Rehabilitation Issues in Women With Anterior Cruciate Ligament Deficiency

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SUMMARY
Anterior cruciate ligament (ACL) noncontact injuries occur more frequently in female than in male athletes. Many studies investigated possible predisposing factors such as joint laxity, hormonal influences, lower limb alignment, notch shape and dimension, ligament size, and neuromuscular control. To our knowledge, there are no ACL rehabilitation protocols especially studied for women. Our approach is a time-based and criterion-based progressive rehabilitation protocol, with preoperative, early, and late postoperative phases. Preinjury, preoperative, and postoperative biomechanical quantitative evaluations are used to monitor rehabilitation. Sport-specific epidemiologic observation of noncontact ACL injury mechanism can help in identifying movements and situations that pose a risk to the ACL. These data can be used to modify training and to prevent injuries and re-injuries. In our opinion, it is not necessary to have a gender-specific rehabilitation protocol, but it is necessary to have better sport-specific neuromuscular conditioning, which should include plyometrics, postural balance, and functional agility exercise protocols.

Key Words: Anterior cruciate ligament, Female, Knee, Rehabilitation

INTRODUCTION
The number of women participating in sports has increased markedly in recent years.¹ Female athletes have a higher rate of anterior cruciate ligament (ACL) injury, two to eight times greater than males.² The possible predisposing factors for ACL injuries in women have been described in several studies.³–⁶ These factors can be categorized as gender-specific, sport-specific, and condition-specific. Gender-specific risk factors are generalized joint laxity, increased hormonal influences, different lower limb alignment (hip-knee-ankle, wider pelvis, increased genu valgum, increased Q angle), decreased intercondylar notch width, and decreased ligament size. Sport-specific factors are equipment, field conditions, and type of sport (contact or noncontact). In the third group are training methods, experience, muscle strength, endurance, neuromuscular characteristics (slower muscle reaction time and different muscle recruitment order), and technique and ability in executing specific athletic tasks. Some of the condition-specific factors are also gender-specific, and they can be improved. However, nearly always, they are unlikely to match male athletes’ characteristics. Given the high number of ACL lesions and reconstructions in women athletes, there is a need to improve preoperative and postoperative rehabilitation protocols and to develop prevention strategies for both healthy and ACL-reconstructed athletes. To our knowledge, no gender-specific rehabilitation protocols are reported in the literature. In this article, we review the literature on major rehabilitation and prevention issues, and we present rehabilitation protocol guidelines, with a special emphasis on women athletes.

Preoperative Period
The interval between ACL injury and reconstruction must be used by the patient to obtain reduction of joint swelling and pain, regain complete range of joint movement (ROM), recover normal gait, and maintain muscle tone and neuromuscular control. The time needed to reach these targets is also a function of meniscal and other ligamentous lesions. Cryotherapy is a mainstay of treatment to reduce pain and swelling, together with rest. If necessary, the patient can take analgesics or non-steroidal anti-inflammatory drugs (NSAIDs), and can use a light compression sleeve, as

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needed. Active and passive joint motion, with knee flexion-extension and stretching of the hamstring to prevent flexion contracture, should be started immediately to obtain or maintain a range of motion equal to that of the contralateral knee. Isometric muscle contractions, especially straight leg raises (Fig. 1), should be performed in this phase. Electrical muscle stimulation (EMS) of the quadriceps and hamstring should start to slow progression of muscle atrophy. Crutches should be used to allow partial weight-bearing, which should be increased as tolerated. We do not allow weight-bearing in patients with multiple ligamentous lesions; moreover, a brace is prescribed. We also use a brace if patients with ACL lesion experience “giving-way” during activities of daily living. When the above targets are reached, a biomechanical evaluation is performed before surgery. If surgery is delayed, concentric and eccentric exercises are prescribed, both in open kinetic chain (OKC) and closed kinetic chain (CKC), first without (Fig. 2) and then with the use of resistance. Closed kinetic chain exercises and coactivation of quadriceps and gastrocnemius seems to be important for knee stability in patients with ACL deficiency. If there are no giving-way episodes, the patient must also start simple proprioceptive exercises with a wobble board. To decrease the time of reflex hamstring contraction latency (RHCL) and to improve dynamic knee stability, a program of CKC exercises combined with exercises on wobble boards seems to be more effective than a traditional muscle strengthening alone. The difficulty of the exercises can be increased by performing them with closed eyes.

Recently, a decision-making scheme was proposed for returning patients to high-level activity with nonoperative treatment after isolated ACL tears. The method is based on screening administered through some tests. These include single, triple, cross-over, and timed hop tests, quadriceps femoris maximum voluntary isometric strength tests, global rating of knee function, the Knee Outcome Survey Activities of Daily Living scales, and the number of giving-way episodes from the time of the ACL lesion to the tests. Before the tests, patients must have no pain or swelling, and full ROM. The long-term consequences on the knee joint of a high-level activity practice with an ACL deficiency have not been established until now. Recently, some investigations have been performed to study the stabilizing mechanism in joints with ACL deficiency. Biomechanical Evaluation

Quantitative evaluation of variables such as muscle strength, muscle activity, range of motion, joint stability, postural balance, and motion and gait patterns is important for the rehabilitation of athletes with ACL deficiency. We usually perform these tests on healthy athletes before and during the sport season, and we have therefore collected data of normal values for each athlete. These data are useful to identify rehabilitation targets if an athlete sustains an injury. The values obtained studying the healthy leg before the ACL lesion are more valid than data collected from the contralateral uninjured leg after the ACL lesion has occurred.

An ACL-deficient athlete is tested before surgery, and at the fourth and twelfth postoperative months. We evaluate concentric and eccentric isokinetic strength. Stabilometry is performed with a force platform. We test postural balance with a K.A.T. 2000 unstable platform (Kinesthetic Ability Trainer; Breg, Vista, CA). Electrical muscle activity, recruitment order, and reaction times are recorded with telemetric multichannel surface electromyography. Gait analysis is studied with force platforms. Motion analysis is performed with optoelectronic systems of cameras linked to computer.
Data from gait analysis, motion analysis, and electromyography are recorded and then analyzed in a synchronized way. The threshold to detect passive motion (TTDPM) to evaluate kinesthesia and the reproduction of passive position (RPP) to evaluate proprioception are static tests, performed while sitting, and thus not useful in monitoring rehabilitation of athletes who usually perform fast movements. Some patients, despite good results in biomechanical and clinical evaluation, are not subjectively satisfied after reconstruction. We believe that this is because of a lack of conditioning of the propriocceptive system, which cannot be tested properly and completely.

Physical Therapy Modalities

Cryotherapy (the therapeutic use of cold) is used to reduce pain and joint swelling, immediately after the ligament lesion and in the postoperative phase. There are several ways to obtain tissue cooling, from simple bags filled with crushed ice to continuous flow cold and compression devices. A swift reduction of pain12 and joint swelling13–15 is necessary, given their inhibitory role on quadriceps function. We prescribe cryotherapy after each physiotherapy session for 20 minutes, using an ice bag. If there is swelling, a cold compression unit is preferable. There is no agreement in literature about the effectiveness of cryotherapy. Some authors16–19 observed reduction in postoperative pain, length of hospital stay, and analgesics consumption. Other studies showed no improvement in hospital stay, knee girth, pain scale, analgesics consumption, ROM, and drainage from the surgical wound.20–22 Barber23 compared crushed ice with continuous flow cold therapy after ACL reconstruction. Continuous flow cryotherapy allows better knee flexion, lower analgesics consumption, and lower Visual Analog Scale (VAS) and Likert pain scores. Ohkoshi18 and Martin24 demonstrated lowering of intraarticular temperature using continuous flow cryotherapy. We doubt the efficacy of ice bags applied over surgical dressing, because there is no evidence of reduction in skin temperature. However, they can be used for their placebo effect. When using cryotherapy, it should be kept in mind that too tight a placement of the apparatus for too long may cause nerve injury.25,26

There has been investigation of EMS of the quadriceps after ACL reconstruction. Combined with isometric muscle contractions of the quadriceps, EMS improved rehabilitation significantly compared with isometric exercises alone.27 After identical surgical procedures and the same postoperative regimens, the women’s quadriceps muscles atrophied twice as much as the men’s.28 The authors also found that women benefited from electrical stimulation more than men. In men, there was no significant difference of atrophy, irrespective of the use of EMS. In women, there was highly significant reduction of the degree of atrophy after EMS.

These findings could result from the number of testosterone hormone receptors in female and male quadriceps muscles,29 (Sartok T, thesis, Stockholm 1983), and could be determined by whether these receptors were occupied by testosterone. The authors found that women have a much higher content of unoccupied testosterone receptors than men. Because testosterone initiates muscles anabolism after trauma or surgery, and because men have more testosterone in their blood than women, women atrophy more, and benefit more from EMS, than men. Lynn Snyder-Mackler30,31 found better recovery of quadriceps strength and of normal gait using high-intensity EMS after ACL reconstruction.

In the light of these results, the early initiation of EMS after ACL injury and after ACL reconstruction helps female athletes to maintain or regain muscle function more quickly. We introduce EMS from the third postoperative week, if wound healing is complete. In the postoperative period, EMS should not produce extension of the leg to avoid excessive strain of the graft. Therefore, we recommend administering EMS with the knee fully extended.

At present, portable EMS devices are popular among athletes. It is difficult to compare the various EMS devices and to establish the real effectiveness of this machine, because of the many variables and automatic modulation of the stimulation. We explain to the athlete that EMS is only a small part of the rehabilitation process, and that the device cannot substitute for active exercises. More studies are needed to investigate the efficacy of EMS. A randomized, double-blinded, controlled study published in 1999, matching exercises alone with EMS combined with exercises, reported no advantages in isometric and isokinetic muscle torque in the EMS group.52

Postoperative Treatment

We use a time-based and criterion-based rehabilitation protocol. The targets of the postoperative rehabilitation are to regain full ROM with hyperextension equal to the contralateral knee, to regain muscle strength, and to retrain the propriocceptive system, returning the athlete to the level of pre-injury activity. Histologic studies on ACL graft showed that ligamentization process takes from 133 to 3 years.34 Clinical studies on the safety of accelerated rehabilitation35,36 demonstrated that surgical technique (positioning, tensioning, fixation) and rehabilitation are more important than biologic characteristics of the graft. In the last few years, the rehabilitation programs used for ACL reconstruction performed with bone patellar tendon bone (BPTB) or with doubled semitendinosus and gracilis (STG) tendon tend to be the same, because of the improvement of fixation for STG.37–39

Researchers at the University of Vermont 40–48 studied in vivo, with a strain gauge placed on the anteromedial band of the ACL, the effects on the ligament of OKC and CKC exercises, stair climbing, and bicycling. They showed the safety profile of a variety of exercises at the various stages of the ROM, with or without resistance. Before these studies, clinical and biomechanical investigations suggested that CKC exercises were safer and more effective than OKC in ACL rehabilitation.49–53 A combination of OKC and CKC exercise is recommended.54 Another recent study comparing OKC and CKC reported no significant differences in functional improvement (level walking, stair ascent, stair descent) measured by gait analysis in the first 6 weeks after surgery.55 An
investigation performed among the members of the American Orthopedic Society for Sports Medicine showed wide variability in postoperative care (weight-bearing, braces, duration of physical therapy, return to activity). Guidelines and targets of our rehabilitation program are as follows: brace locked at 0° for 7 days; ROM 0° to 90° at the end of the first postoperative week (immediately after the removal of the brace), without using continuous passive motion (CPM); ROM 0° to 120° at the end of the second postoperative week; full weight-bearing and full ROM between the third and the fourth postoperative week; initiation of swimming and of exercising with resistance at the end of the fourth postoperative week; starting of generic proprioceptive exercises with wobble board at the end of the sixth postoperative week.

Proprioceptive Training

Eriksson asked in a recent editorial if it is possible to train proprioception; moreover, he stated a need to come to a consensus about definitions. Proprioception is the ability to know the position of a part of the body in space. Assessment of proprioception is performed with a modified isokinetic dynamometer to investigate the joint position sense of the patients, using the RPP test. The term proprioception is often used as synonymous with the proprioceptive system. This is composed of proprioception itself, kinesthesia, visual afferents, and vestibular afferents. This system provides the necessary information for the control of posture and locomotion. Kinesthesia, the ability to detect joint motion and direction, can also be evaluated with a modified isokinetic dynamometer to measure the threshold to detect passive motion (TTDPM) at slow angular speed. Reproduced passive positioning and TTDPM are passive and static tests. They cannot reproduce the high-speed, dynamic, and sudden movements that cause ACL lesions in athletes. In addition, training of proprioception and kinesthesia could perhaps improve sport specific movements, but not prevent joint injuries or protect the ACL graft. The test that could be employed for this endpoint is the measure of the reflex hamstring contraction latency (RHCL), because contraction of the hamstring limits anterior tibial displacement. The role of the hamstring is more important in women as a compensatory mechanism to reach better functional joint stability. Hamstring and quadriceps reaction times appear to be the best variables to evaluate subjective knee function. Recently, a Japanese study demonstrated that an ACL–hamstring reflex arc exists in humans. Despite all the above tests, there is no valid method to evaluate the proprioceptive system, and we can only test its components (kinesthesia by TTDPM, proprioception by RPP).

Another useful test is stabilometry (by force platform) to evaluate static balance. Dynamic balance and coordination training can be measured with an unstable platform. None of these tests is able to evaluate properly the whole of the proprioceptive system. The so-called generic proprioceptive training is usually performed with exercises on wobble boards, increasing difficulty by lowering the stability of the board, closing the eyes, or performing movements such as simulated steps upon the board (Fig. 3).

Proprioceptive training should probably be more properly named balance training, coordination training, or neuromuscular training. Proprioception should not be trained alone, but in concert with the whole system. After proprioceptive training, the results of the relevant quantitative evaluations did improve. There are only a few studies investigating the preventive role of this modality of training. Generic proprioceptive training programs are similar in the preoperative phase, after ACL reconstruction, and in the prevention setting. Because mechanoceptors are present in each joint structure, including meniscus, posterior cruciate, medial collateral, and lateral collateral ligaments, when facing a patient with an ACL-deficient knee, one should tackle all the components of the joint proprioceptive system. Proprioceptive exercises may be even more important in women, considering the gender-specific risk factors for ACL injuries (joint laxity, decreased ligament size, neuromuscular control with slower muscle reaction time, and different muscle recruitment order).

FIG. 3. Proprioceptive exercise with a board simulating a step to increase difficulty.
There is no agreement on the effectiveness of wobble board training. Caraffa reported a decreased ACL injury rate in a group of male soccer players trained with a balance board training program. A Swedish study on female soccer players did not detect a protective effect of a balance board training program. Other studies, of female handball players, female soccer players, and female basketball players, confirmed the advantages of a prevention program. Another preventive protocol, the Santa Monica or PEP (Prevent injury, Enhance Performance) Program, has been proposed. It consists of a 15-minute, five-part program (avoid vulnerable positions, increase flexibility, increase strengthening, perform plyometrics, and increase proprioception through agility exercises), to be performed at the beginning of practice at least twice a week.

Hewett et al. conducted a prospective study to evaluate the effect of neuromuscular training based on plyometric-jump exercises on the incidence of knee injury in female athletes. The results showed that in the trained female, there was a decreased incidence of knee injury. Heidt et al. described a reduction of lower leg injuries in female soccer players if preseason conditioning, including plyometric exercises, was performed.

Shelbourne and Davis reported that a program of functional sports agility starting from the fifth postoperative week does not influence stability. Therefore, proprioception should have the same relative weight of regaining full ROM and muscle strength in rehabilitation after sports injuries.

**Sport-Specific Training**

In our patients, we start generic proprioceptive training at the end of the sixth postoperative week after surgery, after a clinical evaluation; 15 days later, they begin running in a straight line. Ten weeks after surgery, patients can start running with change of direction, after a clinical evaluation. At the end of the third postoperative month, patients can start sport-specific training. Muscle training focuses on endurance (to delay muscle fatigue and consequent decline of proprioception) more than on pure strengthening exercises, together with proprioceptive training to prevent re-injuries. At the end of the fourth postoperative month, before allowing the athlete to return to play, clinical and biomechanical quantitative evaluations are performed to check stability, ROM, muscle strength and activity, postural balance, motion, and gait pattern.

In this period, athletes also start to perform unexpected movements in the field, simulating a game. To identify which of these movements are more frequent and dangerous for ACL injury, epidemiologic gender-, sport- and level-specific surveys are necessary, because there is little research that identifies the critical phases of each sport and the exact mechanisms of injury. Recent investigations to evaluate in vivo ACL strain during soccer high risk situations for ACL injury, such as rapid deceleration, have shown that during this movement, there is a high level of ACL strain. Biomechanical analysis of the identified at-risk movement can evaluate the degree of risk of given situations, thus allowing us to plan sport-specific exercises in the late phases of rehabilitation.

**CONCLUSIONS**

Sport-specific and role-specific epidemiologic surveys are necessary to ascertain the exact incidence and the dangerous movements and high-risk situations of ACL lesions in sport, especially in sports that pose high risks for female athletes, such as basketball or volleyball, to develop individualized exercise programs. Gender-specific training or rehabilitation programs are probably not necessary, but greater attention to neuromuscular factors is needed to prevent injury and to rehabilitate the athletes more effectively.

Biomechanical evaluation and clinical examination are important to monitor rehabilitation and to correlate research data with functional results. Quantitative measurements of muscle strength and endurance, ROM, joint stability, motion analysis, gait analysis, electrical muscle activity, and postural balance are useful to check an athlete’s neuromuscular characteristics and to improve performance, allowing rational and individualized sport-specific training and rehabilitation before or after an ACL injury.

Training of the proprioceptive system, performed by selective muscle-strengthening, balance, and sport-specific functional agility exercises, helps to enhance body control and acquire better conditioning in healthy subjects, and to obtain better rehabilitation in ACL-reconstructed female athletes. Moreover, this type of training should allow the player to react more quickly when there is an unexpected situation of poor balance, avoiding a possible joint injury (or re-injury after ACL reconstruction) or diminishing its consequences. These concepts have greater impact on women athletes, given women’s anatomic and neuromuscular risk factors for ACL injury.

**REFERENCES**


