p<0.05$). There were significant decreases in extensor peak torque scores at $60°s^{-1}$ and $180°s^{-1}$ in the operated legs ($p=0.042$ and $p=0.007$, respectively). There were significant decreases in the thigh circle 5 cm and 10 cm above the patella 6 weeks post-surgery and significant increases at 10 cm and 15 cm above the patella 13 weeks post-surgery in the operated legs ($p<0.016$).
Conclusion: The Gulhane ACL Rehabilitation Protocol could be used following ACL reconstruction. *Turk J Phys Med Rehab 2013;59:117-22.*
Key Words: Anterior cruciate ligament, rehabilitation, protocol

Özet

Amaç: İyi planlanmış bir rehabilitasyon protokolü ön çapraz bağ (ÖÇB) tamir operasyonunun kendisi kadar önemlidir. Bu çalışmanın amacı postoperatif akut dönemde uygulanan kapsamlı bir rehabilitasyonun -Gülhane Ön Çapraz Bağ Rehabilitasyon Protokolü- 13 haftalık süre sonunda ÖÇB tamiri uygulanmış bireylerde etkin olup olmadığını ortaya koymaktır.
Gereç ve Yöntem: Bu prospektif klinik çalışmaya unilateral artroskopik ACL tamir cerrahisi uygulanmış ve kemik-patellar tendon-kemik grefti uygulanmış 58 erkek hasta alındı. Hastaların alt ekstremite denge performansları cerrahiden 2 gün önce ve cerrahiden 13 hafta sonra KAT (Kinesthetic Ability Trainer) 2000 denge sistemi ile ölçüldü. Ayrıca aynı günlerde izokinetik test uygulandı. Buna ilaveten cerrahiden 1, 6 ve 13 hafta sonra hastaların diz ve uyluk çevresi (patella üzeri, patella üstü 5 cm, 10 cm ve 15 cm) ölçüldü.
Bulgular: Hastaların ortalama yaşı 26,63 idi. 31 hasta sağ, 27 hasta sol ÖÇB tamiri görmüş idi. Hastaların postoperatif dönem dinamik denge skoru cerrahi öncesine göre belirgin olarak gelişmiş idi ($p<0,05$). Opere olan bacakta ekstansör pik tork skorları $60°s^{-1}$ ve $180°s^{-1}$'lik açısal hızlarda belirgin olarak azalmış idi ($p=0,042$ ve $p=0,007$, sırasıyla). Cerrahi olan bacakta 6. haftada patella üstü 5 cm ve 10 cm'de uyluk çevresi belirgin olarak azalmış idi ($p<0,05$), ayrıca 13. haftada patella üstü 10 cm ve 15 cm'de uyluk çevresi belirgin olarak artmış idi ($p<0,05$).
Sonuç: Gülhane ön çapraz rehabilitasyon protokolü ÖÇB tamiri sonrası uygulanabilecek bir protokoldür. *Türk Fiz Tıp Rehab Derg 2012;59:117-22.*
Anahtar Kelimeler: Ön çapraz bağ, rehabilitasyon, protokol

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Introduction

The anterior cruciate ligament (ACL) is one of the most commonly injured structures of the knee joint and it plays a major role in maintaining normal knee function. Although surgical reconstruction often provides good results, there remains a great deal of room for improving knee function after this procedure. Physiotherapy-based rehabilitation programs are often used after ACL reconstruction surgery (1,2). A well-planned post-operative rehabilitation protocol is as important to the final outcome after ACL reconstruction as the surgery itself. This is reflected by the volume of publications generated each year related to various technical and treatment protocols employed for rehabilitation after ACL reconstruction. Different kinds of exercises and other neuromuscular training programs have been introduced to facilitate healing. Some training programs were designed to improve muscle function and increase neuromuscular control, while others seek to improve balance and proprioception at the joint (3,4).

In general, these programs are designed to maximize function by restoring range of motion (ROM), strength, and neuromuscular coordination, (5,6) and typically commence during the acute in-patient period. Early rehabilitation objectives include restoration of knee ROM, pain management, reduction of swelling, early ambulation, and initial recovery of muscle strength. A variety of treatment modalities have been used during this period, including cryotherapy, ROM exercises, continuous passive motion (CPM), strengthening exercises, electrical stimulation (ES), bracing, and gait education (7).

The effectiveness of comprehensive management protocols (including ES, EMG biofeedback, ROM and strength, CPM, pool-based exercises, treadmill and body weight supported treadmill systems, etc.) during the early post-operative period appears, at the current time, to be unsubstantiated by prospective clinical outcome studies. The aim of the present study was to investigate whether a comprehensive approach to acute post-operative rehabilitation -the Gulhane ACL Rehabilitation Protocol- significantly affected post-operative outcome in ACL reconstruction cases over a 13-week period.

Materials and Methods

This prospective clinical trial included 58 male patients who underwent elective unilateral, arthroscopically assisted ACL reconstruction and received a bone-patellar tendon-bone graft. Informed consent was provided by all the patients. All surgery was performed by the same experienced surgeon with a standard arthroscopic single-incision technique. Patients were excluded if they had previously undergone surgery on the reconstructed knee, or had sustained a concurrent injury to the contralateral ligament repair. The ACL reconstruction procedure performed was identical in all patients.

A KAT (Kinesthetic Ability Trainer) 2000 balance system was used to quantify balance performance of the lower extremities 2 days before surgery and 13 weeks post-surgery. Additionally, isokinetic tests were performed at the same time points. The isokinetic testing was performed with a Cybex 6000 computer-controlled isokinetic dynamometer. Conventional concentric and concentric continuous isokinetic tests were used. During the tests, the subjects continuously pushed the lever arm of the isokinetic device up and down through the entire ROM between 10° and 90° (0° = straight leg) while measuring knee flexor and extensor concentric peak torque, and total work at 60° s^{-1} and 180° s^{-1} of angular velocity. The patients did not have prior experience with the isokinetic dynamometer and were familiarized with the testing procedures by performing consecutive warm-up trials for each muscle group and speed, one of which was maximal contraction. During testing the patients performed 4 maximal continuous flexion-extensions for angular velocity of 60° s^{-1}, a 20-s rest was allowed between the concentric and eccentric tests, and between legs. The same researcher conducted all the tests, and the patients were verbally encouraged to exert maximum effort. Concentric peak torque and total work scores at 60° s^{-1} and 180° s^{-1} of angular velocity were evaluated. Additionally, knee and thigh circle measurements (5, 10, and 15 cm above the patella) were obtained in both legs 1, 6, and 13 weeks post-surgery.

The patients were transferred to Gulhane Military Medical Academy, Turkish Army Forces Rehabilitation Center 2 days after surgery. The Gulhane ACL Rehabilitation Protocol was used for all patients. Details of the Gulhane ACL Rehabilitation Protocol are shown in Table 1 and the materials essential for the protocol are shown in Table 2. This is the first study evaluating the efficacy of the protocol. SPSS v.13.0 for Windows was used for all statistical analyses. The paired samples t-test was used to compare pre-operative and post-rehabilitation scores. Repeated measures ANOVA followed by post-hoc analyses was used for multiple comparisons. A p value of less than 0.05 and 0.016 was considered significant.

Results

The clinical trial included 58 male patients with a mean age of 26.63 years (range: 19-34 years). In all, 31 patients underwent right and 27 patients underwent left ACL reconstruction. The median time from the index injury to ACL reconstruction was 15.84 weeks (range: 2.5-36 weeks).

Table 3 shows the balance and isokinetic test results. Dynamic balance improved significantly from pre-surgery (balance index: 1094.51±412) to post-surgery (balance index: 887.89±365) ($p<0.05$). A significant improvement in static balance was not observed ($p=0.195$). Post-surgery, there were significant decreases in extensor peak torque scores at 60° s^{-1} and 180° s^{-1} in the operated legs ($p=0.042$ and $p=0.007$, respectively), and isokinetic scores in the healthy legs significantly improved.

Table 4 and 5, and graphic 1 and 2 show the leg circle measurements for both legs 1, 6, and 13 weeks post-surgery. There were significant decreases in the thigh circle 5 cm and 10 cm above the patella 6 weeks post-surgery ($p=0.001$ and $p=0.003$, respectively) and significant increases at 10 cm and 15 cm above the patella 13 weeks post-surgery ($p=0.004$ and $p=0.001$, respectively) in the operated legs. Additionally, knee circle measurements decreased significantly in the operated legs and thigh circle measurements improved significantly in all the healthy legs.

Discussion

Comprehensive management is advocated during the early post-operative period (5). Both neuromuscular and strength training are included in the Gulhane ACL Rehabilitation Protocol in the form of isometric exercises, ES, EMG biofeedback, ROM and strength exercises, CPM, pool exercises, treadmill and body weight-supported treadmill system, etc. during the early post-operative period of ACL rupture repair.

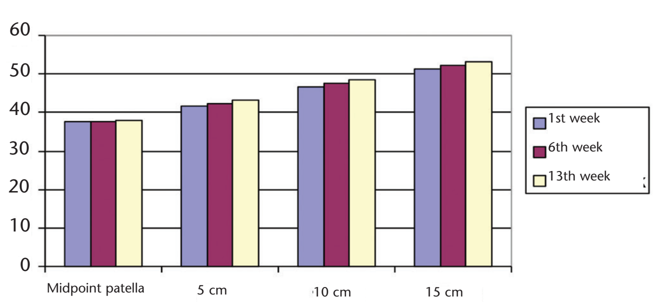
An important component of this protocol is strength training, and quadriceps and hamstring exercises, which have been traditionally prescribed after ACL reconstruction, and are justifiable in terms of muscle strengthening and/or atrophy prevention and tissue-healing physiology, however, the safety of performing quadriceps exercises during this early phase, when the graft is thought to be its weakest and susceptible to damage, is a matter of debate (8). Nonetheless, a number of published protocols advocate quadriceps and hamstring exercises, such as isometric exercises and straight leg raises (7,9,10).

In an effort to maximize patient effort to contract the quadriceps femoris and the hamstring muscle, and to enhance

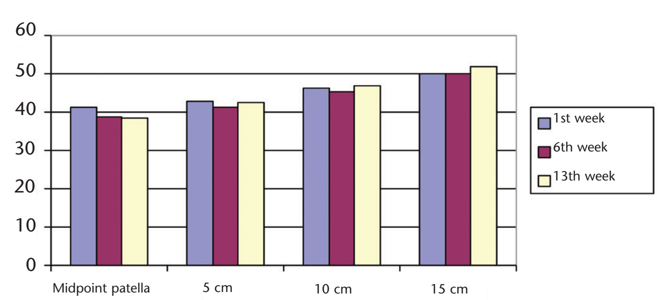
Table 1. Gulhane ACL Rehabilitation Protocol.

PROTOCOL	1. week	2. week	3. week	4. week	5. week	6. week	>6. week
Cold/Cry-cuff/elevation	+	+	+	-	-	-	-
Antibiotics and anti-inflammatory drugs	+	+	+	-	-	-	-
Continuous Passive Motion	+	+	+	+	-	-	-
Patellar Mobilization	+	+	+	+	-	-	-
Ankle movements	+	+	+	+	+	-	-
Straight Leg Raising	+	+	+	+	+	-	-
Hamstring Sets	+	+	+	+	+	+	+
İsometric Exercises	+	+	+	+	+	+	+
Electrical Stimulation	+	+	+	+	-	-	-
Electromyographic biofeedback	+	+	+	+	-	-	-
Body weight supported treadmill	-	+	+	+	-	-	-
Sliding on wall	-	+	+	+	-	-	-
Cycling with low resistance and speed	-	-	-	+	+	+	+
Hip thera exercises	-	+	+	+	+	-	-
CKC exercises while sitting	-	-	+	+	+	+	+
Pool	-	-	+	+	+	+	+
Releasing the brace	-	-	-	+	-	-	-
Stopping parachute	+	+	+	+	-	-	-
CKC exercises with cinetron	-	-	-	+	+	+	+
Leaving the brace	-	-	-	-	+	+	+
Stabilometer exercise and test with KAT 2000 stabilometry	-	-	-	-	+	+	13. week
Cybex test	-	-	-	-	-	-	13. week
Mild Trainings	-	-	-	-	-	-	13. week
Running (Tartan Pist)	-	-	-	-	-	-	13. week

CKC: Closed kinetic chain



Graphic 1. Healty leg circle mesurements at 1., 6. and 13. week.



Graphic 2. Operated leg circle mesurements at 1., 6. and 13. week.

Table 2. Essential materials for "Gulhane ACL Rehabilitation Protocol".

- Isokinetic knee extension machine
- Cold Pack, Cry-cuff, ice
- Continuous Passive Motion
- Pneumotic Compression Machine
- Sandbag
- Teraband
- Body weight supported treadmill
- Electrical stimulation
- EMG Biofeedback
- Treadmill
- KAT 2000 stabilometer
- Balance board
- Plates balls
- Bicycle
- Closed Kinetic Chain Machine
- Cybex
- Gym activities (Skatemaster, Stepmaster, Aktive-Resistive Hip and Knee exercising machines)

Table 3. Preop and post rehabilitation (at 13.week) stabilometric and isokinetic scores of the patients.

Stabilometric and isokinetic parameters	Preop scores	Post rehabilitation scores (at 13. week)
Static stabilometer	616.36	496.08
Dinamic stabilometer	1094.51	887.89*
Operated leg flexor PT at 60º/second	98.58	101.20
Operated leg flexor PT at 180º/second	70.96	75.94
Operated leg extensor PT at 60º/second	148.29	126.56**
Operated leg extensor PT at 180º/second	98.70	89.34*
Operated leg flexor TW at 60º/second	106.81	109.43
Operated leg flexor TW at 180º/second	74.96	81.67
Operated leg extensor TW at 60º/second	149.31	141.56
Operated leg extensor TW at 180º/second	106.68	103.39
Healthy leg flexor PT at 60º/second	107.53	120.13**
Healthy leg flexor PT at 180º/second	77.22	86.63**
Healthy leg extensor PT at 60º/second	191.13	198.93*
Healthy leg extensor PT at 180º/second	114.82	125.01*
Healthy leg flexor TW at 60º/second	119.05	135.58**
Healthy leg flexor TW at 180º/second	84.56	96.58**
Healthy leg extensor TW at 60º/second	192.62	208.24*
Healthy leg extensor TW at 180º/second	129.17	143.34**

*p<0.05, **p<0.001
PT: Peak Tork; TW:Total Work

the rate of force production, clinicians may choose to augment the exercise with a training method that facilitates higher levels of motor unit activity and more complete contractions during exercise. As force development is a result of both neural and muscular elements, the training method should facilitate both. One conventional choice is ES, which artificially activates the intramuscular branches of a motor nerve, causing muscle contraction. Another method that has been used to facilitate greater levels of muscle activity and more complete muscle contractions is EMG biofeedback. Biofeedback allows a patient to monitor voluntary contraction. Via surface electrodes, muscle activity in a targeted muscle is converted into a visual or audible feedback signal. The patient can use this feedback to augment diminished joint receptor feedback and monitor the quality of muscle contraction more effectively (i.e. the level of muscle activity) (11,12).

Normal everyday activities and sports-related activities require coordinated neuromuscular control and muscle strength sufficient to perform the required movements and activities. As such, the aim of rehabilitation programs for ACL injury is to normalize dynamic knee joint stability and muscle strength of the lower extremity. The present study shows that there was a significant improvement in dynamic balance and thigh circle measurements in the operated legs after employing the Gulhane ACL Rehabilitation Protocol, however, a significant improvement in static balance and extensor total work scores was not observed. The significant decreases we observed in extensor peak torque scores might be due to the bone-patellar tendon-bone graft technique be used for ACL reconstructions. Operated leg flexor peak torque and total work scores increased, but not in a statically significant manner. Nevertheless, increased flexor peak torque and total work scores in the operated legs indicate improvement in the ability of the hamstring muscle-an ACL agonist-to resist forces that strain the ACL, however, significantly increased dynamic balance scores and no change in static balance scores might have been due to the learning effect.

Previous investigations of the effect of neuromuscular training have examined patients with ACL deficiencies (4,7,13,14). They all report significantly improved knee function due to the implementation of rehabilitation programs. Gerber et al. (15) reported that a 12-week focused resistance training program resulted in greater increases in quadriceps femoris and gluteus maximus muscle volume and function than standard rehabilitation. Despite some limitations in these studies, they all showed significantly improved knee function with the

Table 4. Leg circle mesurements of both leg at 1., 6. and 13. week (Repeated measures Anova).

Leg Circle Measurements (cm) ± standard deviation	Postop 1. week	Postop 6. week	Postop 13. Week	p*
Healthy leg knee circle at patella midpoint	37.60±2.33	37.64±2.20	37.94±2.06	<0.001
Healthy leg thigh circle at 5 cm over patella	41.76±3.85	42.20±3.68	43.29±3.74	<0.001
Healthy leg thigh circle at 10 cm over patella	46.55±4.49	47.42±4.37	48.36±4.39	<0.001
Healthy leg thigh circle at 15 cm over patella	51.27±4.64	52.23±4.43	53.26±4.28	<0.001
Operated leg knee circle at patella midpoint	41.26±2.57	38.77±2.31	38.56±2.12	<0.001
Operated leg thigh circle at 5 cm over patella	42.85±3.73	41.31±3.65	42.45±3.80	<0.001
Operated leg thigh circle at 10 cm over patella	46.12±4.30	45.33±4.30	46.94±4.39	<0.001
Operated leg thigh circle at 15 cm over patella	50.05±4.35	50.08±4.52	51.75±4.51	<0.001

Table 5. Post hoc analyses (alfa–α- was calculated as 0.016 by Bonferroni correction).

Parameters	Postop 1.-6. weeks (p)	Postop 1.-13. weeks (p)	Postop 6.-13. weeks (p)
Healthy leg knee circle at patella midpoint	0.66	0.004*	0.002*
Healthy leg thigh circle at 5 cm over patella	0.02	0.001*	0.001*
Healthy leg thigh circle at 10 cm over patella	0.001*	0.001*	0.001*
Healthy leg thigh circle at 15 cm over patella	0.001*	0.001*	0.001*
Operated leg knee circle at patella midpoint	0.001*	0.001*	0.09
Operated leg thigh circle at 5 cm over patella	0.001*	0.10	0.001*
Operated leg thigh circle at 10 cm over patella	0.003*	0.004*	0.001*
Operated leg thigh circle at 15 cm over patella	0.91	0.001*	0.001*

use of rehabilitation programs that included neuromuscular exercises, as compared to only strength training exercises in patients with ACL deficiencies. Only a very limited number of controlled trials on the effects of neuromuscular training after ACL reconstruction have been reported (16,17). None of these studies provide baseline data (pre-operative data) and all have major limitations. A study by Liu-Ambrose et al. (16) provided limited data on the clinical effects of neuromuscular training, included only 5 patients in each group, and used the intervention for more than 6 months after surgery. They used peak torque time of the hamstring muscles as the main outcome measure, in addition to concentric and eccentric torque of the quadriceps femoris and hamstring muscles, the single-leg hop test, and the Lysholm scale score. The neuromuscular training group had a higher percentage of change in isokinetic torque than the strength-training group, but the differences between the groups in functional ability and patient-reported knee function (Lysholm scale score) were not significant. The study most likely had limited power to detect any differences in Lysholm scale scores or in other knee function test results. They concluded that neuromuscular training alone induced gains in isokinetic strength, and that restoring and increasing quadriceps femoris muscle strength is essential for maximizing the functional ability of the reconstructed knee joint.

Cooper et al. (17) studied the effect of a neuromuscular training program versus that of a traditional strength training program during a 6-week intervention (n=15 in each group). The patients joined the study 4-14 weeks after surgery. Power analysis was based on hop tests, which were included as an outcome measure only at follow-up, and the strength training group was significantly younger than the neuromuscular training group. The authors used 2 different graft types (hamstring and patellar tendon), there were more female patients in the strength training group than in the neuromuscular training group, and they only included patients that could walk without crutches, had full ROM, had no quadriceps femoris muscle lag, and had minimal joint effusion. The authors reported no strength measurements, and there were no differences between the two groups at follow-up regarding the hop tests. The strength-training group, however, had less swelling and improved walking and squatting, as compared to the neuromuscular training group. Cooper et al. (17) concluded that there appeared to be no benefit from neuromuscular training in the early post ACL reconstruction period. Similarly, Risberg reported no differences between the two rehabilitation groups 3 months post-surgery, but that a prolonged rehabilitation program (up to 6 months) seemed to result in some benefit for the neuromuscular training group (7).

The Gulhane ACL Rehabilitation Protocol is a more comprehensive neuromuscular training model than that reported by Risberg et al., Cooper et al., Fitzgerald, Ihara, Beard, and Lui-Ambrosso et al. (4,7,13,16-19). Optimal healing of the ACL is dependent on rehabilitation. Clinical investigation of patients after ACL surgery show that immobilization of the knee or limited motion without muscle activity can lead to poor functional recovery (20), whereas aggressive rehabilitation programs that include immediate walking and weight bearing were proven to be more effective than conservative rehabilitation (21).

CPM is occasionally used to increase knee ROM after ACL reconstruction and to promote rapid post-operative recovery, as well as in some other knee pathologies such as arthrosis

(21). Clinical trials have been conducted on the efficacy and effectiveness of CPM for regaining ROM after surgery, but results are contradictory (5). Pool exercise, and treadmill and body weight-supported treadmill systems are rarely used for ACL rehabilitation; (5,22) however, isolated effects of these treatments could not be detected in our study, thus, all of them were applied to all patients at the same time.

The primary limitation of the present study is the lack of a control group. As such, we were unable to objectively and prospectively compare the efficacy of the Gulhane ACL Rehabilitation Protocol. Moreover, not using the Lysholm scale for evaluations is another limitation of this study. Nevertheless, the results obtained appear to be valuable. Prospective randomized clinical trials are necessary to more definitively determine the efficacy of the Gulhane ACL Rehabilitation Protocol. In conclusion, the results of the present study indicate that the Gulhane ACL Rehabilitation Protocol could be used following ACL reconstruction.

Conflict of Interest
Authors reported no conflicts of interest.

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