Three-Dimensional Center of Mass Relative to the Center of Pressure in ACLD Copers Walking Uphill

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Summary

Anterior cruciate ligament (ACL) injuries often lead to knee instability and gait asymmetry, which may increase fall risk. ACL-deficient (ACLD) copers regain function without surgery, but subtle postural deficits may persist, particularly during demanding tasks. This study examined the inclination angle (IA) and its rate of change (RCIA) in ACLD copers during uphill walking. Compared to controls, ACLD copers showed increased IA on the affected side and reduced IA and RCIA on the sound side across gait phases ($p<0.05$). These findings suggest forward leaning on the affected limb for stabilization and cautious adjustments on the sound side, highlighting compensatory gait asymmetry.

Introduction

ACL injuries often result in knee instability, altered gait, and increased fall risk due to impaired balance control [1]. While ACLD copers regain function without surgery, subtle deficits in stability and neuromuscular control may persist, particularly during inclined walking. Copers often exhibit reduced knee flexion, diminished knee extensor moments, and increased reliance on hip and ankle muscles to protect the knee, but these adaptations may lead to asymmetrical loading and imbalance [2]. IA and RCIA assess whole-body dynamic balance. This study investigates IA and RCIA in ACLD copers during uphill walking to identify postural asymmetries.

Methods

Thirteen ACLD patients and thirteen healthy controls, matched for age, gender, height, and mass, participated. ACLD was confirmed clinically and via MRI. Copers had ACL injury for 3 months to 5 years without instability during walking. Participants walked uphill on a 10-meter walkway with a 3-meter section at 3°, 6°, and 9° inclines. Ground reaction forces (GRFs) and 3D motion were captured. IA and RCIA were calculated from COM-COP relationships in sagittal and frontal planes. A mixed-design ANOVA assessed group and slope effects ($p<0.05$).

Results and Discussion

Compared to controls, ACLD copers exhibited increased sagittal inclination angle (IA) on the affected side at heel-strike and reduced IA on the sound side ($p<0.05$). At toe-off, IA increased on the sound side, with no differences on the affected side ($p<0.05$). In the frontal plane, IA increased on the sound side at heel-strike and decreased during swing ($p<0.05$). The sagittal IA range increased on the affected side during stance, while the frontal IA range increased on the sound side. RCIA was reduced on the sound side in both sagittal and frontal planes at heel-strike and swing ($p<0.05$). These results suggest forward leaning on the affected limb for stabilization and cautious adjustments on the sound side, indicating bilateral gait asymmetry and compensatory postural adaptations.

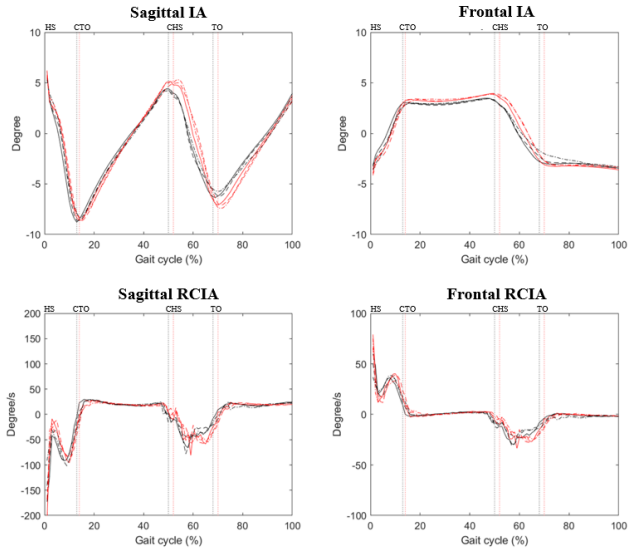

Figure 1. Ensemble-averaged IA and RCIA in the sagittal and frontal planes for the affected side (red), sound side (black dashed), and Control group (black) during a gait cycle across 3°, 6°, and 9° uphill walking.

Conclusions

ACLD copers display altered IA and RCIA patterns during uphill walking, suggesting compensatory stability strategies. Forward leaning on the affected limb aids knee stabilization, while slower adjustments on the sound side reflect cautious control. These asymmetries highlight the need to assess dynamic stability to reduce fall risk and guide rehabilitation.

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References

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