Effects of Seat Height and Resistance on Knee Joint Kinematics and Moments During Stationary Cycling Using Three-Dimensional Fluoroscopic Imaging and Instrumented Paddle

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Summary

This study examined how seat height and resistance affect knee kinematics and joint loading during stationary cycling using 3D fluoroscopic imaging. Results show that high seat height shifts medial cartilage contact posteriorly, which may benefit anterior-medial knee osteoarthritis. Resistance increases knee joint moments, with standard seat height under resistance (SR) exhibiting the highest peak loading. Lowering the seat slightly reduces peak moments while maintaining similar patterns. These findings provide insights for optimizing rehabilitation and injury prevention strategies.

Introduction

Stationary cycling is widely used in knee rehabilitation, particularly for patients recovering from ligament injuries and reconstruction. Understanding the effects of seat height and pedaling resistance on knee biomechanics is crucial for optimizing rehabilitation protocols and preventing excessive joint loading. This study investigates how variations in seat height and resistance influence knee joint moments and articular contact mechanics using three-dimensional fluoroscopic imaging. The findings provide insights for personalized rehabilitation strategies and injury prevention in clinical and sports settings.

Methods

Twelve healthy male participants (age: 23.4 ± 1.71 years, height: 1.74 ± 0.04 m, mass: 69.6 ± 12.2 kg, BMI: 23.0 ± 3.67) without neuromusculoskeletal disorders were recruited. Each participant's left knee was imaged using CT (voxel size: 0.586 × 0.586 × 0.625 mm³) and MRI to create subject-specific bone models. Participants performed stationary cycling at 30 rpm under four conditions: standard seat with resistance (SR), standard seat without resistance (SN), lower seat with resistance (LR), and lower seat without resistance (LN). A bi-plane fluoroscopy system (30 Hz) was used to track knee motion during cycling. Bone models were registered to fluoroscopy images using a volumetric model-based method, from which rigid-body kinematics and articular contact points were calculated. Pedal reaction forces and moments were measured using an instrumented pedal, and knee joint moments were calculated by these forces relative to the knee joint center based on registered bone poses.

Results and Discussion

Knee kinematics and loading varied with seat height and resistance. High seat height shifted the medial cartilage contact posteriorly, potentially reducing anterior-medial knee stress, while the lateral contact translated anteriorly. Resistance (SR, LR) increased knee loading, with SR showing the highest peak moment. Lowering the seat slightly reduced peak moments while maintaining a similar trend. No-resistance conditions (SN, LN) minimized joint stress. These findings highlight the need to optimize seat height and resistance for rehabilitation and injury prevention.

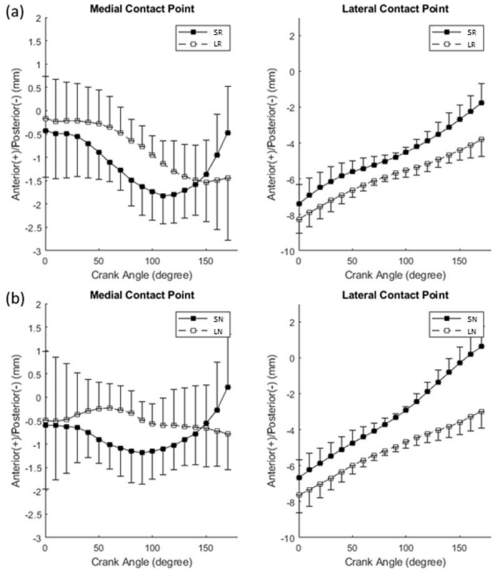

Figure 1: Comparisons of the contact positions between high seat height (black markers) and low seat height (white markers) conditions are shown in (a) for loaded and (b) for unloaded.

Conclusions

Seat height and resistance significantly affect knee kinematics and joint loading during stationary cycling. A high seat height alters medial-lateral cartilage contact patterns, potentially benefiting individuals with anterior-medial knee osteoarthritis. Resistance increases knee joint moments, with SR showing the highest peak loading. These findings provide valuable biomechanical insights for optimizing cycling parameters in rehabilitation and injury prevention.

Acknowledgments

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References

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