NEUROMUSCULAR CONTROL TRAINING EXERCISES FOR PATELLOFEMORAL PAIN SYNDROME- A NARRATIVE REVIEW

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Abstract—Patellofemoral pain syndrome (PFPS) is a common cause of anterior knee pain affecting adolescents, young adults, and physically active populations. Increasing evidence suggests that neuromuscular impairments, including altered muscle activation, impaired proprioception, and poor dynamic movement control, play a significant role in the development and persistence of symptoms. Neuromuscular control training (NCT) aims to restore coordinated muscle activity, improve joint stability, and optimize lower limb biomechanics during functional tasks. This narrative review synthesizes contemporary evidence regarding the effects of neuromuscular control training exercises in individuals with PFPS. Current literature indicates that NCT, particularly when combined with hip and knee strengthening, balance training, and movement retraining, is effective in reducing pain, improving function, and correcting biomechanical deficits. However, variability in intervention protocols and outcome measures limits definitive conclusions. Integrating neuromuscular control strategies should be considered a key component of comprehensive PFPS rehabilitation.

Index Terms—Patellofemoral pain syndrome, neuromuscular control, motor control training, proprioception, rehabilitation.

I. INTRODUCTION

Patellofemoral pain syndrome (PFPS) is one of the most prevalent knee disorders encountered in clinical and sports medicine settings. It is characterized by diffuse anterior knee pain that is aggravated during activities that increase patellofemoral joint loading, such as stair climbing, squatting, running, and prolonged sitting with knee flexion [1]. Despite its high prevalence, PFPS remains challenging to manage due to its multifactorial etiology and heterogeneous clinical presentation.

Traditional rehabilitation strategies for PFPS have primarily focused on isolated quadriceps strengthening and patellar alignment techniques. Although these approaches may provide symptomatic relief, recurrence rates remain high, and many individuals experience persistent functional limitations [2]. Recent biomechanical and neuromuscular research has shifted the focus toward proximal and distal contributors, including impaired neuromuscular control of the hip, knee, and trunk [3]. Abnormal movement patterns, such as excessive dynamic knee valgus, altered muscle activation timing, and reduced proprioceptive acuity, have been strongly associated with increased patellofemoral joint stress.

Neuromuscular control training (NCT) aims to address these deficits by enhancing coordinated muscle activation, improving joint stability, and optimizing movement strategies during functional tasks. This narrative review explores the theoretical basis, clinical application, and evidence supporting neuromuscular control training exercises in the management of PFPS.

II. METHODS

A narrative literature review was conducted using electronic databases including PubMed, Scopus, Web of Science, and Google Scholar. Literature published up to 2025 was searched using combinations of keywords such as “patellofemoral pain syndrome,” “neuromuscular control training,” “motor control,” “movement retraining,” “proprioception,” and “rehabilitation.” Priority was given to randomized controlled trials, systematic reviews, meta-analyses, and clinical practice guidelines. Studies investigating neuromuscular,

proprioceptive, or movement-based exercise interventions were included. Articles focusing solely on passive treatments or isolated strengthening without neuromuscular components were excluded.

III. RESULTS

A. Neuromuscular Deficits in Patellofemoral Pain Syndrome

Individuals with PFPS commonly demonstrate impaired neuromuscular control during functional activities. Kinematic studies have identified increased hip adduction and internal rotation, excessive knee valgus, and reduced trunk stability during tasks such as squatting and stair descent [4], [5]. Electromyographic investigations further report delayed activation of the vastus medialis oblique and reduced gluteal muscle recruitment, contributing to altered patellofemoral joint loading patterns [6].

B. Effects of Neuromuscular Control Training

Neuromuscular control training programs incorporating balance exercises, movement retraining, and task-specific drills have demonstrated clinically meaningful reductions in pain and improvements in functional performance [7]. Several randomized controlled trials report superior outcomes when neuromuscular training is combined with hip and knee strengthening compared to strengthening alone [8]. Improvements in dynamic knee alignment and movement quality have also been observed following NCT interventions.

C. Proprioceptive and Adjunctive Neuromuscular Interventions

Recent studies highlight the role of proprioceptive and foot intrinsic muscle training in PFPS rehabilitation. Incorporation of balance training and short-foot exercises has been shown to enhance postural control, reduce pain, and improve lower limb strength [9]. Additionally, neuromuscular electrical stimulation used as an adjunct to exercise therapy may offer modest improvements in quadriceps strength, although evidence for pain reduction remains inconsistent [10].

IV. DISCUSSION

The findings of this narrative review support the inclusion of neuromuscular control training as a central component of PFPS rehabilitation. Unlike traditional isolated strengthening approaches, NCT targets movement quality and coordinated muscle activation across the kinetic chain. Improvements in proprioception, motor planning, and dynamic alignment likely contribute to reduced patellofemoral joint stress and symptom relief.

Despite promising results, considerable heterogeneity exists across studies with respect to exercise selection, training dosage, and outcome measures. Some trials report no additional benefit of neuromuscular training beyond strengthening alone, suggesting that patient selection and baseline movement impairments may influence treatment response [11]. Future research should focus on standardized intervention protocols, long-term outcomes, and identification of patient subgroups most likely to benefit from neuromuscular approaches.

V. CONCLUSION

Neuromuscular control training represents an evidence-based and clinically relevant intervention for individuals with patellofemoral pain syndrome. By addressing deficits in movement control, proprioception, and muscle coordination, NCT contributes to pain reduction, functional improvement, and correction of biomechanical abnormalities. Integration of neuromuscular strategies alongside strengthening and functional training should be considered essential for comprehensive PFPS management.

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