

Comparison of Modalities and Strength and Motor Control Training Methods after Anterior Cruciate Ligament Reconstruction Surgery and Recommendations

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Abstract:

Anterior cruciate ligament injury is a very common sports injury, accounting for about 70 percent or more, and the literature reports that the prevalence of ACL rupture in the general population of the U.S. is about 1 in 3,000, and the injury can lead to instability of the patient's knee and have a huge impact on his or her return to sports, and may even induce osteoarthritis, among other things. In this article, three different modalities and two different Strength and Motor Control Trainings are introduced and the specific effects of each method are described, then several common metrics are summarized to compare the efficacy of each method, to derive some therapeutic guidelines for the use of more efficient therapies in clinical practice. It is also hoped that it will have a beneficial impact on the recovery of patients after ACL surgery, promoting the restoration and strengthening of their function.

Keywords: Modality; Strength and Motor Control Training; NMES; Electromyographic Biofeedback; Eccentric Training; Isokinetic Training.

1. Introduction

An anterior cruciate ligament (ACL) is a crucial component that keeps the knee stable. ACL injuries often result in knee instability. The instability may increase the risk of secondary osteoarthritis of the knee. In England, there are thought to be 30,000 primary ACL repair surgeries carried out each year, while data from the Swedish ACL registry indicates that there are 71 surgeries performed for every 100,000 people annually [1]. Regarding the performance of elite athletes upon their return to competition, six studies found that performance declined following surgery, while five found that postsurgery performance was either unchanged or improved from preinjury levels. Thus, postoperative rehabilitation is very important for ACL injuries [2].

Six distinct clinical practice guidelines indicate that ACL rehabilitation can mitigate pain and discomfort, rehabilitate muscular strength and lower limb functionality, and facilitate a safe return to competitive athletics without the risk of re-injury [3]. Eighty percent of patients undergoing

ACL reconstruction successfully resume sports activities, yet only sixty-five percent can return to competitive sports and achieve their pre-injury performance level [4].

During anterior cruciate ligament reconstruction (ACLR), the application of Kinesio-taping (KT) demonstrated efficacy in reducing edema and alleviating pain during the initial stages of postoperative rehabilitation [5]. Early application of NMES mitigates contractile dysfunction and attenuates skeletal muscle atrophy following surgery and the primary injury [6]. Enhancing knee extension is a benefit of early rehabilitation following ACL restoration using EMG-BFB therapy. The development of postoperative knee extension can be significantly influenced by improved vastus medialis innervation [7].

There are various clinical practices on rehabilitation after ACL reconstruction surgery [4]. This review will focus on a few of the more commonly used methods of the above methods: NMES, Electromyographic biofeedback, Kinesio-taping, Eccentric training, Isokinetic training, and so on to compare and analyze the effect of ACL rehabilitation and discuss their applications.

2. Modality

2.1 Neuromuscular Electrical Stimulation

Neuromuscular Electrical Stimulation (NMES) is part of a rehabilitation program, it is a physical factor therapy, and it is mostly used as an adjuvant to rehabilitation to prevent future injuries and issues with nerve activation. It works by creating an electric current through electrodes applied to the muscles to trigger muscle contraction. To prevent future problems such as arthropathy, it is necessary to prolong the postoperative use of NMES or to use it more frequently on a weekly or daily basis to prevent loss of muscle size and strength as well as asymmetry of the limb when returning to sports and When attempting to resume the degree of activity before the injury [6]. According to research findings, neuromuscular electrical stimulation (NMES) can be effectively employed during the initial two weeks following knee surgery, utilizing a frequency of ≥ 50 Hz, the highest intensity available, biphasic current waveform, large-sized electrodes, and a duty cycle ranging from 1:2 to 1:3 (with slopes lasting for 2-3 seconds). This approach demonstrates significant efficacy in restoring quadriceps muscle strength [8]. Quadriceps muscle weakness, as well as lower limb loading asymmetry, are two major problems after ACLR, and according to some studies, it can be found that incorporating a two-month structured resistance training intervention in the early stages of rehabilitation can be a great enhancement for the quality of rehabilitation due to the superimposed functional function of neuromuscular electrical stimulation [9]. It has also been shown that repetitive sit-stand-sit exercises (STSTS) can effectively restore quadriceps strength and symmetry during lower extremity loading when NMES therapy is performed in the early postoperative period [10].

2.2 Electromyographic Biofeedback

Electromyographic biofeedback (EMG-BFB) is used to increase muscular activity and contraction. Patients must participate at every level of the neural system to complete the second learning process for the quadriceps contraction. Due to the increased vertical strength of the knee after ACLR, which leads to a decrease in its motion and stiffness of the knee, making the return to motor activity sluggish, in one study, quadriceps strength and knee function were dramatically enhanced by isometric strengthening performed with an aided EMG-BF. It has been discovered that when it comes to speeding up knee extension

recovery, biofeedback outperforms electrical stimulation (ES) [11]. Patients commonly undergo quadriceps atrophy in the early postoperative period; this is mainly caused by a persistent condition known as atrogenic muscular inhibition (AMI), which impairs muscle activation, causes weakness, atrophy, and interferes with muscle strengthening. Using biofeedback as a therapeutic strategy to manage AMI after ACL repair surgery may prove beneficial. The patient can modify their muscle activity thanks to the real-time feedback of electrical muscle activation. Less extreme stresses that exacerbate AMI may result from this control [12]. Patients can also experience a loss of knee extension. After arthroscopic knee surgery, patients may experience torque, function, and range of motion activation via sEMG-triggered NMES during knee extension. It helps people who have had knee surgery to improve their knee extension AROM [13]. There's also a study has shown that EMG- BFB of the medial femoral muscle is effective in improving innervation of the medial femoral muscle and postoperative knee extension when compared to other methods, such as electrical stimulation, aquatic exercise, and proprioceptive training [7].

2.3 Kinesio Tape

Kinesio tape (KT) is a thin, elastic tape that is applied to the skin's surface to correct injured musculature by toning or stimulating the underlying muscles. Following ACL surgery, KT resulted in quicker improvements in knee edema, thigh circumference, and range of motion while using less analgesics. Furthermore, KT has been shown in previous studies to lessen pain during the initial postoperative phase. Additionally, KT somewhat mitigates the effects of proprioception loss on the patient's proprioception, balance, and functional performance [15] and enhances gait patterns, subjectively reported joint function, and proprioception [14, 15]. In one group of studies, the use of KT to intervene in the recovery of patients was found to result in a very significant improvement in the threshold of injuriousness in the face of mechanical stimuli, as well as a reduction in the enlargement of the knee joint dimension due to edema in the acute phase due to the effect of KT, and a faster return to preoperative levels [16]. It is reported that KT can not only lead to improved proprioception but also result in both an enhanced walking pattern and an improved knee joint's subjective function. Additionally, this study supports the conservative treatment of ACL ruptures by utilizing KT as a potential supporting assistance [17].

In Table 1, the same indicators that can be affected by the three modalities are summarized and the effects of these indicators are compared to the effectiveness of the three

methods. It should be noted that there are still some indicators that cannot be compared because of the different experimental methods, such as proprioception and so on.

Table 1 The effect of three modality methods [8-17]. ↑: Increasing; ↓: Decreasing; →: No normally effect.

Evaluation Index	NMES	Electromyographic Biofeedback	Kinesio tape (KT)
Knee flexor muscle strength	↑	↑	→
Knee extensor muscle strength	↑	↑	→
Morphology of the thigh muscles and tendons	↑	→	↑
Symmetry of the lower limb loading	↑	→	→
Knee extension for the AROM	→	↑	↑
Balance	→	↑	↑
Pain Level	→	→	↑

3. Strength and Motor Control Training

3.1 Eccentric Training

The eccentric exercise proved to be more efficacious in facilitating quadriceps recovery from strength losses following ACL surgery due to its capacity for eliciting superior enhancements in neural activation and muscle hypertrophy [18]. Utilizing concentric and eccentric cross-education (CE) to optimize quadriceps strength has been demonstrated to enhance post-surgical recovery of quadriceps strength in the early stages of rehabilitation, owing to the implementation of isokinetic training programs involving both concentric and eccentric contractions [19]. Additionally, a study investigating the incorporation of progressive eccentric and concentric training into the standard ACL rehabilitation protocol has suggested potential enhancements in functional outcomes following autogenous hamstring graft ACL reconstruction, as indicated by improvements in the Lysholm knee scale, vertical leap test performance, single hop-for-distance test results, and scores on the ACL-QOL questionnaire [20]. In late-stage ACL healing, eccentric-oriented exercise improves lower body strength, vertical leap, injured leg single-leg hop, injured leg triple-leg hop, and above-average single-leg vertical jump for athletes [21]. Recently, in a Marlon et al [22]. Open kinetic chain eccentric training was discovered to be a secure and successful method for quadriceps muscle recovery following ACL surgery in one study. Recreational athletes undergoing ACL rehabilitation may see

an increase in quadriceps muscle mass and strength with isokinetic and eccentric exercise. When training, a comprehensive approach should be considered, including both concentric and eccentric training.

3.2 Isokinetic Training

The isokinetic rehabilitation system can provide multi-angle isokinetic training, centripetal and centrifugal isokinetic training, effectively promote muscle strength recovery and neuromuscular control, to achieve early postoperative rehabilitation, reduce the risk of re-injury, and improve knee joint function. A study shows that postoperative isokinetic training of the thigh muscle group plays a positive role in promoting muscle strength recovery and early ligament shaping of patients after ACL reconstruction, which may be more conducive to the long-term recovery of patients [23]. According to earlier research, athletes who have had an ACL repair benefit from isokinetic muscular strength training in terms of their ability to regain knee flexor and extensor muscle strength (60 °/s). Additionally, it might strengthen young athletes' quadriceps and other muscles. Regular isokinetic muscular strength training has been demonstrated to increase knee flexion, extensor strength, extensor endurance, kinaesthesia, 30° position perception, and balance in randomized control trials when compared with aerodynamic resistance training [24]. According to an alternative study, the 6-week ECC isokinetic training demonstrated superior efficacy in enhancing peak torques in both the quadriceps and hamstrings compared to the CON isokinetic training [25]. In Table 2, the same indicators that can be affected by the

two Strength and Motor Control Trainings are summarized and the effects of these indicators are compared to compare the effectiveness of the three methods. It is important

to note that other metrics could not be compared because of the different test methods, such as the Hamstring Symmetry Index (LSI) and so on.

Table 2 The effect of two strength and motor control training methods [19-25]. ↑: Increasing; ↓: Decreasing; →: No normally effect.

Evaluation Index	Eccentric training	Isokinetic training
Knee flexor muscle strength	↑	↑
Knee extensor muscle strength	↑	↑
Functional performance	↑	→
Peak torque (PT)	↑	↑
flexor endurance	\	→
extensor endurance	\	↑

4. Conclusion

In this article, the effects of three modalities and two Strength and Motor Control Trainings are compared to their effects after ACL reconstruction. From the results, it can be found that: (1) Among the three modalities: NMES, Electromyographic Biofeedback(EB), and KT, the effects of NMES and EB have greater clarity regarding the restoration of knee flexor and extensor muscle strength, while EB and KT have a greater improvement in the patient’s flexor AROM and balance function, also the combined results show that EB has a certain degree of effect on the recovery of various functions. The comprehensive comparison results show that EB has a certain effect on the recovery of all functions, which is more comprehensive than the other two methods, and its effect can be further explored. (2) While both eccentric and isometric training have a significant impact on the recovery of knee flexor and extensor strength in the two Strength and Motor Control Trainings, eccentric training exhibits a greater influence on the rehabilitation of knee flexor and extensor muscle groups, leading to improved functional performance. On the other hand, isokinetic training demonstrates superior enhancement in endurance specifically for the extensor muscle groups. In conclusion, incorporating eccentric training alongside other modalities would be preferable for patients aiming to restore functional performance. It is recommended that future studies include additional experiments to further validate these conclusions, with potential implications for clinical treatment.

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