Influence of Subject Specificity of Gait Data on Internal Tensile Stress Distributions in Meniscus

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Summary

This study compared subject-specific and generalized gait inputs on meniscus mechanics in musculoskeletal finite element (MS-FE) knee models for three individuals. Simulations showed higher internal stresses in the medial meniscus with generalized gait input, while subject-specific gait input produced more uniform stress distribution between medial and lateral menisci. This highlights the importance of gait input selection on internal meniscus mechanics, potentially affecting tissue failure and injury risk assessment.

Introduction

Knee menisci have a critical role in knee functions like load distribution, impact absorption, joint stability, and lubrication. The function of knee menisci can be simulated, e.g., using MS-FE models. The simulated internal mechanical responses (stress, strain) can serve as predictors for meniscus injuries, degenerative tears, and knee osteoarthritis. However, uncertainties in knee-specific gait parameters often complicate FE modeling. Since measuring these gait parameters requires complex and clinically impractical setups, researchers frequently rely on generalized gait data from the literature. Yet, the impact of using subject-specific versus generalized gait data on simulated knee meniscus mechanics remains unclear. To address this, we investigated how the mechanical behavior of knee menisci differs in FE models when using subject-specific and generalized gait data.

Methods

We used knee joint models of three female subjects with osteoarthritis from our previous study [1]. Briefly, walking trials at self-selected speeds were conducted while markers trajectories (Vicon Plug-in Gait lower body marker set [2]) and ground reaction forces were recorded. Subject-specific gait data consisted of knee moments, knee flexion angle, and joint contact forces averaged from five trials. Generalized gait data was created by averaging data from 15 individuals with knee osteoarthritis [3], scaling contact forces to body mass. Subject-specific and generalized gait inputs were applied to the femoral reference point, and the stance phase of one gait trial was simulated (Figure 1). Using a validated MS-FE framework [3], menisci were modeled as fibril-reinforced poroelastic material, cartilage as fibril-reinforced poroviscoelastic, and attachments as linear springs, with bovine material properties. The collagen fibril orientation in the meniscus was circumferential (Figure 1), while in the cartilage, it was arcade-like.

Results and Discussion

FE simulations revealed differences in stress distributions between generalized and subject-specific gait inputs. Under generalized gait data, higher tensile stress concentrations were observed in the medial meniscus during the majority of the stance phase. Subject-specific gait produced more uniform stress distributions between the medial and lateral menisci across all subjects. These findings highlight how the choice of gait input can influence stress predictions in knee joint modeling, which could have implications for assessing meniscus injury risks based on mechanical loading patterns.

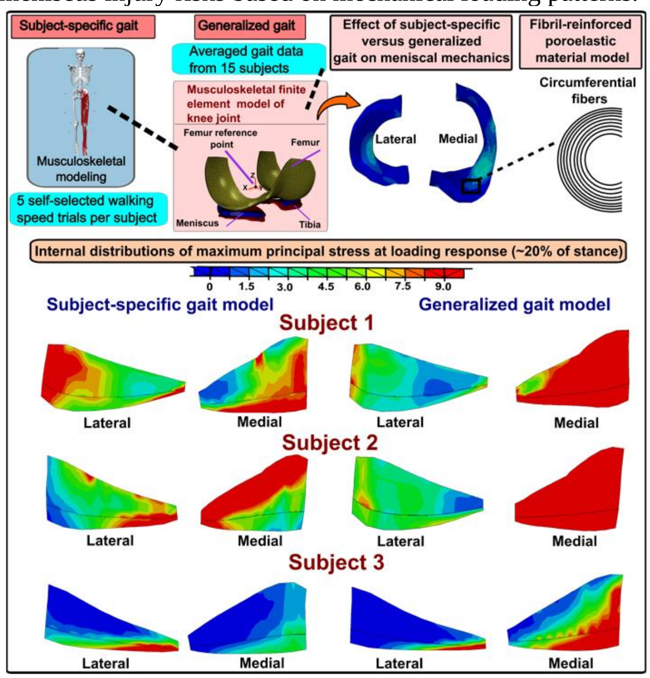

Figure 1: Comparison of internal tensile stress distributions in mid-meniscus cross-sections under subject-specific and generalized gait inputs at loading response (~20% of stance).

Conclusions

Subject-specific and generalized gait inputs yielded different meniscal stress distributions in FE knee models. These differences emphasize the potential influence of gait input selection on meniscus injury risk assessments.

References

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