Muscle Contribution to Net Joint Moments at the Hip and Knee Joints during Loaded Squats with and without Bounce

Hoon Kim[1,2], Basil Achermann[3,4], Taewoong Kong[2], Gyeongeun Lee[2], Silvio Lorenzetti[3,4]
[1]Department of Sports Medicine, Soonchunhyang University, South Korea
[2]Department of Software Convergence, Soonchunhyang University, South Korea
[3]Institute for Data Analysis and Process Design, ZHAW, Switzerland
[4]Institute for Biomechanics, ETH Zurich, Switzerland
Email: hkim0625@sch.ac.kr

Summary

This study investigated the effects of the bounce on muscle contributions to net joint moments (NJMs) at hip and knee during loaded squats. Bounced squats increased hip and knee NJMs compared to non-bounced squats, with greater hamstrings contribution at the hip and vastii contribution at the knee. These highlight the role of the stretch-shortening cycle in enhancing muscular demands with bounce and provide insights for optimizing techniques to improve lower-limb strength with bounce during squat.

Introduction

Squats are essential for developing lower extremity strength. "Bounce" technique is widely used to enhance muscle forces via stretch-shortening cycle (SSC) [1]. While load and depth effects are well-studied [2], the influence of bounce on muscle contributions to net joint moments (NJMs) remains unclear. This study investigated how bounce affects muscle contributions to the NJMs during loaded squats.

Methods

Nine healthy resistance-trained subjects performed loaded squats (0%, 25%, 50%, 75%, and 100% of body mass) with and without bounce. Hip and knee NJMs and contributions of adductors, hamstrings, gluteus maximus, vastii muscles (VAS), rectus femoris, tibialis anterior, gastrocnemius, and soleus to the NJMs were estimated using OpenSim. Two-way repeated measures analyses of variance were used.

Results and Discussion

There were significant main effects for bounce and load in hip NJM and significant differences in pairwise comparison at all loads in hamstrings' contribution to the hip NJM with ($p < 0.001$) (Figure 1). There were significant main effects for bounce and load in knee NJM and significant main effect for bounce in contribution of VAS ($p < 0.001$). The findings of this study show specific muscles' contribution to hip and knee NJMs depending on the squat style. The greater hip and knee NJMs during bounced squats compared to non-bounced squats was driven by greater contributions of hamstrings and VAS, respectively. These emphasize the role of hamstrings in controlling hip extension and VAS in controlling knee extension required in bounced movements, likely due to the enhanced use of SSC and the demand for extension during rapid transitions.

Conclusions

This study provides practical guidance for designing squat exercise styles, particularly in determining whether to incorporate a bounce, to enhance lower-limb strength and power. Future research should explore the effects of bounced squats on joint loads in terms of risks of injury.

Acknowledgments

This work was supported by Early-Career Grant 2024 Call of the Leading House for Asia (ECG_022024_01), SNSF (200021_192289/1), BK21 FOUR (No. 5199990914048), and Soonchunhyang University Research Fund.

References

[1] Manabe Y et al. (2007). *J Sports Med Phys Fitness*, **47**: 1
[2] Bryanton MA et al. (2012). *J* Strength Cond Res, **26**: 2820

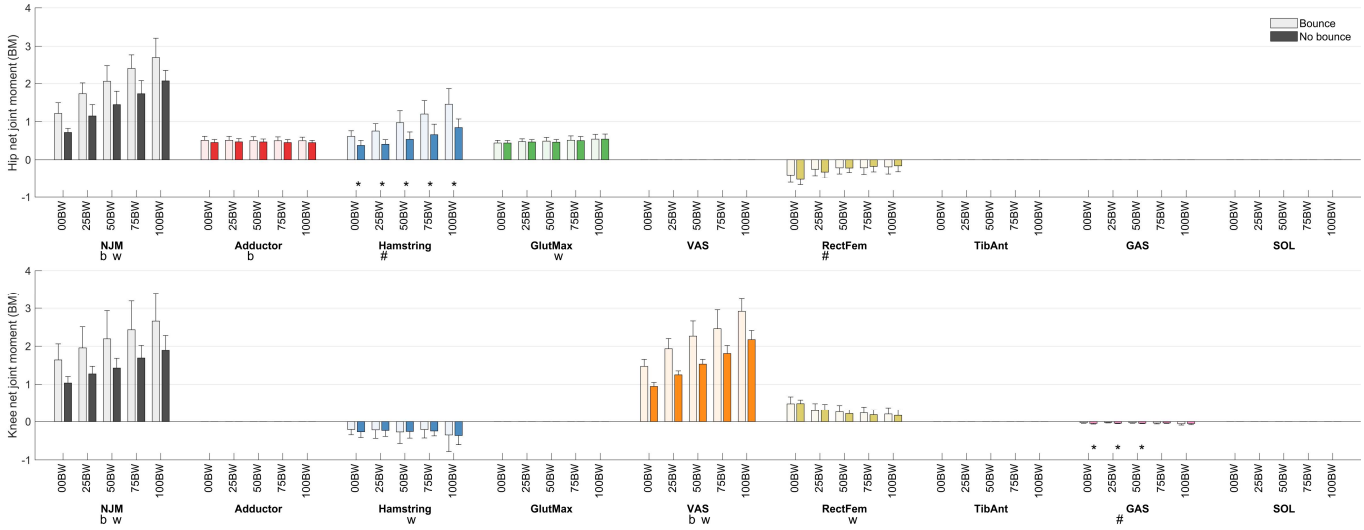

Figure 1: Mean ± SD of peak muscle contributions to hip and knee NJMs during bounced- and non-bounced-squats in each load condition. #, b, w, and * represent significant interaction effects, main effect for squat style, main effect for load, and pairwise comparison, respectively.