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Evidence-Based Physical Therapy Rehabilitation Strategies for Knee Dysfunction: Paradigm Shift from Passive Intervention to Active Management

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Abstract. Knee dysfunction, including KOA, ACL restoration (ACLR), and PFPS, is one of the leading causes of pain, exercise limitation, and reduced quality of life in adults worldwide, and it imposes a significant socioeconomic burden on the healthcare system. This study aims to review current evidence-based PT rehabilitation strategies for knee dysfunction. It focuses on summarizing and combining multimodal treatment methods such as therapeutic exercise, physical mode, manual therapy, and patient education. The review of available high-quality RCTs and CPGS showed the following three conclusions: first, therapeutic exercise based on strength training and neuromuscular control is the basis, and integrated hip-knee-core chain training is superior to regional strength strengthening training alone. Second, maneuvers such as joint mobilization and the use of bandaging are important for remission in the acute phase, but if they are not combined with active training, there is little additional benefit in long-term functional gain; Thirdly, patient education (especially pain neuroscience education) and psychological interventions (e.g., cognitive behavioral therapy and medication adherence management) are key factors affecting the outcome, especially for reducing kinesiophobia. This pape highlights the importance of the process from the passive treatment model to the active participation of patients, and also provides clinicians with an idea for the selection of individualized, staged and evidence-based rehabilitation programs.

Keywords: Knee joint dysfunction, physical therapy, evidence-based rehabilitation, therapeutic exercise, manual therapy, multidisciplinary intervention.

1. Introduction

The knee joint is the most complex and most biomechanically loaded structure in the human body and plays an important role in load-bearing, walking, and dynamic movement control. Knee joint dysfunction, whether in the process of degeneration (such as knee OA) or after traumatic injury requiring ACL reconstruction, or due to overuse conditions (such as PFPS), is one of the main causes of chronic pain, dysfunction, and reduced quality of life in adults worldwide [1,2]. Epidemiology predicts that the global incidence of KOA will continue to grow, and it is estimated

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that its incidence will increase by 74.9% by 2050 compared with 2020 levels, highlighting the urgent need for effective, accessible and sustainable non-surgical treatment methods.

On an international level, the use of physiotherapy as the primary conservative treatment for the management of KOA and ACLR rehabilitation has been established by various prestigious organizations such as the American Physical Therapy Association and the National Institute for Health and Care Excellence. Recently, high-level evidence has been established for the use of various aggressive forms of treatment [3,4]. In the management of KOA, the primary treatment is therapeutic exercise; however, recent advances have shown the importance of comprehensive interlocking training for the hip, knee, and core muscle tissues, which has been shown to be more effective than quadriceps training alone [3,5]. In ACLR rehabilitation, recent evidence has established the safety and effectiveness of open kinetic chain training from a restricted range of motion four weeks after surgery, which can improve quadriceps strength without compromising the integrity of the graft [6,7]. In the early stages of ACLR rehabilitation, the use of adjunctive therapies such as neuromuscular electrical stimulation can effectively treat quadriceps depression; however, the use of cryotherapy and transcutaneous electrical nerve stimulation can be useful in the treatment of acute pain.

Chinese rehabilitation medicine is currently undergoing a transformation from empirical medicine to evidence-based medicine. Relevant research has verified that the treatment of KOA with combined traditional Chinese and western medicine is feasible and effective. For instance, acupuncture combined with comprehensive rehabilitation nursing intervention can greatly improve the lower limb alignment index level in KOA patients [8]. Nevertheless, there are still some challenges: the rehabilitation medical quality is uneven and inadequate; there is a lack of unified and standardized rehabilitation treatment guidelines and plans; and the psychological symptoms of kinesiophobia are ignored [9,10].

Although a great deal of research activity is evident, research has been predominantly aimed at validating a particular intervention approach. There is a significant lack of understanding with respect to a comprehensive approach that is both stage-specific and personalized for various sub-types of dysfunction, for instance, distinguishing rigid dominant versus unstable dominant KOA, various sub-types of PFPS, and various sub-types of ACLR grafts. Moreover, the precise time for the integration of passive interventions with active exercises is unclear. Therefore, this paper summarizes the clinical decision-making process based on the ICF and staged rehabilitation, combined with the current evidence-based evidence: starting from assessment and stage classification, and then to therapeutic exercise, supplemented by manual therapy and body modeling, and finally to patient education and long-term self-management.

2. Assessment and stage classification: prerequisites for precision rehabilitation

Effective rehabilitation is based on correct evaluation. Standardized patient-reported outcome measures provide underlying outcome and prognostic information. The most commonly validated measure for KOA is the Osteoarthritis Index developed at the University of Western Ontario and McMaster Universities, which provides a comprehensive assessment of pain, stiffness, and physical function [5,11,12]. The knee Injury and Osteoarthritis Outcome Score also provides a reliable measure of pain, symptoms, life movements, sports and recreation functions, and knee-related quality of life [6]. For PFPS, the Kujala anterior knee Pain Scale is the preferred outcome measure and has shown excellent reliability in assessing functional status [1]. For patients with ACLR, the International Knee Documentation Committee subjective Form and the Knee Outcome Survey Activities of Daily Living Scale provide valid functional assessments [6,7].

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Most importantly, kinesiophobia (fear of movement and reinjury) should be evaluated before surgery and during the entire rehabilitation course. With the use of the Tampa Scale for Kinesiophobia as a reference tool for the evaluation of kinesiophobia, it has been established that a greater score on the TSK significantly predicts the outcome for the recovery of the range of motion after surgery [9,13]. With a 1-point rise in the score on the TSK, 0.47° is subtracted from the angle of flexion for the knee. The impact of mental health on the function of the body cannot be taken lightly.

Objective measures have multiple domains. Range of motion in the joints using a universal goniometer provides basic information regarding defects in flexion and extension that may reflect joint effusion, capsule restriction, or arthrogenic muscle depression [6,8]. Artificial muscle testing for muscle strength provides clinical utility, while isokinetic movement at a rate of 60 degrees per second provides accurate quantification of force asymmetry, a key factor for recovery of movement after ACLR bb0. Functional tests, such as the one-leg squat test, have revealed deficits in dynamic postural control and maladaptive movement patterns such as genu valgus that may result in patellofemoral pain and ACL injury risk [3,4]. Advanced biomechanical assessments such as gait analysis have quantified the knee adduction moment that is a key indicator for loading the medial fascial compartment in KOA, which is related to the severity of imaging findings and disease progression [5].

Classification of stages on the basis of tissue healing and functional recovery milestones is useful in the selection of interventions that are most suitable. The acute/inflammatory phase, which may be the first 1 to 2 weeks after injury or surgery, emphasizes the need to control pain and swelling, protect the tissue, and encourage painless range of motion without any prolonged immobilization, which may result in muscle atrophy. The repair/recovery phase, which may be between 2 to 12 weeks, focuses on the full restoration of joint range of motion, progressive strength training, neuromuscular control re-education, and the initiation of weight-bearing activities. The functional reconstruction phase, which is more than 12 weeks, focuses on the enhancement of movement patterns, durability, motor specificity, and safe return to the pre-injury level of activities [6,7].

3. Therapeutic exercise: cornerstone of rehabilitation

Therapeutic exercises are considered to have the strongest evidence for the treatment of knee dysfunction. The importance of therapeutic exercises has been supported by various systematic reviews and clinical guidelines. Land-based therapeutic exercises have shown their short-term effects in reducing pain in the knee joint and improving physical functions in all patient populations [3,5].

Strength training is one of the main components that requires careful consideration in selecting exercises. Regarding ACLR rehabilitation exercises, the debate about open versus closed power chain exercises has been resolved with new evidence. It has been proven that ACL strain during open kinetic chain leg extension (3.8%) is much lower than that during normal walking (13%) [6,7]. It has also been proven that initiation of open-chain exercises in a restricted range of motion (from 90 to 45 degrees of flexion) at week 4 after surgery is safe and does not affect graft integrity; rather, it is better for regaining quadriceps strength than closed-chain exercises alone [6,7]. A more conservative approach may be considered for patients with hamstring tendon grafts; however, there is evidence for the safety of doing so with the use of proper loading parameters [7].

On the other hand, for KOA and PFPS, closed power chain exercises such as squats, lunges, and step exercises can more accurately mimic functional activities and minimize stress on the patellofemoral joint compared to their open power chain counterparts [3,4]. Nevertheless, under

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suitable conditions, open power chain exercises can be beneficial for strengthening muscles. The strengthening of the quadriceps femoris muscle group is a major objective of KOA rehabilitation, and research suggests that strengthening this muscle group can minimize joint load, shock absorption, and functional capacity [3,5]. For ACLR and PFPS, it is important to simultaneously strengthen the hip abductor, external rotator, and popliteal muscle groups, as weakness of these muscle groups can result in kinematic changes such as femoral rotation and subsequent patellofemoral joint stress [1,4,6].

Neuromuscular control and proprioceptive training is based on the quality of movement, not the strength of individual muscles. Moving from static balance training on stable surfaces, through dynamic one-leg standing on unstable surfaces, and onto perturbation training and jumping and landing exercises, is a systemic challenge for the sensorimotor system [3,4]. As a preventative regimen for the athlete, a series of exercises that include strength training, explosive strength training, and core stability training have shown that they are able to prevent ACL injury, as well as improve functional outcomes for the reconstructed. This is through the emphasis on proper landing techniques and the avoidance of genu valgum, which directly affects the patella and ACL.

Cardiovascular endurance training is the final component of the regimen. Low-impact exercises, such as stationary cycling, elliptical training, and water-based exercises, minimize loading on the joints, maximizing cardiovascular training [3,5]. Aquatic training is advantageous in the early stages of rehabilitation, as it reduces the load of gravity, maximizing strength training [3]. Cycling is useful in maximizing range of motion in the knee, and stationary cycling is commenced in the first week post-ACLR.

4. Manual therapy and physical methods: adjunctive and collaborative interventions

Manual therapy techniques, when used in conjunction with active exercises, can be of significant benefit as an adjunct. Joint mobilization using Maitland or Kaltenborn classification can be used for the resolution of stiffness in ACLR, and with exercises, joint mobility can be improved [6]. In the case of KOA, manual therapy with exercises offers better pain relief in the short term, while in the long term, the benefits are comparable with exercises alone.

The purpose of the KOA is different. McConnell taping, Mechanical reduction of the patella using rigid tape provides immediate pain relief during functional movement in patients with PFPS and allows painless movement [4]. Evidence for Kinesio tape(KT), an elastic tape designed to promote or inhibit muscle activity, is varied. Although some studies have reported that KT is beneficial for pain and proprioception, meta-analysis has shown that kinesio tape has no significant advantage over sham tape, and the effect may be more reflected in providing more sensory information than physical correction [4,14].

Recommendation: The evidence for the use of physical approaches is not consistent. Cryotherapy can be effective in reducing pain medication and edema within the first 3 days after surgery. During this period, pressurized cryotherapy has more benefits than the use of cryotherapy alone. Neuromuscular electrical stimulation can have a moderate effect on quadriceps strength immediately after ACL-R surgery for functional movements [6]. When the patient cannot tolerate high joint loads, blood flow restriction training can be a promising method for the early development of strength without impairing the integrity of the graft [6].

Therapeutic ultrasound, passive mobilization, and counter-pulsation, as well as mechanical devices that include whole-body vibrators, are not recommended because of the absence of strong evidence of their greater efficacy than active exercises alone, as well as the high costs involved in

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these interventions. Clinicians should focus on active patient involvement rather than passive interventions. Conservation use, i.e., withholding acute pain relief during active exercises.

5. Patient education and long-term self-management

Patient education is an integral part of rehabilitation but is commonly overlooked. Pain neuroscience education works to reduce maladaptive beliefs about pain and to help patients understand that pain does not necessarily mean tissue damage. This reduces kinesiophobia and increases participation in movement. This type of education has been found to be very useful for patients with chronic pain conditions like KOA and those with high fear avoidance beliefs following surgery.

Cognitive behavioral therapy (CBT), a psychological intervention, has many benefits for multidisciplinary rehabilitation programs. Cognitive behavioral therapy combined with physical rehabilitation has a significant effect on kinesiophobia compared with conventional physical therapy for patients with kinesiophobia; the effect is still evident after 6 months post-treatment. Multidisciplinary care that includes physical therapy, psychological care, and nursing education reduces the time to the first postoperative activity by more than 11 hours compared with usual care for patients with KOA; it reflects the benefits of physical education after overcoming psychological obstacles.

Weight control is one of the important factors that influence the outcome of KOA. Weight loss in overweight or obese patients with KOA leads to a reduction in pain that is related to the amount of weight loss (5% to 10%) [3,5]. Weight loss leads to a reduction in the pressure on the knee joint with a synergistic effect when combined with exercise; however, it does not reduce gait speed [3]. Adherence management strategies are the key to the optimization of long-term results. Tele-rehabilitation, through the digital platform, has proven to be effective in the management of KOA, similar to conventional physiotherapy. A structured home exercise program, along with regular monitoring and feedback, helped to keep the patients engaged, and the results were better with the therapist-directed program than the self-directed program alone. Goal setting, progress monitoring, and decision-making are essential to increase the motivation and self-efficacy of the patients, which are important determinants of behavior change.

6. Conclusions

Evidence-based physiotherapy is an essential component of the management of knee dysfunction, and successful recovery depends on a shift from passive intervention to active patient engagement and self-management. Three main conclusions are supported by the available clinical evidence. Evidence-based physiotherapy is an essential component of the management of knee dysfunction and successful recovery depends on a shift from passive intervention to active patient participation and self-management. Based on the current clinical evidence, the following three main conclusions were drawn. Firstly, strength-and neuromuscular control-based therapeutic exercise is the intervention with the highest level of evidence. Modern therapeutic approaches emphasize strength training of the whole hip-knee core chain rather than only local muscle groups. If the range of motion of the joint is controlled, then open chain training can be performed at the appropriate time after surgery without adverse results. Secondly, handicraft therapy and physical therapy can be advocated as adjunctive treatments. Joint release can improve postoperative stiffness, and bandages can temporarily relieve pain and promote exercise compliance. Cryotherapy, neuromuscular electrical stimulation, and flow-restriction training have well-positioned evidence of use, but passive approaches are no substitute for active exercise, and weak support measures should be used with

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caution. Third, patient education and psychological support are important to the final outcome. Pain neuroscience education can reduce kinesiophobia, an important barrier to recovery, while integrative cognitive behavioral therapy can reduce fear and thus accelerate early mobility.

Weight management is indispensable in KOA treatment, and diet and exercise have synergistic effects. Both distal rehabilitation and structured self-management programs can enhance patient treatment compliance and continuity, and their evidence-based framework can standardize clinical behavior and achieve individualized staged intervention. The main limitations of this study are the lack of primary data due to the narrative review design and the heterogeneity of knee joint dysfunction, which limits its application to rare lesions. Future research should also focus on the use of wearable devices with sensors and artificial intelligence for the development of a personalized plan of rehabilitation and feedback on motion in real-time. More research should be conducted on the optimization of multidisciplinary care, particularly in association with psychological support and biomechanical correction. A large-scale machine learning approach, stratifying individuals according to phenotypes, should be used for the development of subgroup-specific protocols, shifting from standardized care to purposeful precision rehabilitation.

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