Orthotics and Prosthetics

Characterization of Prosthetic Feet for Weighted Walking in Service Members with Lower-Limb Amputations

Despite the large number of prosthetic feet available to persons with lower limb amputation, the mechanical properties best suited to specific ambulatory tasks are largely unknown. Service members with major limb loss often perform load carriage tasks in returning to service or other high-impact occupations. Researchers at Walter Reed National Military Medical Center, Extremity Trauma and Amputation Center of Excellence (EACE), and Minneapolis Veterans Affairs first mechanically characterized nine commercially available prosthetic feet (Figure 1) and subsequently investigated loaded walking in two feet at the extremes of stiffness profile; specifically, one with the most "linear" stiffness profile and one with the most "non-linear" stiffness profile (i.e., largely increased stiffness at loads exceeding body weight) (*Golyski et al. 2017a, 2017b, Koehler-McNicholas et al. 2017, Nickel et al. 2017*). The non-linear foot was hypothesized to better accommodate weighted walking, as the biological ankle-foot exhibits a similar non-linear stiffness to maintain shape with load. Fourteen males with unilateral transtibial amputation walked in two feet marketed towards carrying loads, with and without an added 22-kilogram load, and at speeds of 1.34 and 1.52 meters per second. Contrary to the hypothesis, the non-linear stiffness foot exhibited higher loads in the sound limb than the linear foot at both speeds and loading conditions (*Golyski et al. 2017a, 2017b*). Additionally, the non-linear foot produced less positive work in terminal stance, which may explain increased sound limb loading. The mechanical properties of the two prosthetic feet may explain the deviation from the initial hypothesis. Specifically, overall stiffness was larger for the non-linear foot. Higher prosthetic foot stiffness has been suggested to result in larger first peak vertical ground reaction force on the intact limb. Such larger passive stiffness results in lower energy absorption and proportional return, and has been previously associated with increased intact limb loading. Results of this study indicate that a more compliant prosthetic foot may reduce intact limb loading and provide greater stability, independent of the linearity of stiffness, when walking with or without added load. These findings demonstrate the importance of supplementing mechanical with clinical testing to understand the biomechanical implications of the full complement of mechanical properties in any prosthetic device.

> Knowledge from this study could lead to more informed choices in prosthetic foot selection for Service members interested in returning to active duty or participating in high performance activities.

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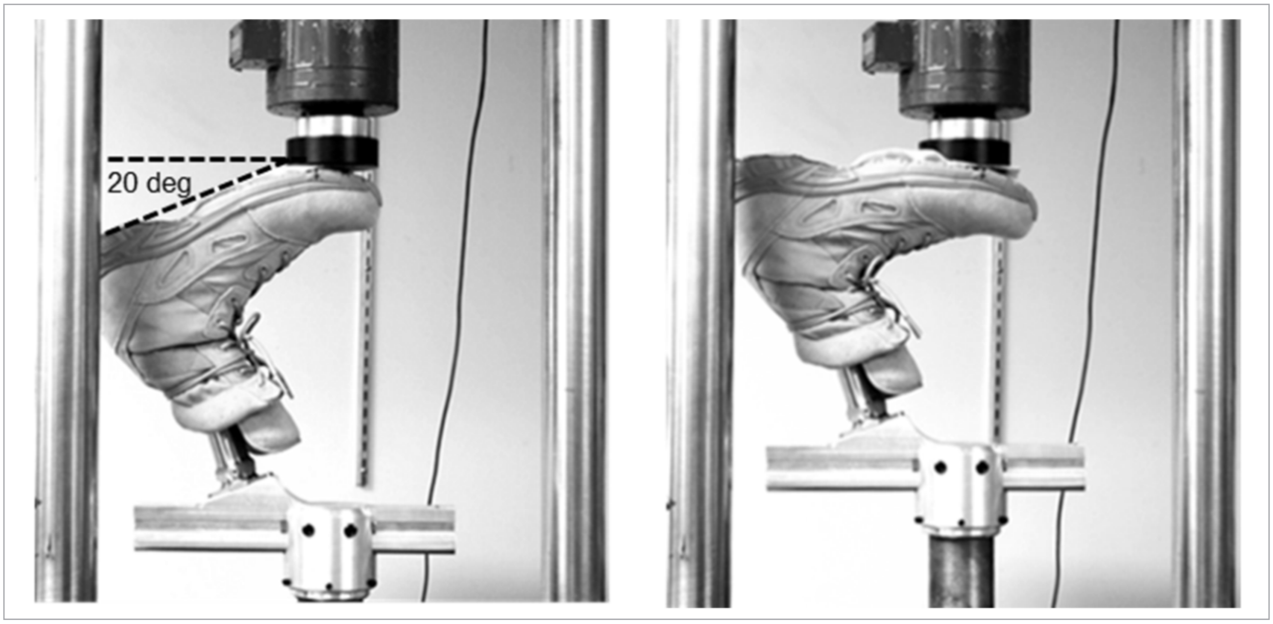

FIGURE 1: Load versus deflection profiles were obtained using a servohydraulic universal test frame (MTS 858, MTS, Eden Prairie, MN) with axial/torsional capabilities, and a load cell (MTS 661-21A-01, MTS, Eden Prairie, MN). The foot was mounted in the fixture such that the plantar surface of the boot was set at a 20-degree angle from horizontal, simulating forefoot loading as defined by the ISO 10328 standard. Load versus deflection curves were used to calculate forefoot stiffness, which were normalized by BW to calculate means across subjects. (Figure 2 from Koehler-McNicholas et al. (2017) used with permission from authors)

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