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Design and Implementation of a Neuromuscular Training Program Following Anterior Cruciate Ligament Reconstruction

May Arna Risberg, PT, PhD[1]
Marianne Mørk, PT[2]
Hanne Krogstad Jenssen, PT[2]
Inger Holm, PT, PhD[3]

Neuromuscular training programs are increasingly integrated into clinical practice for lower extremity rehabilitation. A few rehabilitation programs have been evaluated for patients with anterior cruciate ligament (ACL) deficiency and for injury prevention, but there is limited scientific evidence of the effect of neuromuscular training following ACL reconstruction. Therefore, a neuromuscular training program was developed for patients after ACL reconstruction. The objective of the neuromuscular training was to improve the ability to generate a fast and optimal muscle firing pattern, to increase dynamic joint stability, and to relearn movement patterns and skills necessary during activities of daily living and sports activities. The main areas considered when designing the postoperative rehabilitation program after ACL reconstruction were: ACL graft healing and ACL strain values during exercises, proprioception and neuromuscular control, and clinical studies on the effect of neuromuscular training programs. The rehabilitation program consists of balance exercises, dynamic joint stability exercises, jump training/plyometric exercises, agility drills, and sport-specific exercise. The patients exercise 3 times a week for 6 months. The scientific and clinical evidence for the rehabilitation program are described and the main exercises in the program are outlined.
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Neuromuscular training has become integrated into clinical practice for both upper and lower extremity rehabilitation.[43,45] According to the definition of neuromuscular control, neuromuscular training could be defined as training enhancing unconscious motor responses by stimulating both afferent signals and central mechanisms responsible for dynamic joint control. The biomechanics of the knee are altered after anterior cruciate ligament (ACL) injury, but neuromuscular training may enhance control of abnormal joint translation during functional activities by inducing compensatory alterations in muscle activity patterns.

The objectives of neuromuscular training are to improve the nervous system's ability to generate a fast and optimal muscle firing pattern, to increase dynamic joint stability, to decrease joint forces, and to relearn movement patterns and skills. The exercises are designed to induce compensatory changes in muscle activation patterns and facilitate dynamic joint stability in patients with ACL injury. The goal is to achieve a state of "readiness" of muscles to respond to joint forces resulting in enhanced motor control.[67,70]

Several studies have evaluated outcome after ACL reconstruction,[2,6,23–25,28,30,32,40,41,47,54,74,75] but very few have evaluated the effect of different rehabilitation programs following ACL surgery.[12,76] Only a few studies have evaluated the effect of neuromuscular training, and most of those have focused on either subjects with ACL-deficient knees[8,27,39] or the effect of training on injury prevention.[18,36,37,71]

[1] Center for Clinical Research, Ullevaal University Hospital, Oslo, Norway.
[2] Department for Physical and Rehabilitation Medicine, Ullevaal University Hospital, Oslo, Norway.
[3] Biomechanics Laboratory, National Hospital Orthopaedic Center, University of Oslo, Norway.
Send correspondence to May Arna Risberg, Center for Clinical Research, Ullevaal University Hospital, 0407, Oslo, Norway. E-mail: mrisberg@enitel.no

Ihara and Nakayama[39] were the first to evaluate neuromuscular training consisting of balance exercise and perturbation training. Four subjects with ACL-deficient knees who had "giving way" symptoms went through a training program 4 times per week for 3 months. The patients were compared to a control group of 5 subjects. Significant improvement was found in peak torque time and rising torque value of the hamstrings in the training group compared to the control group. These researchers concluded that the training program apparently had the potential to shorten the time lag of muscular reaction.

Beard et al[8] studied 50 subjects with ACL-deficient knees randomly assigned to a proprioceptive training program or a traditional strength training program. The proprioceptive program included balance, dynamic joint stability, and perturbation training. Both programs were performed using circuit training. Warm-up and stretching preceded and followed the exercise circuit. The neuromuscular training program consisted of 1 hour of intensive training 2 times per week for 12 weeks and a home exercise program. The exercises were performed in weight-bearing positions. The traditional strength training program included the same number of training sessions, but the exercises were mostly performed in non–weight-bearing positions with the objective of increasing the strength of lower limb muscles. No attempt was made to increase speed of contraction. An indirect measurement of proprioception, the reflex hamstring contraction latency, was used in addition to Lysholm functional score and knee joint laxity. The study demonstrated a significant improvement in the neuromuscular training group for mean hamstring contraction latency and for Lysholm functional score compared to the traditional strength training group.

Fitzgerald et al[27] studied 26 patients with acute ACL rupture. The patients were randomly assigned to a standard rehabilitation program with or without perturbation training exercises. Adding the perturbation training to the standard rehabilitation program reduced the risk of continued episodes of giving way of the knee during sports activities and maintained the knee function at the 6-month follow-up compared to the patients in the standard rehabilitation program.

Hewett et al[37] developed a jump/plyometric training program to evaluate the effect of the training program on landing mechanics and lower extremity strength in female athletes. The program was designed to decrease landing forces by teaching neuromuscular control during landing and to increase vertical jump height. The same group did a prospective study where a jump training program was included to reduce the risk of knee injuries in athletes.[36] Their study showed that the incidence of knee injuries decreased significantly in female athletes compared to male athletes.[36]

To our knowledge, no studies have been published on the effect of neuromuscular training after ACL *reconstruction*. Current research on the effect of neuromuscular training, knowledge about graft healing after ACL reconstruction (bone-patellar tendon-bone graft), research on proprioception and neuromuscular control, and our clinical experience with patients who have ACL reconstruction were considered during the design of our rehabilitation program.[53]

EVIDENCE GUIDING THE DEVELOPMENT OF THE NEUROMUSCULAR REHABILITATION PROGRAM FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

The main topics for developing the neuromuscular rehabilitation program following ACL reconstruction involve: (1) graft healing response and ACL strain values during exercises, (2) function of ligament mechanoreceptors, and (3) neuromuscular control. However, evidence in this field is limited and inconclusive, and there are many conflicting and controversial areas. Following our discussion of the 3 main topics, the different types of training included in the rehabilitation program are described, and the main exercises for each type of training are outlined. The entire rehabilitation program is described in the Appendix.

Graft Healing Response and Anterior Cruciate Ligament Strain Values During Exercises

The goal of the rehabilitation program after ACL reconstruction is to restore joint motion and lower limb performance, and regain muscle strength to the preinjury level *without* producing excessive graft strain during healing of the graft. In contrast to development of a rehabilitation program for patients with ACL deficiency, the graft healing responses and ACL strain values during exercises have to be considered in the design of a rehabilitation program for patients after ACL reconstruction.

Experimental studies of healing of the ACL graft have demonstrated that the graft requires a long time to revascularize and heal.[1,35] Therefore, the ACL graft has been considered vulnerable during the first weeks after ACL reconstruction.[16,49] According to results from animal studies, strenuous rehabilitation exercises should not be included immediately after surgery, and aggressive rehabilitation programs should not start immediately after ACL reconstruction.[16,49] However, experience from use of graft materials with biomechanical properties similar to the normal ACL,[58] adequate fixation strength,[51] and clinical evidence of no increased laxity after aggressive rehabilitation programs[22,63,64] have led many to recommend aggressive rehabilitation programs. But evidence for the remodeling process in the human ACL graft is unknown. A previous study by our group demonstrated that linear stiffness properties and ultimate failure load of a human ACL graft 8 months after reconstruction were about 90% of the values for the uninjured knee.[13] That case study indicated that strenuous exercises could at least be introduced 8 months after ACL reconstruction.

The effect of different rehabilitation exercises on the healing response of an ACL graft is still unclear. However, different strain values of the ACL have been reported for different rehabilitation exercises.[10,11,29] Beynnon et al[11] studied the effect of weight-bearing and non–weight-bearing exercises on strain behavior of the normal ACL in human subjects while performing squatting and active flexion-extension of the leg. They showed that maximum ACL strain values obtained during squatting did not differ from those obtained during active flexion-extension. Furthermore, the strain values during squatting were unaffected by the application of elastic resistance during the exercise. These data indicate that non–weight-bearing and weight-bearing exercises produce about the same amount of strain, suggesting that non–weight-bearing exercises can be introduced as early as weight-bearing exercises after ACL reconstruction. However, weight-bearing exercises have been shown to produce a more favorable functional outcome and are usually recommended.[17]

Beynnon et al[12] evaluated the effect of an aggressive versus a nonaggressive rehabilitation program.[68] These rehabilitation programs were designed based on their previous studies of ACL strain values for different rehabilitation exercises. The program included the same exercises, but one group started the exercises at week 2 and the other group at week 6. Preliminary results indicated that prescribing exercises early after ACL reconstruction (accelerated rehabilitation program) may increase knee joint laxity, but no significant differences were found regarding patient perception of knee function. Other nonrandomized clinical trials on aggressive rehabilitation programs have concluded that these programs are effective and do not produce increased knee joint laxity.[63] Based on these conflicting results, more evidence from clinical randomized trials is needed.

Function of Ligament Mechanoreceptors

Anatomical studies have demonstrated the existence of mechanoreceptors in the human ACL.[60,61] Pitman et al[52] used arthroscopic procedures to provide direct evidence for the presence of active proprioceptive receptors within the intact ACL of the human knee. Animal studies have shown that these particular receptors are specific for detecting joint position as well as for initiating reflex muscle contraction about the knee.[31]

The decrease of proprioceptive sense in the ACL-deficient knee has been well examined.[4,15,20,48] Barrack et al[4] demonstrated a significant decrease in kinesthesia of 37% in patients after complete ACL rupture and concluded that patients who sustained a complete ACL tear may experience a decline in proprioceptive function contributing to the progressive instability and disability often observed after this injury. Moreover, Corrigan et al[20] and MacDonald et al[48] reported a significant increase of 39% and 21%, respectively, in the threshold to detection of passive motion in ACL-deficient knees. Beynnon et al[14] also reported a significant decrease in kinesthetic awareness in ACL-deficient knees.

Different results of the effect of ACL surgery on proprioception have been reported.[5,44,46,48] MacDonald et al[48] studied proprioception in subjects with ACL reconstruction and found that proprioception did not improve after reconstruction when compared to subjects with ACL-deficient knees. Barrett[5] studied joint position sense in subjects with ACL-deficient, ACL-reconstructed, and normal knees and reported significantly poorer joint position sense in ACL-reconstructed knees compared to normal knees, but significant improvement compared to ACL-deficient knees. Lephart et al[44] examined patients with ACL reconstruction 11 to 26 months after surgery and observed a significant increase in threshold to detection of passive motion at near extension in reconstructed knees. These results were confirmed by a recent study by Fischer-Rasmussen and Jensen,[26] who found decreased proprioception of the knee joint in people with both ACL-deficient and ACL-reconstructed knees. Fremerey et al[30] recently published a prospective longitudinal study evaluating proprioception (joint position sense) after ACL reconstruction and found impaired proprioception 3 months after surgery compared with preoperative findings. Six months postoperatively, the proprioception was restored to near full extension and flexion, whereas proprioception in the midrange position was still impaired. A strong correlation ($r = 0.76$) was found between proprioception and patient satisfaction.

Results from studies evaluating proprioceptive deficits after ACL reconstruction vary. This can partly be explained by the recent evidence of the timing of reinnervation of the graft (postoperatively) and the wide variety of tests used to evaluate proprioception. It has been demonstrated that free patellar tendon grafts in dogs are partly reinnervated 6 months after surgery.[3] Although no innervation was observed in the ACL grafts immediately after surgery, histological examination of the graft tissue 6 months after surgery revealed that all 6 grafts contained neural elements with equal numbers of mechanoreceptors and free nerve endings. Other animal studies have confirmed that mechanoreceptors regenerate gradually after ACL reconstruction.[65] Human studies have confirmed the results of these animal studies. Ochi et al[50] found that sensory reinnervation in the reconstructed ACL was closely related to the function of the knee.

Barrett[5] identified the recovery of proprioception as the most important factor for a functionally good result after ACL reconstruction. Co et al[19] reported a significant difference in proprioception between ACL-reconstructed and normal knees but concluded that the results were not clinically significant because the reconstructed and the normal knees both performed better than the normal control knees. They suggested that training could restore much of the loss in proprioception because the subjects with reconstruction went through a rehabilitation program for both knees.

The contribution of joint receptors to kinesthesia and position sense has been a matter of debate, and the topic has frequently been reviewed.[42] Evidence exists for a significant influence of muscle afferents and ligamentous joint afferents on position and movement sense. There are also reasons to believe that there might be considerable variation among different individuals in the use of joint afferent information,[4] and there might be inherent differences among subjects. Possible genetic differences among different individuals have been studied.[59] This research has included an assessment of the subjects' abilities and enduring characteristics or traits.[59] The "single subject" designs differ from the experimental approach in which differences among individuals are ignored in order to concentrate on the average performances of larger groups of subjects. More research on individual differences would contribute to the knowledge of the effect of rehabilitation and training programs.

Neuromuscular Control

Simply restoring mechanical restraints is not enough for a functional recovery of the knee[34,62,66] because the coordinated neuromuscular controlling mechanism required during daily living and sport-specific activities would be neglected. Rehabilitation programs cannot alter a mechanical knee joint instability but may affect the neuromuscular control and the dynamic joint stability. A lag in the neuromuscular reaction time can result in dynamic joint instability with recurrent episodes of joint subluxation and deterioration. Therefore, both mechanical stability and neuromuscular control are probably important for long-term functional outcome, and both aspects must be considered in the design of a neuromuscular rehabilitation program after ACL reconstruction.

Injury to the ACL has been shown to result in altered somatosensory information that may adversely affect neuromuscular control.[55] Several studies have reported differences in neuromuscular performance in ACL-deficient and reconstructed knees.[7,73] Beard at al[7] studied the reflex hamstring contraction latency in subjects with reconstruction preoperatively and then postoperatively at 3 and 6 months. There was a significant improvement in the neuromuscular control following reconstruction of the ACL, but only for those with poor proprioception prior to surgery. Huston and Wojtys[38] evaluated possible predisposing neuromuscular factors for ACL injuries in athletes of both sexes compared to nonathletes. Female athletes required significantly more time to generate maximum hamstring muscle torque than male athletes. A different muscle recruitment order was found in a limited subgroup of female athletes. Furthermore, significant differences in the recruitment order of the lower extremity muscles were observed between males and females. In a recent study, Wojtys and Huston[72] found significantly impaired neuromuscular function 12 to 18 months after ACL reconstruction, although 80% of the subjects believed that they had regained their preoperative functional level. Quadriceps and hamstring muscle reaction time were identified as the best indicators of subjective knee function.

Some patients with ACL injuries compensated well for their loss of the knee stabilizer (copers), but others did not (noncopers).[56,57] Rudolph et al[56] identified movement strategies in copers and noncopers and found that copers had movement strategies similar to those of uninjured subjects. Copers stabilized their knee with a greater contribution from the ankle plantar flexors, indicating that the significance of gastrocnemius muscles as contributors to dynamic knee joint stability should be emphasized during the rehabilitation program. The noncopers showed a reduction in range of motion and external knee flexion moment, but no evidence of quadriceps avoidance gait was found. Neither copers nor noncopers had any reduction in quadriceps activation.

THE NEUROMUSCULAR REHABILITATION PROGRAM

The rehabilitation program consists of balance exercises, dynamic joint stability exercises, plyometric exercises, agility drills, and sport-specific exercises. The program is divided into 6 phases of 3 to 5 weeks each (Appendix). Specific exercises are described for each week in the rehabilitation protocol. Most patients in our rehabilitation program are ready to progress at the speed given in the protocol, but not all patients will be able to progress at the same pace. Patients who sustain pain, swelling, or range of motion deficits undergo treatments until these impairments are resolved. Criteria used to determine readiness for progression include no increased pain or

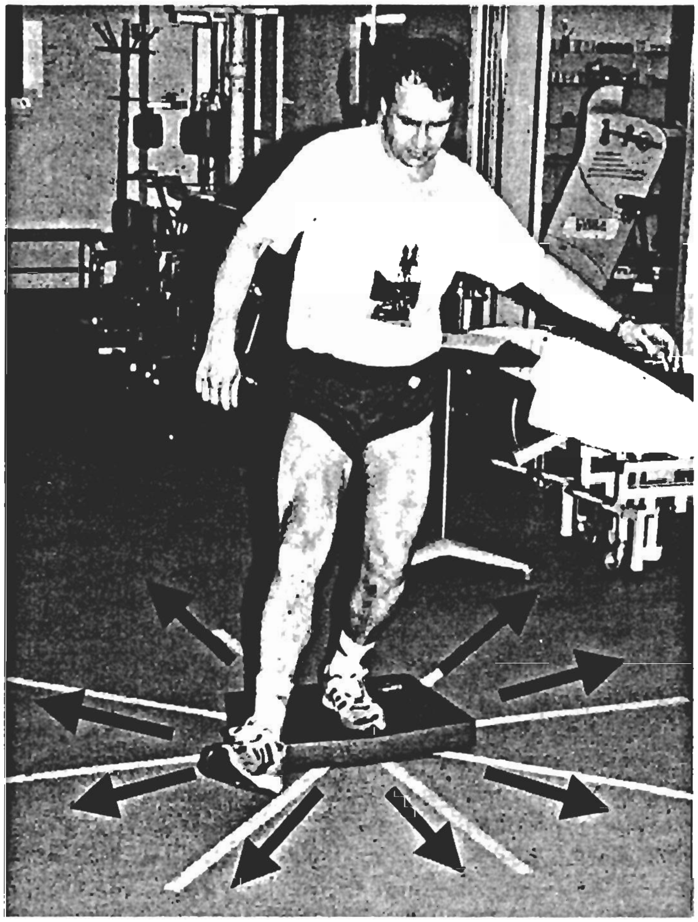

FIGURE 1. Dynamic joint stability exercise using the "star."

swelling and the ability to maintain postural control of the position before movements are superimposed on the position. The patients first need to be aware of the position of the body in space before tolerating movements into space or reacting to a perturbation. When the patient is able to successfully perform the exercise on a flat, even surface, the exercise is made more challenging by changing the surface to balance mats, a wobble board, or a trampoline. Furthermore, sensory feedback is challenged by excluding vision, challenging the vestibular system through changing the base of support, and using distractions, such as a

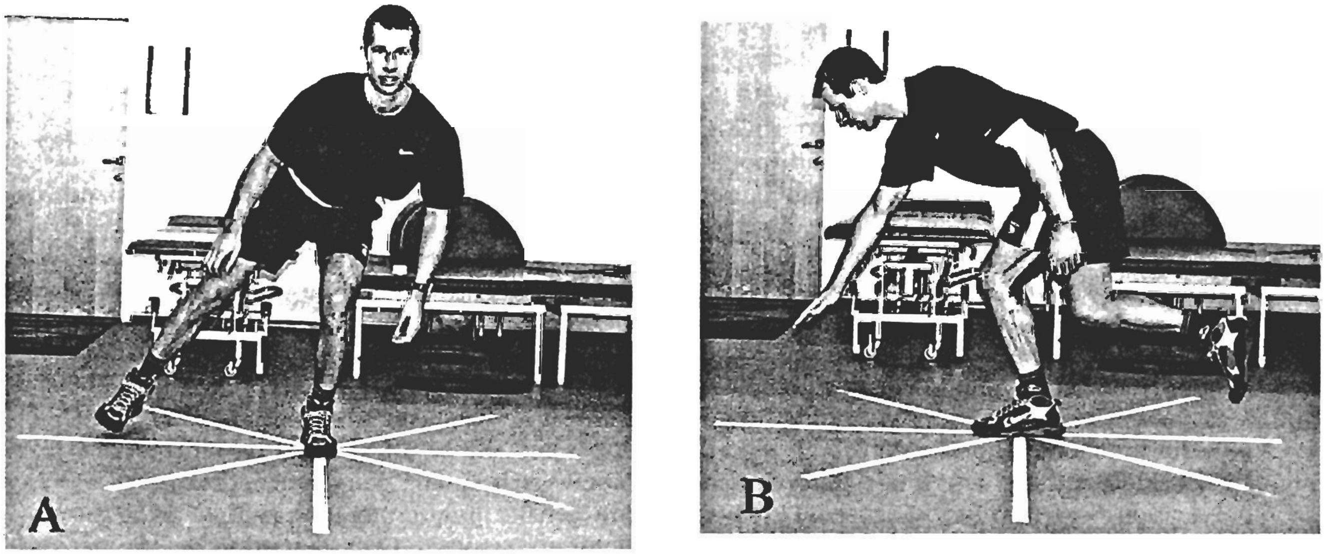

FIGURE 2. (A) Balance reach leg. (B) Balance reach arm.

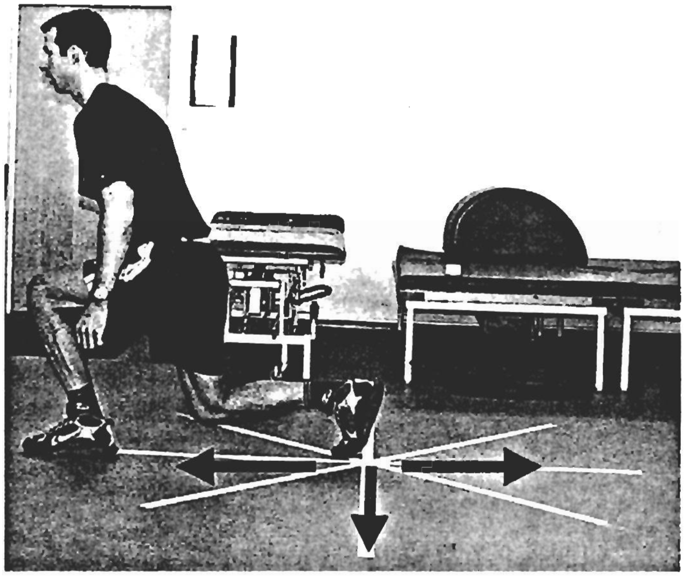

FIGURE 3. Lunge exercise using the "star."

ball or sudden and unexpected change in movement directions. No knee braces are used following the knee surgery or during the rehabilitation program.

FIGURE 4. Step-up exercise on a wobble board.

Balance Training

Berg[9] described "balance" as the ability to maintain a position, the ability to voluntarily move, and the ability to react to a perturbation. All of these components are important for neuromuscular control. To distinguish between balance training, dynamic joint stability training, and perturbation training, balance training is used in this rehabilitation program for exercises pertaining to the first part of the definition (the ability to maintain a position). Accordingly, "balance training" exercises focus on awareness of posture and the position of the body in space with the aim of maintaining equilibrium without changing the base of support. Balance exercises include the double and single leg stance on even, flat surfaces, on a balance mat, on a wobble board, and on a trampoline.

Three sensory systems contribute to the maintenance of balance: the visual, the vestibular, and the somatosensory (ie, proprioceptive). Any of these systems may dominate, and all are context dependent.[21] Balance seems to affect both the injured leg and the uninjured leg in patients with ACL deficiency. Zatterstrom et al[77] found significant disturbance of balance in both the injured leg and the uninjured leg after ACL rupture compared with a reference group of normal subjects. Values of the uninjured leg were normalized after 3 months of training, but the injured leg still showed increased body sway. Normal balance parameters on the injured side were found at examination after 12 months and persisted up to 36 months posttraining.

Dynamic Joint Stability Training

Exercises aimed at the second part of Berg's definition,[9] the ability to voluntarily move, address dy-

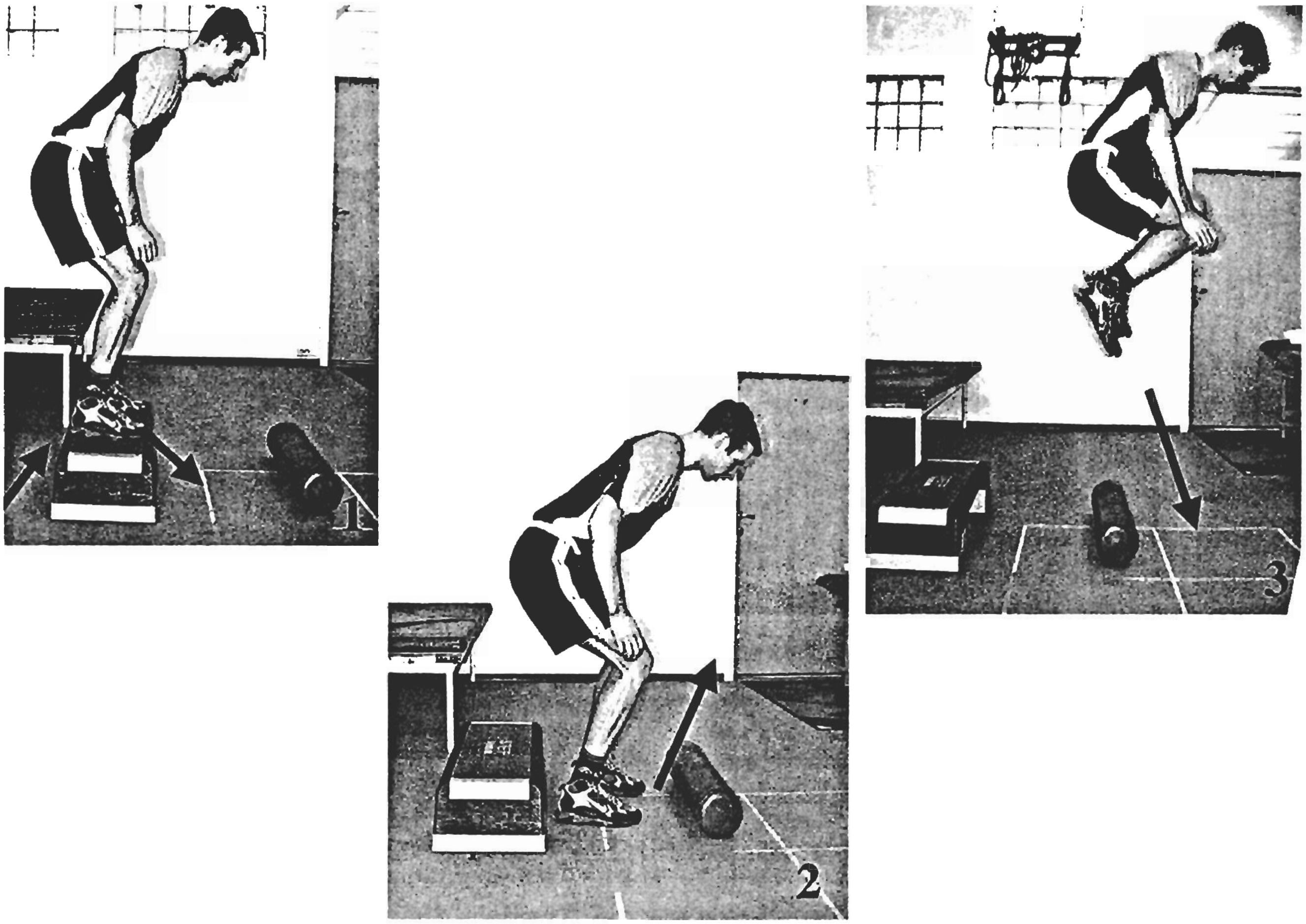

FIGURE 5. Series of plyometric training jumps.

namic joint stability training in our rehabilitation program. The concept of dynamic joint control training was first introduced in 1986.[39]

Several of the exercises included in the dynamic joint stability training use vectors on the floor, called the "star" (Figure 1), to reference the start and the direction of the exercises described by Gary W. Gray in 1995.[33] The 8 vectors are 45 degrees apart. The patient is oriented on the vectors in reference to the lower extremity that is being exercised and in reference to the direction of the exercise. Successful return is pointed out for each exercise.

The exercises are performed in the frontal, sagittal, and diagonal planes. The star is used for the 1-leg stance on the floor with a balance mat and a wobble board. It is used with the step-up and step-down exercises in 3 different directions. Furthermore, it is used for the balance reach leg exercise (Figure 2A) and the balance reach arm exercise (Figure 2B). The star is also used for the lunge exercise (Figure 3) where the movements are performed in the 3 different planes. The exercises can be changed by varying the planes of motion, the range of motion (ankle, knee, or hip), the loading (use of bars), the speed, and the amount and type of feedback (tactile, as with different kinds of surfaces, visuals, or distractions).

Dynamic joint stability exercises are done by using balance reach leg (Figure 2A) and balance reach arm (Figure 2B) on an even, flat surface, on a balance mat, and on a wobble board; lunge exercises and lunge exercises with weights; step-up (Figure 4) and step-down exercises; squatting exercises with and without weights on an even surface, a balance mat, a wobble board, and a trampoline; and squatting exercises on 1 leg.

Jump Training, Plyometric Training, and Sport-Specific Training

Jump training is used for exercises involving jumping in addition to exercises aimed at improving or changing technical performance, especially during landing. Plyometric training is sometimes synonymous with jump training. The term plyometric is defined as "quick and powerful movement involving prestretching the muscle and activating the stretch-shortening cycle to produce a subsequently stronger concentric contraction."[69] During hopping, energy is first stored and thereafter released in a manner similar to a spring. These exercises are used to facilitate quick changes in directions and to improve muscle power (strength per unit time).

Agility training programs are designed to allow the patient to adapt to quick changes in directions, acceleration and deceleration, and cutting activities. Shuttle runs are used to expose the lower extremity to quick changes in starting and stopping maneuvers. Cones are often used to enhance running with cutting activities. After agility drills are performed and the patient masters the technique, sport-specific skills can be incorporated in the agility training and also in the context of playing situations.

Jumping exercises using plyometric training include 2- and 1-leg jumps on the trampoline, balance mat, wobble board, and an even, flat surface, as well as 180-degree jumps, vertical jumps, scissors jumps, and a series of jumps (Figure 5).

Sport-specific activities can include running, lateral running and backward running, shuttle runs, and agility drills (figure-of-eight running, running with quick changes in directions, cutting activities, and ball catching, throwing, passing, and kicking).

Return to Sports

We allow patients to begin sports activities when (1) they can tolerate the full speed agility training and sport-specific activities, (2) the involved leg has less than 15% muscle strength deficit (isokinetic quadriceps muscle strength), and (3) the involved leg has less than 15% deficit for the single-leg hop, the triple jump, and the stair hop tests at the 6-month follow-up.

To monitor the rehabilitation program and record compliance, each week the patient and the physical therapist record the exercises, the amount of time carrying out each exercise, and the amount of time spent on other activities outside the clinic. Pain during activity is recorded on a visual analogue scale each week.

The effectiveness of this rehabilitation protocol on short- and long-term follow-up is not known at this time, but the protocol is currently being evaluated in a randomized clinical trial at our institutions. The effect of this protocol on proprioception, balance, muscle activity patterns, muscle strength, knee joint laxity, and return to preinjury activity level will be evaluated.

CONCLUSIONS

Further clinical research is needed to evaluate the effect of neuromuscular training programs on dynamic joint stability, muscle recruitment patterns, and coordination of muscle groups in the lower extremity during gait, running, or other activities. There is also a need to evaluate what kind of exercises in a neuromuscular training program affect impairments or disabilities in both patients with ACL deficiency and those who have ACL reconstruction.

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APPENDIX

Descriptions of the Rehabilitation Exercises

The rehabilitation program starts the second week after surgery, 3 times a week for 6 months. Only the new exercises that are introduced each week are described below. The involved leg is used if nothing else is stated.

Phase 0: Early Postoperative Phase

Weeks 1–2

Goal: full passive knee extension and reduced swelling.

Patients are hospitalized for 1 to 3 days. After discharge from the hospital and until the rehabilitation program starts at the outpatient clinic, patients do a home program with the main focus on restoring full range of motion and reducing swelling. To reduce swelling, the patient should keep the leg elevated, repeat ankle plantar flexion-dorsiflexion range of motion exercises, and perform isometric quadriceps and hamstrings exercises. Crutches are used to improve gait and to reduce swelling. Full knee extension is the most important goal the first week. Gravity is used to restore full knee extension by using 2 chairs, with the leg elevated on a hard pillow under the heel when sitting or with the leg elevated on the edge of the bed in supine position.

Phase 1: Walking Phase

Weeks 2–4

Goals: normal walking pattern; controlled balance double limb support; controlled balance single limb support; controlled dynamic stability of the *uninvolved leg*.

Crutches are used with weight-bearing as tolerated until 2 to 4 weeks after surgery. The criterion for discontinuing the use of crutches is no limping. Weight-bearing exercises are started as early as possible. If full weight-bearing is not tolerated during squatting exercises, counterweights are used to avoid swelling or pain. Cold therapy (glacier packs) is applied for 15 minutes immediately after training as long as swelling is present.

- ➢ Stationary bicycle to improve range of motion and reduce swelling
- ➢ Walking exercises on the floor
- ➢ Walking exercises on a treadmill to improve gait patterns after discontinuing crutches
- ➢ Squatting exercises: if the patient has persistent swelling or pain, squatting exercises are performed in a pulley apparatus with the use of counterweights
- ➢ Gastroc exercises: standing heel rising exercise
- ➢ Single leg stance exercise, *starting* on the uninvolved leg
- ➢ Single leg stance, involved leg
- ➢ Balance reach leg exercise and balance reach arm exercises on *uninvolved* leg
- ➢ Lunge exercises: anterior, anterior/lateral, lateral, posterior/lateral, and posterior directions on *uninvolved leg*
- ➢ Step-up exercises: anterior, lateral, posterior, starting with *uninvolved* leg

Phase 2: Balance and Dynamic Joint Stability Phase

Weeks 5–8

Goals: controlled balance double limb support, uneven surface; controlled balance single limb support, uneven surface; controlled dynamic stability, double limb support; controlled dynamic stability, involved leg; step-up and step-down; squatting, 2 legs; sideways and backwards walking.

Week 5
- ➢ Single leg stance eyes closed
- ➢ Single leg standing on balance mat, appropriate knee and hip position
- ➢ Wobble board, 2 legs
- ➢ Balance reach leg, involved leg
- ➢ Balance reach arm, involved leg
- ➢ Step-up, both legs

Week 6
- ➢ Backwards and sideways walking on treadmill
- ➢ Wobble board, 2 legs with bars/weights
- ➢ Wobble board, 2 legs, throwing ball
- ➢ Wobble board, 1 leg
- ➢ Step-down, uninvolved leg

Week 7
- ➢ Single leg stance, trampoline, throwing ball
- ➢ Step-up and step-down, involved leg, different direction
- ➢ Balance reach leg, balance reach arm, balance mat, and wobble board

Week 8
- ➢ Lunge exercise with bars/weights
- ➢ Single leg stance, trampoline, throwing ball, different directions (front, back, and sideways)
- ➢ Single leg stance, balance mat, throwing ball
- ➢ Step-up, wobble board

Phase 3: Muscle Strength Phase

Weeks 9–12

Goal: increased muscle strength.

- ➢ Slide board exercises
- ➢ Single leg stance with weights, eyes closed
- ➢ Wobble board single leg, eyes closed
- ➢ Squatting exercises, wobble board
- ➢ Squatting exercises with weights, increased knee flexion
- ➢ Lunge exercises with weights, increased knee flexion
- ➢ Step-up with weights, increased height and weights
- ➢ Jumps: 2 legs, trampoline

Phase 4: Running Phase

Weeks 13–16

Goals: running; controlled jumps, 2 legs, trampoline; controlled jumps, 2 legs, turns, trampoline.

- ➢ Running on trampoline
- ➢ Running on treadmill
- ➢ Running or jogging outdoors
- ➢ Jump training: 2 legs, trampoline, increased knee flexion
- ➢ 180-degree jump on trampoline

Phase 5: Jumping Phase

Weeks 17–19

Goals: running sideways and backwards; controlled cutting, slow speed; controlled jumping, 2 legs, flat, even surface; controlled bounding for distance; controlled jumps on steps.

- ➢ Running backwards
- ➢ Bounding for distance
- ➢ Jumps: 2 legs, 180-degree turns, flat, even surface
- ➢ Jumps: up and down from a step
- ➢ Running: figure-of-eight, stop-turn-run
- ➢ Agility drills, slow speed

Phase 6: Plyometric and Agility Training Phase

Weeks 20–24

Goals: controlled single leg jumps; controlled vertical jumps; controlled cutting, full speed; controlled sport-specific activities.

- ➢ Single leg jumps, trampoline
- ➢ Single leg jumps, balance mat
- ➢ Single leg jumps, anterior posterior, lateral, flat, even surface
- ➢ Vertical jumps
- ➢ Scissors jumps
- ➢ Series of jumps: 2-footed jump onto 6- to 8-inch step. Jump off step with 2 feet, then vertical jump
- ➢ Agility drills, full speed on a moveable standing platform
- ➢ Sport-specific tasks are added during the agility training depending on the kind of sport the patients may return to

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