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Short communication

Amputee Independent Prosthesis Properties—A new model for description and measurement

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ABSTRACT

A model is presented for describing the Amputee Independent Prosthesis Properties (AIPP) of complete assemblies of trans-tibial prosthetic components distal to the socket. This new AIPP model includes features of both lumped parameter and roll-over models and describes prosthesis properties that are of importance in stance phase, including prosthetic foot geometry, normal stiffness, shear stiffness, and damping (energy dissipation). Methods are described for measuring the parameters of the AIPP model using a custom test-rig, commercial load-cell, and a motion capture system. Example data are presented for five pylon angles reflecting the shank angles seen in normal gait. Through the inclusion of measured AIPP in future in-vivo studies comparing different prostheses more generic information, as opposed to product specific claims, will become more widely available to inform future designs, prescription, and alignment procedures.

1. Introduction

The large majority of studies investigating the effects of prosthesis design on amputee performance have compared the biomechanical and physiological effects of different prostheses, but without reference to their mechanical properties (Hofstad et al., 2004). Unfortunately, this approach cannot provide information on why a particular prosthesis performs differently than the next, only that it does. A smaller number of studies (Berge et al., 2004; Curtze et al., 2009; Flick et al., 2005; Geil, 2001, 2002; Hansen, 2008; Hansen et al., 2000, 2006; Kabra and Narayanan, 1991; Klute et al., 2004; Lehmann et al., 1993a, 1993b; Miller and Childress, 1997; Postema et al., 1997; Sam et al., 2000, 2004; Saunders et al., 2003; Skinner et al., 1985; van Jaarsveld et al., 1990; vd Water et al., 1998) have characterised prostheses in terms of their mechanical properties, measured in ways that are independent of the amputee. However, with notable exceptions (Hansen et al., 2006; Lehmann et al., 1993a, 1993b; Miller and Childress, 1997; Postema et al., 1997; vd Water et al., 1998), very few authors have combined both types of study in an attempt to understand the correlations between Amputee Independent Prosthesis Properties (AIPP) and amputee gait (comfort, biomechanics, and physiological performance). In this context, AIPP are defined to be the mechanical properties of the prosthesis that directly influence the comfort and performance of the amputee. In other words, they are properties that an amputee directly experiences rather than the underlying design details that result in the AIPP. For example, prosthesis stiffness properties influence:

a) the roll-over curve (stance phase kinematics);
b) shock absorption during load acceptance;
c) energy return in late stance.

Therefore the desired AIPP, which provide good amputee performance, can be used as a design specification that the designer attempts to achieve through design details such as prosthetic component geometry and materials selection.

If a greater number of studies are to include the measurement of AIPP, there is a need for a clear and comprehensive means of representing those properties with supporting measurement techniques. Previous work can be loosely categorised using one of the two alternative representations: lumped parameter models or roll-over curves.

A common representation of stance phase properties is the lumped parameter, or spring and damper model (Klute and Berge, 2004; Miller and Childress, 1997). The stiffness and damping properties are quantified through static or dynamic testing, and usually measured only in the sagittal plane (Berge et al., 2004; Klute et al., 2004; Lehmann et al., 1993b; Miller and Childress, 1997; van Jaarsveld et al., 1990). The roll-over shape, as described by Hansen et al. (2000), is the path followed by the centre of pressure (COP) described in a coordinate frame attached to the prosthesis shank.

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