Toe-Out Landing Reduces the Risk of Lateral Ankle Sprain in People With Chronic Ankle Instability

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Summary

Landing often predisposes individuals to lateral ankle ligament injuries, yet directly measuring ligament strains during exercise remains challenging. We recruited 30 individuals with chronic ankle instability (CAI) and used a three-dimension rigid-body foot model driven by kinematic data to simulate ankle ligament strains under different landing conditions, aiming to identify a safe landing approach.

Introduction

During landings, lateral ankle sprain (LAS) occurs in up to 57% of cases, with the anterior talofibular ligament (ATFL) and calcaneofibular ligament (CFL) frequently injured in individuals with CAI [1]. Direct measurement of ligament strain during motion is challenging; previous studies relied on indirect measures such as ground reaction force and joint torques. However, recent advancements in three-dimensional rigid-body foot modeling now enable direct simulation of ligament strain during landing. While out-toeing has been suggested to decrease lateral ankle ligament strain, this hypothesis lacks sufficient validation. In this study, we recruited CAI participants and employed a three-dimensional rigid-body foot model to assess ATFL and CFL strains under toe-out landing (TL) and natural landing (NL) conditions. We hypothesized that TL would reduce both ATFL and CFL strain compared to NL.

Methods

Thirty participants with CAI were recruited. Each landed on a specialized trap-door device, with the unaffected limb on a support platform and the affected limb on a moveable platform that could be flipped 24° inward and 15° forward to simulate a LAS condition. Two landing conditions were tested: NL with a natural toe-out angle and TL with an increased toe-out angle exceeding 150% of NL. Kinematic data were collected using a 12-camera motion analysis system, and ATFL and CFL strains were calculated using a three-dimensional rigid-body foot model. Data were analyzed using paired sample t-tests and Pearson's correlations.

Results and Discussion

Compared to NL conditions, the ATFL strain decreased ($p < 0.001$, $d = 2.42$), while the CFL strain remained unchanged ($p = 0.229$, $d = 0.09$, fig. 1) under TL conditions. The toe-out angle was negatively and strongly correlated with the ATFL strain ($r = -0.743$, $p < 0.001$) but not with the CFL strain ($r = 0.153$, $p = 0.251$, fig. 2).

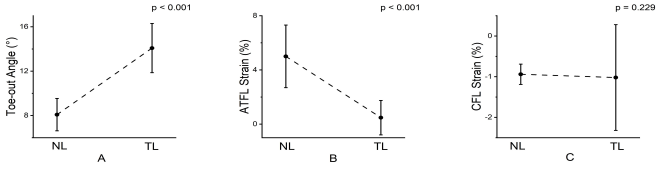

Figure 1: Toe-out angle and ligament strains between NL and the TL conditions

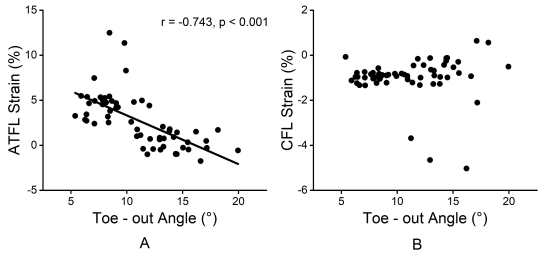

Figure 2: Correlations of toe-out angle to ligament strains

Out-toeing may mitigate the ATFL strain through three mechanisms. Firstly, reduced ankle inversion shortens the ATFL's origin-to-insertion distance [2]. Secondly, a larger toe-out angle tightens the talocalcaneal groove against the tibial protrusion, enhancing ankle stability and reducing ATFL dependence [3]. Thirdly, ATFL load reduction may align with peroneal muscle behavior during toe-out landing, particularly pre-activation of the peroneus longus and co-contraction with the tibialis anterior [4].

Conclusions

Increasing the toe-out angle may reduce the ATFL strain and maintain the CFL strain during drop-landing in people with CAI, thereby reducing the risk of LAS.

Acknowledgments

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