Untangling Genetics and Environment in Foot Biomechanics: Insights from Identical Twins

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Summary

This study examines the relative influence of genetic and environmental factors on foot morphology and function in identical twins. Twin pairs showed close correlations of foot length and arch height, indicating strong genetic determination for morphological traits. Functional traits such as the kinematic coupling of the first metatarsophalangeal joint and the medial longitudinal arch showed comparatively lower correlations, suggesting that they were more influenced by environmental differences. Our results highlight the relative plasticity of foot mechanics, while also indicating that static morphology is less sensitive to environment. These findings improve our understanding of foot biomechanics and may inform personalized strategies for the prevention and management of foot pathologies.

Introduction

Foot morphology and function are partly shaped by genetic background, but their plasticity in response to environmental factors remains unclear. While foot length and arch height are considered heritable traits, they may also be influenced by environmental factors such as physical activity and footwear. Functional traits could also be influenced by environment. One such function is the kinematic coupling between the first metatarsophalangeal joint (MTP) and the medial longitudinal arch (MLA), which is thought to serve as an indicator of the foot's windlass mechanism [1]. This study examines these traits in identical twins to disentangle genetic and environmental effects on foot form and function.

Methods

Eighteen pairs of identical twins and a control group of 19 individuals participated. Foot length and arch height were measured alongside functional kinematic coupling between MTP and MLA motion during heel raise tasks. The coupling was quantified using the Distal Foot Coupling Ratio (DFCR) [1]. Variance components analysis, incorporating linear mixed-effects models, was used to separate genetic and environmental contributions, while Bland-Altman plots assessed measurement variability.

Results and Discussion

Foot length (93.8%) and arch height (81.2%) showed high between-pair variance (Fig. 1A and B), indicating strong genetic influence. In contrast, DFCR during heel raises exhibited relatively low between-pair variability (25.2%) (Fig. 1C), suggesting significant non-shared environmental contributions. Bland-Altman analyses confirmed higher variability in functional traits within twin pairs compared to the morphological traits.

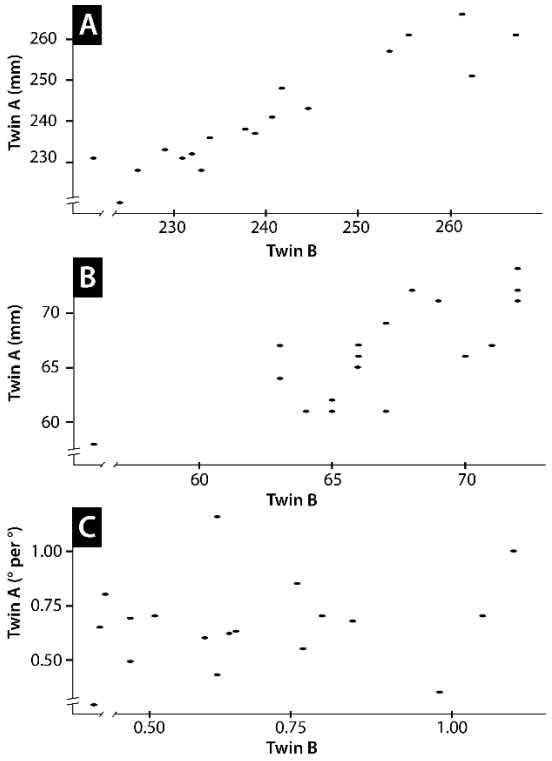

Figure 1: Comparison between pairs of identical twins for A) Foot length, B) Arch height and C) Kinematic coupling between the first metatarsophalangeal joint and the medial longitudinal arch.

Conclusion

Our results suggest that genetic factors primarily determine foot anatomical traits like length and arch height, while functional traits, such as kinematic coupling, are more influenced by environmental factors like physical activity and neuromuscular adaptation.

These insights help explain susceptibility to foot pathologies, such as flatfoot or plantar fasciitis, where both structural and functional factors play a role. Identifying high-risk individuals based on foot mechanics could support personalized prevention strategies, including targeted exercises or footwear recommendations. Further research should explore longitudinal changes and incorporate kinetic and neuromuscular analyses.

Reference

[1] Williams et al. (2022). *J Foot Ankle Res*, **16**;15(1):16.