The Impact of Targeted Lower-Limb Exercises on Biomechanical and Neuromuscular Adaptations for Preventing Medial Tibial Stress Syndrome

Ayman Bouamama[1,2] and Bora Büyüksaraç[1]
[1]Department of Biomedical Engineering, Bahçeşehir University, İstanbul, 34450, Turkey
[2] Email: ayman.bouamama@bahcesehir.edu.tr

Summary

Preventing Medial Tibial Stress Syndrome (MTSS) is crucial for active populations. This study assessed single-leg lateral hops (SLLH) and controlled step-downs (CSD) for biomechanical and neuromuscular adaptations relevant to MTSS prevention. Twenty participants, divided into SLLH and CSD groups, performed jump-landing tests. Analysis incorporated EMG, motion capture, and force plate data. SLLH significantly reduced dominant leg loading rate ($p<0.01$), peroneus brevis activity, and increased knee flexion while decreasing non-dominant leg CoP displacement. CSD produced less pronounced effects. These findings support SLLH as a promising intervention for reducing tibial stress and informing MTSS prevention.

Introduction

MTSS, often known as shin splints, is a frequent lower limb injury, especially common in runners, gymnasts and military personnel[1], primarily through excessive tibial loading and aberrant pronation. While current prevention emphasizes load management and supportive devices, exercise-based interventions remain underexplored. SLLH and CSD were selected for their potential to improve lower limb stability and neuromuscular control[2][3]. This study examined SLLH and CSD's immediate biomechanical and neuromuscular effects, hypothesizing their potential to reduce MTSS risk through tibial loading and pronation-related adaptations.

Methods

Twenty participants (age: 25 ± 3) were randomly assigned to SLLH and CSD groups (10 per group). Each participant performed their assigned exercise for three sets of six repetitions per leg. Single-leg forward jump-landing assessment tests were completed on a force plate before and after intervention. Analysis included surface EMG [Tibialis Anterior (TA), Peroneus Brevis (PB), Soleus (SOL), Gastrocnemius Medialis (GM), Rectus Femoris (RF)], joint kinematics and ground reaction forces. Key parameters included loading rate, EMG features (AUC, RMS, MAX) and kinematic variables (ROM, MAX angles). Statistical analysis used paired t-tests or Wilcoxon signed-rank tests ($p<0.05$).

Results and Discussion

Post-SLLH adaptations, expressed as percentage changes using pre-SLLH as baseline, are presented in (Figure 1). A decrease of 21.36% and 25.28% in loading rate and PB-AUC, respectively, was observed for the dominant leg, indicating reduced tibial loading and improved neuromuscular control. Knee flexion showed a 9.79% increase in ROM and a 7.80% increase in MAX angle, enhancing shock absorption. The non-dominant leg exhibited an 18.95% reduction in CoP displacement, reflecting improved balance. Neuromuscular adaptations included a decrease of 39.60% in TA-RMS, 26.99% in PB-AUC, and 21% in RF-RMS, suggesting more efficient landing mechanics. These adaptations address key MTSS risk factors.

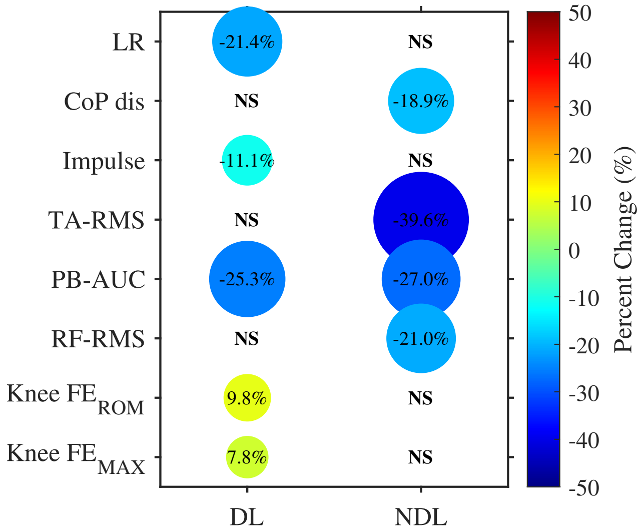

Figure 1: Bubble Chart of Biomechanical and Neuromuscular Parameter Changes Post-SLLH. Bubble size represents absolute percent changes, and color indicates direction of change. Cells marked "NS" denote non-significant changes ($p \geq 0.05$). DL (dominant leg), NDL (non-dominant leg), LR (loading rate), CoP dis (center of pressure displacement), TA-RMS (tibialis anterior RMS), PB-AUC (peroneus brevis area under the curve), RF-RMS (rectus femoris RMS), and Knee FE (knee flexion-extension)..

Conclusions

SLLH demonstrates immediate biomechanical and neuromuscular adaptations relevant to MTSS prevention. Reduced tibial loading combined with improved kinematics and neuromuscular control supports its efficacy as an intervention for at-risk populations. These findings establish a foundation for exercise-based MTSS prevention programs, though longitudinal studies are needed to validate long-term benefits and MTSS incidence impact.

References

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