How does Exercise-Induced Fatigue Alter Neuromuscular Control during Three-Point Jump Shots in Highly Trained Basketball Players?

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Summary

This study examines the effect of exercise-induced fatigue on neuromuscular control in basketball players' three-point jump shots. Fifteen male players were fatigued through shuttle sprints and vertical jumps. EMG data from 16 muscles were analyzed. Results showed a decrease in shooting accuracy post-fatigue, with the number of muscle synergies reducing from five to four. Fatigue led to merged synergies during the preparation phase and significant changes in the push-off phase. The study highlights the CNS's adjustments in motor control strategies to maintain shooting performance under fatigue.

Introduction

Exercise-induced fatigue significantly impairs three-point jump shot accuracy by affecting neuromuscular control, including muscle activation patterns and postural balance [1]. However, the underlying mechanisms of these impairments remain unclear. Muscle synergies are low-dimensional control modules organized within the central nervous system that coordinate muscle activation to produce efficient movement patterns [2]. Synergy analysis offers a valuable approach to understanding how multiple muscles work together to optimize shooting performance [3]. This study aimed to compare the muscle synergies of highly trained basketball players during three-point jump shots before and after exercise-induced fatigue to better understand neuromuscular coordination under fatigued conditions.

Methods

Fifteen highly trained male basketball players participated in this study. Fatigue was induced through a high-intensity protocol combining shuttle sprints and vertical jumps to simulate game-related conditions. During pre- and post-fatigue testing, participants performed three-point jump shots continuously on force plates until three successful and three unsuccessful attempts were recorded, following a standardized warm-up and immediately after fatigue induction. Surface electromyography (EMG) was recorded from 16 muscles across the trunk, upper, and lower extremities during the shooting task. Muscle synergies were identified using non-negative matrix factorization (NNMF) to compare neuromuscular coordination before and after fatigue.

Results and Discussion

We observed five muscle synergies in successful shots before fatigue, which were reduced to four after fatigue. Unsuccessful shots consistently displayed four synergies both pre- and post-fatigue. Fatigue caused a merging of muscle synergies during the preparation phase, shifting from distinct upper and lower limb activation pre-fatigue to continuous co-activation post-fatigue, closely associated with changes in the center of pressure. During the ball elevation phase, the modular organization of muscle synergies remained unaffected with fatigue. However, significant alterations were observed in the motor modules and primitives of synergy 4 (responsible for push-off), particularly in the tibialis anterior and gastrocnemius lateral muscles, resulting in distinct muscle activation patterns and temporal shifts. The time-to-peak of synergy 4 vectors occurred significantly earlier before fatigue than after. During three-point jump shots in basketball, the changes in the central nervous system's modular control strategies highlight neuromuscular adjustments that are essential for maintaining shooting performance and accuracy under fatigue.

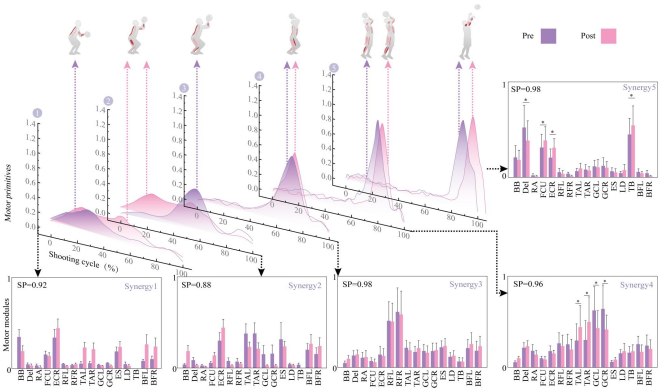

Figure 1: Motor modules and motor primitives of three-point jump shots under pre-fatigue (purple) and post-fatigue (pink) conditions.

Conclusions

This study is the first to compare muscle synergy patterns in three-point jump shots before and after fatigue. It identified five synergies pre-fatigue, which reduced to four post-fatigue. This indicates a simplification of motor control to maintain shooting accuracy. The findings highlight the importance of synergy reorganization and suggest that training could focus on this aspect to optimize shooting techniques.

References

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