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A prosthesis-specific multi-link segment model of lower-limb amputee sprinting

Original Article

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Abstract

Lower-limb amputees commonly utilize non-articulating energy storage and return (ESAR) prostheses for high impact activities such as sprinting. Despite these prostheses lacking an articulating ankle joint, amputee gait analysis conventionally features a two-link segment model of the prosthetic foot. This paper investigated the effects of the selected link segment model's marker-set and geometry on a unilateral amputee sprinter's calculated lower-limb kinematics, kinetics and energetics. A total of five lower-limb models of the Ottobock® 1E90 Sprinter were developed, including two conventional shank-foot models that each used a different version of the Plug-in-Gait (PiG) marker-set to test the effect of prosthesis ankle marker location. Two Hybrid prosthesis-specific models were then developed, also using the PiG marker-sets, with the anatomical shank and foot replaced by prosthesis-specific geometry separated into two segments. Finally, a Multi-link segment (MLS) model was developed, consisting of six segments for the prosthesis as defined by a custom marker-set. All full-body musculoskeletal models were tested using four trials of experimental marker trajectories within OpenSim 3.2 (Stanford, California, USA) to find the affected and unaffected hip, knee and ankle kinematics, kinetics and energetics. The geometry of the selected lower-limb prosthesis model was found to significantly affect all variables on the affected leg ($p < 0.05$), and the marker-set also significantly affected all variables on the affected leg, and none of the unaffected leg variables. The results indicate that the omission of prosthesis-specific spatial, inertial and elastic properties from full-body models significantly affects the calculated amputee gait characteristics, and we therefore recommend the implementation of a MLS model.

Keywords: Energy storage and return; Joint kinematics; Inverse dynamics; Gait analysis; Motion capture.