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Importance of Quadriceps Strength and Postural Balance in Rehabilitation after Anterior Cruciate Ligament Reconstruction

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Abstract: ***Introduction: Rehabilitation of patients with anterior cruciate ligament (ACL) injury has begun to emphasize evaluating and treating proprioception in addition to strength and motion impairments. Proprioception, or joint awareness, is diminished following ACL injury and may not recover fully even after surgical reconstruction. Postural balance: A loss of afferent information from the injured ACL mechanoreceptors presumably results in poorer balance and insufficient proprioceptive feedback mechanisms, thereby reducing function and motor control during activity. Postural stability and balance play a significant role in decision-making for return to play.Balance, proprioception, and coordination training are integral parts of the rehabilitation protocols in patients undergoing ACL reconstruction. Quadriceps facilitation: Combination of early knee extension, weight bearing, and close kinetic quadriceps strengthening facilitate postoperative rehabilitation without putting a load on ligament stability. Close Kinetic Chain exercises are safer than Open Kinetic Chains because they are more functional and impose less strain on reconstructed grafts. Conclusion: The motor programs of existing rehabilitation protocol need to be modified by learning new coordinated movement patterns. CKC exercises minimize shear forces and are useful for simulating functional activities. Early balance and proprioception training on a balance board influences proprioception, muscle strength, posture control and full return to activity***

Keywords: Anterior Cruciate Ligament, proprioception, balance, postural stability

1. Introduction

ACL disruption changes the ability of the knee joint to maintain stability during rotational, accelerative, and decelerative activities, producing instability of the knee during the loaded activities, which may lead to mechanical failure and giving way. ACL plays a major role in the proprioceptive regulation of the knee joint[1].In addition to strength and motion impairments, much emphasis has been given now to treating proprioception during the rehabilitation of patients with anterior cruciate ligament (ACL) injuries. Proprioception, or joint awareness, is diminished following ACL injury and may not recover after surgical reconstruction[2]. Decreased joint awareness after ACL injury may be a result of a loss of afferent input from mechanoreceptors in the ACL itself or altered input from injured or intact mechanoreceptors as a result of ACL injury[3].

Postural Instability

The poor postural balance reflected as increased body sway may be due to loss of afferent information from the injured ACL mechanoreceptors. Patients with insufficient proprioceptive feedback mechanisms have reduced function and motor control during activity [4].Several force plate or platform has been used to investigate the impairment of proprioception resulting from an ACL injury. Different balance studies performed on subjects with ACL deficiency or ACL reconstruction generally report increased sway in this population [5].

Rehabilitation programs following ACL reconstruction (ACLR) are mainly focused onthe restoration of muscle strength around the knee. The concept is changing in the last 10 years. The sensory function of ligaments in relation to functional joint stability has been given equal importance in rehabilitation after a ligament injury. The afferent information regarding body position and balance is provided by the visual, vestibular, and somatosensory systems [6]. This neural input is integrated by the CNS to generate a motor response. Sensory receptors are present in the skin, muscles, joints, ligaments, and tendons. Since a ligament injury causes a disturbance in the somatosensory system it may affect the central programs and motor response[7].

Postural balance and stability play a significant role in decision-making for return to play. Postural control is defined as an individual's ability to control his body position in space while maintaining body stability and orientation. It requires a complex integration of sensory-motor performance and can be altered by motor control anticipation, sensory taping, and central recognition of balance-related physical influences, as well as motion-related changes in the body's center of gravity[8].Although ACL injury is a peripheral musculoskeletal problem, it is currently considered a proprioceptive neurophysiological dysfunction rather than a simple ligament instability. Impaired postural stability and proprioception deficit are observed in patients with ACL injury[1]. Some patients can compensate for the loss of ACL inputs by inputs from other knee and muscle proprioceptors since they do not develop central somatosensory abnormalities or impairment in knee position sense.

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Proprioceptive exercises have been playing a key role in the management of all patients following ACLR. These exercises begin when the patient stands, taking weight on the affected limb during the early post-operative rehabilitation phase. Early gait training at a tolerable pace could also facilitate and restore proprioception.Persistence of postural impairments was even observed following ACLR, which became a major cause of disability[1]**.** Hence rehabilitation objectives following ACLR should focus on an improvement of postural stability by facilitating neuromuscular control.

Quadriceps facilitation

Quadriceps weakness is commonly seen after ACL injury and ACL surgical reconstruction despite taking adequate rehabilitation measures. As a principle, all surgeons primarily focus on quadriceps strengthening. However, many patients are discharged fromthe hospital with supervised physical therapy before the strength deficit is fully resolved. Reduction in quadriceps strength was caused by reduced activation of normally functioning muscle fibers due to altered afferent feedback from the mechanoreceptors of the torn ACL[9]. Reduction in quadriceps cross-sectional area, strength, and muscle activity under EMG have been reported in the affected side of ACL injury [10]. Surprisingly inhibition of opposite uninjured side quadriceps has been observed by some investigators. On the other hand, several studies have shown restoration of hamstring strength after ACL injury [11,12].Prior to the reconstruction of ACL in the injured limb, the quadriceps strength is slightly reduced but the functional performance of the quadriceps is greatly reduced[13].

Discussion on principles of Rehabilitation

The aims of rehabilitation following ACL reconstruction are to restore joint motion and regain muscle strength, function, and postural stability to the preinjury level or a modified level of activity. The duration for which the rehabilitation measure continues is not yet fixed. Some researchers suggest active rehabilitation should continue upto 5-8 months after ACL injury and upto 1 year after ACLR[13]. Core strengthening exercises play an important role by positioning the body'scenter of gravity with respect to the foot-supporting area[14]. For better postural stability, an efficient function of the leg, hip, and trunk muscles is needed to stabilize the body segments and give an adequate positioning of the center of gravity in relation to the supporting area of the foot.

Closed kinetic chain (CKC) exercises have been more popular than traditionally-used open kinetic chain (OKC) exercises [15]. CKC exercises produce fewer shear forces and thereby minimize strain on passive structures[16]. The other advantages of CKC include, increase joint stiffness, and increase muscular coactivation [17] Muscular coactivation ensures even distribution of pressure on the articular surface thereby unloading the jointand is also important in improving joint stability[18].CKC exercises are safer than OKC because they are more functional and imposes less strain on reconstructed graft. The use of both OKC and CKC in ACL rehabilitation has been recommended by some authors[15].

In a limited resource setting, most of our rehabilitation training extends up to 6 weeks of reconstruction of the ligament. Very few of them have scope for a supervised rehabilitation program.A study was done by Zatterstrometal. [19] reported that the supervised group showed greater isokinetic and isometric muscle strength in both quadriceps and hamstring muscles. Functional performance assessed by one leg hop test for distance was significantly longer in the supervised group thanin the traditional unsupervised group. Improvement of muscle strength and functional performance were significant at 12 months in comparison to 6 weeks follow-up. They recommended that 6 weeks rehabilitation period is too short to achieve the desired strength. In our day-to-day practice, several methods are there to measure strength impairments, but few methods are there to quantify functional impairments following ACLR. Hop testing is a valid and reliable method of measuring function following ACLR [20]. However, it can only be administered in the late stages of post-operative ACL rehabilitation and is not appropriate for all patients with ACL deficiency. Force platforms are now available to assess functional performance in the early rehabilitation period.

Peripheral somatosensory loss is strongly related to mechanical joint instability which is the theory behind a compensated and uncompensated ACL injury. Some ACL injury patients can return to full contact sports, while others experience ‘giving way’ and instability during walking. Hence ACL laxicity is unrelated to the ability to return to sports [21]. Similar observations have been experienced by many surgeons that even though the reconstructed ACL appears lax, still the patient does not complain of any instability. The probable mechanisms may include maintenance of proprioception at the knee, activation of a long loop, capsulohamstring complex, or changes in the central representation of proprioception inputs[22,23]. The efficacy of proprioceptive exercises has been studied extensively and proved to be very beneficial in improving proprioception, and posture control. Proprioceptive training with and without visual feedback is found to be improving sensorimotor function by 52%[24].

Achieving knee extension is the foundation for the entire rehabilitation program following ACLR. Combination of early knee extension, early weight bearing, and close kinetic quadriceps strengthening facilitate postoperative rehabilitation without putting a load on ligament stability. Starting close kinetic chain quadriceps training from 3weeks of ACL reconstructioncontribute to a bigger improvement in quadriceps strength [25]. The strength build-up progressively intensifies along with proprioceptive and coordination exercises.To stimulate coordination and control through afferent and efferent information processing, exercises should be enhanced by variation in visible input, surface stability by use of a trampoline, speed of exercise performance, the complexity of the task, resistance, and one or two-legged performance. The ultimate goal is to maximize the strength and endurance of knee stabilizers, optimize neuromuscular control with plyometric exercises, and add sports-specific exercises depending on the working demand of the patient [26].

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Altered Neuromuscular control and postural deficit after ACLR are the predictor of a second ACL injury when the athlete returns to sports [27]. This potential threat is modifiable by rehabilitative intervention. Several studies are there to describe altered movement patternswhich are considered a predictor of ACL injury even in uninjured athletes [28, 29]. Many reviewers & clinicians agreed that early balance and proprioception training on a balance board could positively influence proprioception, muscle strength, posture control, functioning, and fast & full return to activity [30, 31].

Neuromuscular coordination exercises were designed to improve the sensorimotor control of the lower limb muscles during gait activities such as walking and running and other functional tasks and thus improving balance, especially the dynamic one and highly needed for athletes whose performance requires a high degree of motor automation. Postural control exercises such as ankle-disk training, wobble board exercises, standing on foam pads, pillows, etc. might be helpful redevelop a postural-correction strategy and provide a synergistic approach to improve the overall postural stability [32]. Clinicians can opt for single-legged standing balance training on unstable surfaces and gradually progressing in difficulty level could elicit increased muscle activations and co-contraction ratios. Balancing along a frontal axis evoked maximum muscle activity level, and the firm surface the least.

2. Conclusion

Impaired sensory feedback from the injured joint disturbs the postural stability of the limb. The motor programs of existing rehabilitation protocol need to be modified by learning new coordinated movement patterns. Several studies reported impairment of stability and postural control while few reports return to near normal with time. An increase in joint laxicity following ACL injury does not correlate with functional outcomes. Persistent weakness and wasting of the quadriceps have been reported by many studies, however, the strength of the Hamstring muscle can be restored. CKC exercises are believed to be safer and more functional than OKC exercises. CKC exercises minimize shear forces and are useful for simulating functional activities. Further studies are required to know the effect of neuromuscular rehabilitation on overall improvement after ACL reconstruction.

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