Lower-Body Kinematic Evaluation via Single and Multi-Segment Foot for Asymptomatic Presentations of Flatfoot

Katrina R. Cernucan[1,2], Kassidy Knutson[1], K. Bo Foreman[3], Karen M. Kruger[4,5], Amy L. Lenz[1]
[1]Foot & Ankle Mechanics and Morphology Lab, Dept. Mechanical Engineering, University of Utah, Salt Lake City, USA
[2]Rocky Mountain Center for Occupational and Environmental Health, University of Utah, Salt Lake City, USA
[3]Dept. Physical Therapy & Athletic Training, College of Health, University of Utah, Salt Lake City, USA
[4]Dept. of Biomedical Engineering, Marquette University, Milwaukee, USA
[5]Motion Analysis Center, Shriners Children's, Chicago, USA
Email: katrina.cernucan@utah.edu

Summary

Lower-body kinematics were collected via optical motion capture on adults with asymptomatic pes planus (flatfoot) and contrasted with adults with pes rectus (neutral feet). Resulting gait kinematics were obtained and compared via statistical parametric mapping. Significant differences were observed across joint angles of the hips, single-segment foot, and multi-segment foot of the dominant limb that indicate compensatory motions going beyond the foot itself.

Introduction

Pes Planus, also known as flatfoot, has been a potential military disqualification criterion as early as the mid-1800s, even for individuals who do not routinely experience foot pain or discomfort [1]. Contemporary justifications for flatfoot exclusion from armed services typically relate to an elevated risk of injury, such as foot blisters or musculoskeletal injury, or that an originally asymptomatic instance of flatfoot changes to a symptomatic one over time [1]. Although evidence regarding injury outcomes remains mixed, countries with mandatory military service, such as South Korea, often use flatfoot as an exclusion criterion for active-duty service [2]. To elucidate whether kinematic differences exist that may alter injury risk profiles, radiograph-informed multi-segment foot joint angles and lower-body joint kinematics were contrasted for adults with asymptomatic flatfoot (AFF) relative to a healthy control population (CNO) with neutral feet to gauge relative differences in gait kinematics [3].

Methods

Optical-passive motion capture with ground reaction force data were collected for seven adults with neutral feet (CNO, 29.3 ± 2.87 yrs) and seven adults with asymptomatic flatfoot (AFF, 29.4 ± 3.7 yrs). The Milwaukee Foot Model (MFM) was combined with a modified Plug-In Gait marker set to obtain pelvis, hip, knee, single-segment foot, and multi-segment foot kinematics [3]. Weight-bearing computed tomography scans were obtained for all participants to generate radiographic offset inputs required for MFM. Dominant-limb hip, knee, and single-segment foot angles were calculated within Visual3D (HAS-Motion, Kingston, CA), in addition to multi-segment foot joint angles. Statistical parametric mapping (SPM) was utilized to identify ranges of statistically significant differences for all metrics, $\alpha = 0.05$ [4].

Results and Discussion

With respect to MFM outcomes, coronal hindfoot (inv-eversion), coronal forefoot (varus-valgus), and sagittal tibia tilt (not shown) demonstrated statistically significant differences between the CNO and AFF populations over the entirety of the gait cycle (Figure 1). Dominant-limb hindfoot of AFF participants were more everted than CNOs, and distinct compensatory forefoot varus was also noted in the AFF population. These results suggest that flatfoot is associated with significantly modified segment kinematics, even in asymptomatic presentations.

When exploring compensatory impact at other joints, significantly diminished frontal plane hip adduction was noted among AFFs during midswing relative to CNOs (Figure 1), in addition to greater dominant-limb internal hip rotation from heel strike to the end of terminal stance and from midswing to heel strike (not shown in Figure 1). Individuals with AFF demonstrated compensatory motions that suggest medial collapse up the kinematic chain as a result of their morphological and kinematic variations. These in turn may modify an individual's risk for injury, whether by differences in force application along the plantar surface, loading response, or maintenance of lower limb alignment during gait.

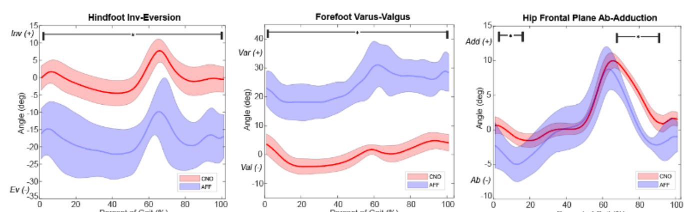

Figure 1: Hindfoot Inv-Eversion (Left), Forefoot Varus-Valgus (Middle), and Hip Frontal Plane Ab-Adduction (Right).

Conclusions

Significant compensatory strategies were observed for adults with AFF relative to controls, in response to their flatfoot. Future work will consider single-segment and multi-segment foot kinetics, in addition to evaluation of non-dominant limb kinetics and kinematics.

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