Estimation of Actuation System Parameters for Prosthetic Ankle

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Introduction: The loss in mobility following amputation results in a degradation of the quality of life of the amputees as it affects many aspects of their personal and professional lives. Lower limb prostheses are used to replace the lost limbs and assist amputees in restoring their missing mobility functions. Despite the current technological advances in prosthetics, amputees still suffer from gait asymmetry and high metabolic energy costs. The gait asymmetry pattern and high metabolic energy costs occur due to: the inability to deliver the required level of assistance/power at the right time and the inertia and mass distribution asymmetry between the intact and the prosthetic leg.

Purpose: The purpose of this study is to identify the energy and actuator requirements for the ankle joint based on data from healthy subjects to improve the amputee performance.

Method: The selection of the actuator and actuation mechanism is based on the maximum peak torque, rated continuous torque, maximum speed, maximum working range required by the mechanism, and the inertia of the system. These parameters are calculated using the clinical gait data for the ankle joint of a healthy subjects from three different published data [1-3].

Results: The average range of motion required for the healthy ankle is $29.5^o \pm 2.9^o$ and the maximum plantarflexion and dorsiflexion angles are $17.9^o \pm 1.8^o$ and $11.6^o \pm 2.8^o$, respectively. The maximum peak torque is 1.5±0.157 Nm/kg that is generated by the ankle joint during the stance phase to assist foot plantarflexion and to give a proper heel rise. The ankle joint generates maximum braking torque of 1.4±0.118Nm/kg at the end of dorsiflexion phase and at the start of the stance phase to resist the body weight. The maximum angular velocity, 39.97±7.5rpm, occurs during the ankle plantarflexion during the stance phase while the maximum dorsiflexion angular velocity achieved in the swing phase is about 22.14±3.7 rpm. The average rated continuous torque is 0.658±0.0638 Nm/kg.

Conclusions: In this study, the estimated kinematic and torque parameters which are required to design and select the actuation system for ankle joint is calculated based on normative data. The results showed that the net positive power required at the ankle joint specifically in the stance phase is markedly larger than the knee joint. The three clinical gait data used in these results have about 20% variability among them because of the variability of marker placement among the several laboratories and the simplified models used for solving the inverse dynamics to calculate the joint torques.

References:

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