

Kinetic and Kinematic Evaluation of Healthy Adult Asymptomatic Flatfoot

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INTRODUCTION: Pes planus, also known as flatfoot, is a foot deformity characterized by a flattening of the arches. Flatfoot can be classified into two categories: asymptomatic and symptomatic. Individuals with symptomatic flatfoot may experience lower extremity discomfort; however, asymptomatic patients may nevertheless have an increased risk of injury and accidents due to potential changes in weight-bearing [1]. Both forms of flatfoot may also be comorbid with conditions including Marfan syndrome and cerebral palsy [2,3]. However, the condition is often found asymptotically in children and adolescents and may continue into adulthood. Because of its prevalence among these populations, previous kinematics research has largely focused upon the effects of pes planus for both symptomatic and asymptomatic pediatric cases [4,5]; however, limited work has been done evaluating the adult population with asymptomatic flatfoot. Whether or not individuals with asymptomatic flatfoot have functional differences relative to neutral feet has been a point of contention, as highlighted by the recently overturned exclusion of asymptomatic pes planus from US military service [6]. Therefore, motivation for this study was to compare lower-extremity kinetic and kinematic gait profiles of adults with asymptomatic flatfoot versus a control population of individuals with neutral feet to identify potential biomechanical differences. We hypothesized that patients with asymptomatic flatfoot would exhibit lower body compensatory mechanisms secondary to medial collapse [7].

METHODS: Optical-passive motion capture was performed at the University of Utah's Motion Capture Core Facility. This study was approved by the University of Utah's Institutional Review Board. Three adults (age: 29.8±6.3yrs, height: 167.2±5.6cm) with asymptomatic flatfoot (AFF) were contrasted against three individuals (age: 27±2.6yrs, height: 183.2±6.4cm) with neutral feet (CNO). Participants' feet were screened by an orthopaedic surgeon for arch categorization. Gait cycles were captured for both populations using a modified Plug-in Gait model. Ground reaction forces (GRFs) were collected using an elevated force structure mounted to a singular force plate (AMTI). The resulting data were post-processed using a Woltring filter employing the generalized cross-validation (GVC) method within Vicon Nexus 2 (Vicon Motion Systems Ltd.), and a 6Hz Butterworth filter was applied on trajectories and GRF data [8,9]. Gait events were identified automatically based on GRF and the target pattern recognition algorithm in the biomechanical post-processing software Visual3D (C-Motion). Joint angles of flexion/extension, abduction/adduction, and internal/external rotation were created for the dominant limb's knee joint and pelvis in Visual3D. For the ankle joint, only dorsi/plantarflexion was considered. Similarly, internal normalized joint moments of the knee were calculated for all three anatomical planes during stance phase, and sagittal moments were computed for the ankle joint. To determine statistical significance, statistical parametric mapping (SPM) was utilized to highlight areas of statistical significance between the AFF and CNO populations across all metrics in their corresponding planes [10]. An *a priori* alpha value of 0.05 was utilized to define statistical significance for analyses.

RESULTS: Statistically significant differences between the control and AFF populations were observed with respect to joint moments over stance. During heel strike, individuals with asymptomatic flatfoot exhibited statistically significant elevated rotational ankle moments relative to their neutral-footed counterparts. For all statistically significant variables, normal-footed individuals' joint angles began and consistently remained closer to zero than asymptomatic individuals. Consistent valgus is observed in the AFF population and statistically significant differences are observed during heel strike and the first half of weight-bearing and late-stage toe-off (Figure 1). Increased posterior pelvic tilt was observed during heel strike, most of weight-bearing, and the latter portion of toe-off (Figure 1). Similarly, greater statistically significant downward pelvic obliquity with respect to the dominant limb is observed for the AFF cohort over the entirety of gait (Figure 1).

DISCUSSION: These findings suggest that individuals with asymptomatic flatfoot perform compensatory motions brought about by their diminished medial longitudinal arch. The combination of more prominent knee valgus and elevated rotational knee moment indicates a greater dependence on the medial portions of the foot when shifting into weight-bearing. Asymptomatic valgus positioning takes place when the limb is either in contact with the ground or in preparation for ground contact. Those with AFF experience greater pelvic posterior tilt to facilitate prompt contact with the ground during heel strike and more stability during weight-bearing and the latter portion of toe-off. A more overt dependence on one side of the body for those with asymptomatic flatfoot may be an indicator of factors such as flatfoot severity. It should be noted that this work only considers participants' dominant limbs, and the severity of flatfoot between limbs can differ. Future work will quantify and contrast the severity of pes planus between both limbs to determine differences with respect to the utilized metrics, while also evaluating the trunk and hip. Additional joint moments and powers will also be considered. Recognizing these differences can help elucidate potential risk factors of injury for adults with asymptomatic flatfoot, inform orthotic designs that can better mitigate compensatory behaviors, and begin to clinically understand differentiating factors between adults with asymptomatic versus symptomatic flatfoot.

SIGNIFICANCE/CLINICAL RELEVANCE: Recognizing functional differences between those with healthy neutral feet and asymptomatic flatfoot can facilitate the identification of compensatory risk factors that may lead to symptomatic flatfoot.

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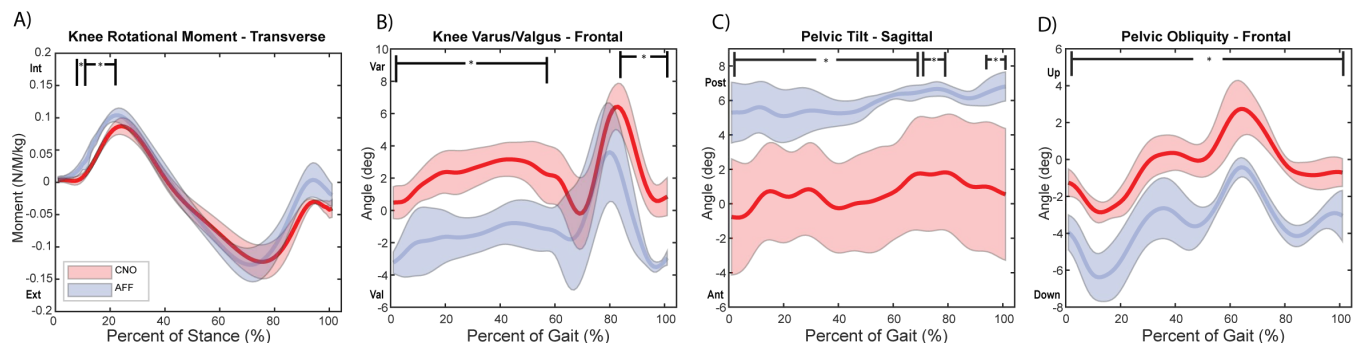


Figure 1. A) Knee internal rotational moment during stance phase, B) Knee varus/valgus positioning over gait, C) pelvic tilt over gait, and D) pelvic obliquity over gait. Areas of statistical significance (alpha = 0.05) are denoted by an asterisk.