

MORPHOMIC AND MATERIAL PROPERTIES OF FEMALE HUMAN FOOT-ANKLE SPECIMENS

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ABSTRACT

The characterization of the morphometric and material properties of the foot and ankle has many applications, including the development of a female-specific finite element model (FEM) to investigate military incidents and determine personal protective equipment standards. The calcaneal and heel pad morphomics and arch characterization parameters of ten female post-mortem human specimens with an age range of 59 to 87 were quantified and statistically evaluated to provide required data for the FEM. Measurements obtained through two-dimensional computed tomography (CT) image post-processing methods quantified the seven parameters that define calcaneal and heel arch morphomics. The highest standard deviation was found in the Bohler angle measurements, which had a mean value of 42.4 ± 14.2 degrees. The results show a mean height of the anterior process (HAP) of 2.4 ± 0.3 cm, length of the calcaneal axis (LCA) of 6.3 ± 0.6 cm, height of the posterior facet (HPF) of 2.5 ± 0.3 cm, length of the posterior facet (LPF) of 2.4 ± 0.3 cm, length of the anterior process (LAP) of 1.6 ± 0.4 cm, critical angle of Gissane of 139.1 ± 8.4 degrees, and heel pad thickness of 2.0 ± 0.4 cm. Heel arch was measured to examine differences in high and low arch ratios because of their influence on injury potential. The highest standard deviation was shown in the first ray angle (RAY) measurements, which had a mean value of 27.9 ± 4.5 degrees**.** Measurement resulted in a mean foot length (FL) of 18.8 ± 1.9 cm, truncated foot length (TFL) of 14.6 ± 1.8 cm, navicular height (NAV) of 3.6 ± 0.6 cm, dorsum height (DORS) of 4.8 ± 0.6 cm, calcaneal first metatarsal angle (CA-MT1) of 114.1 ± 4.0 degrees, and calcaneal inclination angle (CAI) of 140.9 ± 3.7 degrees. An intraobserver repeatability study was performed and resulted in a range of poor to excellent scores, with any low correlation coefficients attributed to a reduced sample size and variable specimen positioning during CT scanning. The required data for a female-specific FEM of the lower leg was acquired and can be applied to advance the understanding of anthropometry-based differences in fracture patterns of foot-ankle bones in military environments, among other applications.

Keywords: arch characterization, biomechanics, calcaneal morphometrics, heel pad thickness

INTRODUCTION

As female military recruitment continues to increase, it is necessary to rely on gender-specific data to accurately evaluate trauma and prescribe safety measures, such as personal protective equipment. In military studies, a finite element model (FEM) can be used to simulate underbody blast trauma incidents, evaluate fracture type under various load conditions, and gear requirements. Previous studies primarily consist of male or non-demographically representative conditions, which requires the collection of additional data. A study performed by Qiang et al. on an Asian group through three-dimensional CT reconstruction showed significant gender-related differences in six out of seven calcaneal morphomic parameters [1]. The calcaneus has a fracture occurrence of approximately two percent of reported fractures and plays a key role in stability, which impacts mobility and injury prevalence and necessitates protective measures through model evaluation [2]. By obtaining measurements from two-dimensional CT scans due to the advantages of choosing a standard slice selection, it is possible to create a statistical shape model similar to that developed by Melinska et al. to examine calcaneal feature geometry and support endeavors such as diagnosis, surgical planning, fracture classification and treatment, and implant procedure development [1,3]. The heel pad plays a unique role in absorbing shock and is also an important input to a foot-ankle complex model [4]. The foot arch ratio provides the dimensional data for an accurate model, especially when injury patterns are evaluated. Williams et. al noted a difference in injury patterns between runners with high and low arches [5]. Military personnel often include running as a part of their physical