Examination of Muscle Synergy in Knee Osteoarthritis Patients during Gait Activities before and after Physiotherapy

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Summary

This study compares muscle synergies of individuals with knee osteoarthritis (KOA) before and after 10 pain-relieving physiotherapy (PT) sessions (one month) as well as to those of an age-matched asymptomatic group during gait activities. Findings indicate that, although there are notable changes in muscle synergies between the KOA and asymptomatic groups, the synergy patterns are not affected significantly by just one month of PT.

Introduction

KOA is a common degenerative joint disease characterized by pain, stiffness, and reduced mobility thus significantly affecting the quality of life [1]. PT treatments improve muscle strength and control, leading to enhanced joint stability and functional performance, while reducing pain and promoting overall mobility and quality of life. Muscle synergy analyses provide a novel approach to assessing changes in muscle coordination and motor control. By examining synergy patterns before and after PT, this study seeks to understand whether there are any muscle synergy changes and also to determine neuromuscular adaptations after a PT treatment [2].

Methods

This study included 25 participants, comprising 14 patients with KOA (grades 2 and 3, Kellgren-Lawrence) who were assessed before and after 10 sessions of PT, along with 11 asymptomatic controls, all aged 45–65 years. The WOMAC Index and VAS questionnaire were used to assess PT effectiveness clinically. EMG data were collected from eight major muscles of the painful knee joint, including the quadriceps, hamstring, and calf muscles. Dimensionality reduction was performed using non-negative matrix factorization (NNMF), with the number of motor modules determined based on VAF (variance accounted for) thresholds (90% global and 80% local). Modules were clustered based on activation patterns using the k-means algorithm. Two indices were calculated: the Synergy Stability Index (SSI) to assess the repeatability of synergy structures and the Synergy Space Index (SCI) to measure the synergy space size [3]. Statistical analyses were performed using t-tests.

Results and Discussion

Patients with knee osteoarthritis had fewer muscle synergies than asymptomatic individuals before undergoing the PT program, in agreement with previous reports [4]. However, no significant differences were observed in the SSI between asymptomatic and KOA before PT. In contrast, significant differences were found in the SCI and the quality of muscle activity matrix reconstruction (VAF). After PT, while there were notable changes in clinical outcomes such as pain reduction (VAS, $p < 0.001$) and quality of life improvement (WOMAC, $p = 0.007$), only the SSI parameter altered considerably.

Table 1: Comparison of key parameters between groups

Parameters	Pre	Post	Asymptomatic
SSI	$0.48 \pm 0.14^{▲}$	$0.53 \pm 0.11^{▲●}$	$0.37 \pm 0.16^{●}$
SCI	$0.10 \pm 0.01^{■}$	0.11 ± 0.02	$0.12 \pm 0.02^{■}$
#Modules	$2.50 \pm 0.38^{■}$	2.54 ± 0.46	$2.88 \pm 0.41^{■}$

Pre – Post: ▲, Pre – Healthy: ■, Post – Healthy: ●, ($p < 0.05$)

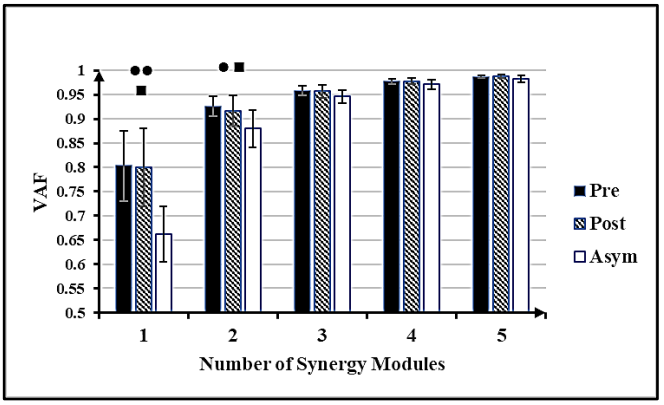

Figure 1: VAF based on the first five modules of synergies, *Pre – Healthy: ■, Post – Healthy: ● ($p < 0.05$), ●● ($p < 0.001$)*

Conclusions

The lower number of synergy modules reflects the reduced complexity of motor control in KOA patients compared to asymptomatic individuals. Despite experiencing reduced pain and improved functionality after PT, no significant improvement was observed in muscle synergy indices.

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