INTERSEGMENTAL DYNAMICS OF THE SWING PHASE OF WALKING IN TRANS-TIBIAL AMPUTEES

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INTRODUCTION

Unilateral, trans-tibial amputees reflect significant inertial asymmetries between the intact and prosthetic limbs [1] and also exhibit temporal, kinematic, and kinetic gait asymmetries during walking [2]. Early modeling research [3] suggested lower extremity inertial symmetry may lead to more symmetrical gait patterns in unilateral amputees. Mattes et al. [1], however, found that matching inertial properties exacerbated existing temporal asymmetries. In an effort to better understand the influence of inertial manipulation on swing phase dynamics for unilateral, trans-tibial amputees, we examined the effect of matching the inertial properties of prosthetic and intact legs on intersegmental dynamics at the knee and hip during walking.

METHODS

Six males with unilateral, trans-tibial amputations (age: 32±12 yrs, body mass: 85±6 kg, body height: 179±6 cm, time since amputation: 3-15 yr), using energy storing prosthetic limbs, were first acclimated to treadmill walking and prosthesis load conditions. Inertial properties of the intact and prosthetic limbs were measured or estimated [4]. In a separate session, subjects completed overground walking at 1.34 m/s as sagittal plane motion and ground reaction force data were sampled (60 Hz and 480 Hz, respectively) under three prosthetic limb inertial conditions: 1) a baseline condition in which no load was added to the prosthetic limb, 2) a 100% mass condition in which prosthetic limb mass and moment of inertia about a transverse axis through the knee were matched to those of the intact limb, and 3) a 50% mass condition in which the added load was half that added to the limb for the 100% condition.

An intersegmental dynamics approach was used to partition net moments about the knee and hip into interaction, gravitational, and muscle components [5]. Absolute angular impulses for each moment component were computed and used to express each as a percentage of the total of the three components.

RESULTS AND DISCUSSION

Net moments and moment components attributed to muscle, gravitational, and interaction during the swing phase (Figure 1) of walking were consistent in amplitude and pattern with published data for able-bodied walking [5]. Intersegmental dynamics at the knee and hip of the intact limb were not affected by inertial increases of the prosthetic limb. In contrast, the magnitude of moment components at both the hip and knee of the prosthetic leg increased systematically as prosthesis inertia was increased. In addition, the relative contributions of the individual moment components were altered, particularly at the knee where the relative contribution of muscle increased and interaction contribution decreased (Figure 2). Increased muscle moments at the hip and knee as prosthesis inertia increased paralleled higher metabolic costs of walking observed by Mattes et al. [1] for the same load conditions.

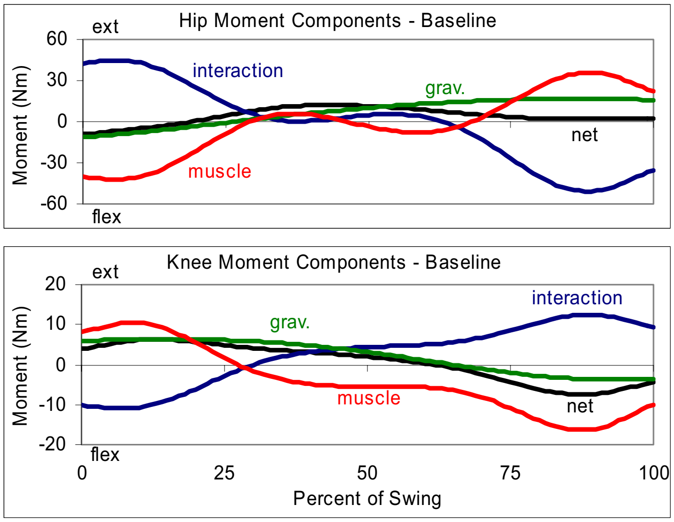

Figure 1. Net joint moment and partitioned components for the hip and knee joints of the prosthetic leg (unloaded condition; swing phase only). Note the counterbalancing effects of the muscle and interaction components at both joints. The intact leg showed similar patterns.

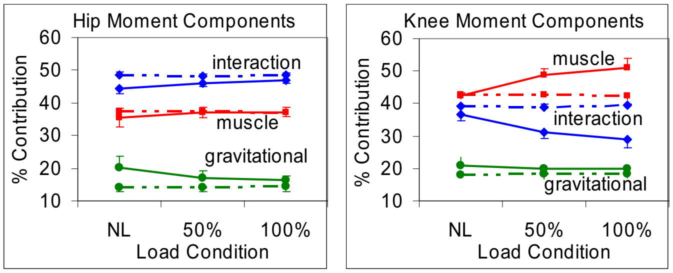

Figure 2. Relative contributions of the muscle, gravitational, and interaction components for prosthetic leg (solid lines) hip and knee were altered as prosthetic limb inertia increased. There were no changes for the intact leg (dashed lines).

CONCLUSION

The increased relative contributions of the muscle moments to the net moments at the hip and knee suggest that the prosthetic limb requires more active control by the musculature as prosthesis inertia increases.

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