Function of the posterior tibialis muscle is important in maintaining stability of the navicular, due to its distal attachment point. Pathological conditions of the posterior tibialis muscle have been documented to contribute to acquired flatfoot (i.e., pes planus) in adults, and posterior tibialis weakness is a primary contributor to medial tibial stress syndrome (MTSS). The incidence of posterior tibial syndromes has been reported to be as high as 35% for naval recruits. Foot classification is based on a wide range of assessments, including motion capture systems, indexes, dynamic assessments, imaging, and clinician observation. Clinicians rely on history, observation, and functional tests to diagnose musculoskeletal conditions and to clinically evaluate pathomechanics. Changes in the kinematics of the lower extremity have been observed when the vertical position of the navicular bone drops, and when the posterior tibialis muscle is fatigued. Recent studies have demonstrated that lower leg fatigue is associated with change in foot coupling mechanics during gait, diminished neuromuscular control, and increased postural sway. Additionally, excessive navicular drop may have an association with anterior cruciate ligament tear.

A number of studies have examined the relationship of lower leg muscle fatigue and foot pronation to specific injuries and overuse syndromes. The purpose of this study was to evaluate navicular drop before and after fatigue of the ankle invertor muscles among individuals with different foot types.

**Context:** Navicular drop is widely believed to be an indicator of elevated susceptibility to pronation-related injuries, which may be increased by fatigue in the muscles that dynamically support the medial longitudinal arch. **Objective:** The purpose of this study was to evaluate navicular drop before and after fatigue of the ankle invertor muscles among individuals with different foot types. **Participants:** 20 male and 16 female recreationally active, college-age volunteers (20.03 ± 1.48 years of age). **Methods:** Navicular drop was measured before and after inducing fatigue in the ankle invertor muscles. Participants’ foot types were classified as high-arch, neutral, or low-arch. **Results:** There was no interaction between foot type and trial, and no main effect for trial. A main effect for foot type was significant (p = .001). Intra-class correlation coefficients for prefatigue and postfatigue measurements indicated good internal consistency. **Conclusion:** Our findings failed to provide any evidence to support the existence of a relationship between ankle invertor muscle fatigue and static measurements of change in navicular height from a sitting to standing position. **Key Words:** Posterior tibialis muscle, foot pronation, muscular fatigue.
includes the posterior tibialis muscle, would result in a comparable change in navicular drop across different foot types.

**Procedures and Findings**

Prior to recruiting participants, institutional review board approval was obtained for the study. Informed consent was also obtained for each participant prior to their involvement. Participants were 20 male and 16 female, recreationally active, college-aged volunteers (20.0 ± 1.5 years of age). No participant reported a history of injury, surgery, physical activity intolerance, or the use of orthotics within three months prior to participating in the study. Participants were instructed to refrain from engaging in exercise for 12 hours prior to testing to eliminate the potential for persisting muscle fatigue.

A fine-tipped felt marker was used to identify the apex of the navicular tubercle on the dominant foot of each participant. Measurement of navicular height was obtained with a 6-inch electronic micrometer (iGaging, San Clemente, CA), which provided a digital reading with a 0.01mm level of precision (Figure 1). Navicular height was first measured in a sitting position, and then in a standing position to determine the amount of navicular drop induced by weight-bearing.° Three successive measurements were obtained by the same researcher, both before and after inducing fatigue. Each participant’s foot was classified as low arch, neutral, or high arch according to the visual criteria established by Dahl et al.°

An isokinetic dynamometer (Biodex System 3, Biodex Medical Systems, Shirley, NY) was used to measure the peak torque generated by the ankle invertor muscles of the dominant extremity (Figure 2). Five repetitions were performed at a test velocity of 30 degrees per second. Each participant then performed up to 6 sets of 10 repetitions of concentric/eccentric ankle invertor exercise at a velocity of 30 degrees per second to induce fatigue in the dominant extremity. A 10-second rest period was allowed between sets. Fatigue was defined as the point at which torque output was decreased by 30% from the initial measurement. Immediately following completion of the fatigue protocol, the navicular height measurement was repeated.

A 3 (foot types) × 2 (trials) analysis of variance was used to evaluate the change in navicular drop after performance of the fatigue protocol at an alpha level of p < 0.05. There was no interaction between foot type and trial (F2,33 = 1.61, p = .214), and no main effect for trial (F1,33 = .109, p = .743). A main effect for foot type was significant (F2,33 = 8.08, p = .001). A Tukey post-hoc test was used to assess differences in post-fatigue navicular drop measurements between foot types. There were significant differences between the neutral and low arch foot types and between the low and high arch foot types (Table 1, Figure 3). Intra-class correlation coefficients for the internal consistency of the 3-measurement sets of pre-fatigue and post-fatigue navicular drop values are presented in Table 2.

![Figure 1](image1.png) **Figure 1** Digital height gauge.

![Figure 2](image2.png) **Figure 2** Participant positioning for strength testing and fatigue protocol.
Discussion

The fatigue protocol did not have a significant effect on navicular drop. There were significant navicular drop differences between neutral and low-arch cases, and between low-arch and high-arch cases, but no significant difference between neutral and high-arch cases. Previous studies of the effect of muscle fatigue have analyzed overall changes in lower extremity kinematics. Isolation of small localized changes may be equally important. Previous research has demonstrated that navicular drop affects hip kinematics, but it does not appear to be a risk factor for traumatic knee ligament injury.

Although fatigue was not found to affect navicular drop, prolonged physical activity may have adverse effects on dynamic function of the posterior tibialis and related foot kinematics. Taping the medial longitudinal arch has been shown to alter foot kinematics and relieve discomfort, which suggests that some relationship exists between abnormal navicular kinematics and development of tendon dysfunction. Patients who exhibit substantial navicular drop may derive benefit from taping or orthotics, as well as therapeutic exercise that increases the strength and endurance of the posterior tibialis.

We did not differentiate low-arch cases on the basis of rigid versus flexible pes planus deformity, which may have affected our results. Other measurements of medial longitudinal arch structure, such as the Feiss-line test, should be considered for future research on the possible effects of fatigue on susceptibility to pronation-related injuries. In addition, specific rehabilitation protocols for pronation-related conditions should be evaluated to document any beneficial changes in foot kinematics.

Conclusions

Our measurements of navicular drop demonstrated an acceptable level of internal consistency, but we did not observe a change in navicular drop after inducing fatigue in the ankle invertor muscles of healthy, recreationally-active, college-age participants. Posterior tibialis muscle fatigue may have an effect on dynamic function of the foot that increases susceptibility to injuries, but our methods failed to provide any evidence to support the existence of a relationship between ankle invertor muscle fatigue and static measurements of change in navicular height from a sitting to standing position.

References


Fredrick Anthony Gardin, David Middlemas, Jennifer L. Williams, Steven Leigh, and Rob R. Horn are with Montclair State University. Monique Mokha, PhD, ATC, Nova Southeastern University, is the report editor for this article.