ON THE FORCE SHARING PROBLEM IN PATIENTS SUFFERING JOINT PAIN

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Introduction

Gait pattern in patients suffering joint pain usually shows alterations which may differ according to the pain origin. Whether caused by an accident, a sport injury or arthritis, the reason for joint pain may be associated to damage on muscles near the joint, damage on cartilage between skeletal segments as well as ligament injury [Calmbach and Hutchens, 2003].

It is well known that the human body is redundantly actuated (i.e., it has more muscles than degrees of freedom), and that leads to the force sharing problem in biomechanics [Anderson and Pandy, 2001]. In this study, we assume that muscles are activated by the Central Nervous System (CNS) according to a minimum-pain strategy. Translating minimum pain into a cost function related to well-defined dynamical variables (muscle forces, muscle stresses, joint contact forces, etc.) is not straightforward. The aim of this work is precisely to investigate the most suitable cost function leading to a distribution of muscle activations consistent with electromyographic data (EMG).

Methods

The kinematical and dynamical gait pattern of a patient with an injured left knee meniscus has been measured in the laboratory. An optical motion capture system composed by 12 Natural Point OptiTrack FLEX:V100R2 cameras has been used to capture the motion, and ground contact forces have been measured by means of two force plates AMTI Accugait. From these data, the total force and moment about the joints (ankle, knee and hip) have been calculated using inverse dynamics.

The results of inverse dynamics are used as inputs to solve the force sharing problem through optimization techniques. The usual eight muscles (Gluteus, Iliopsoas, Hamstrings, Rectus Femoris, Vastus, Gastrocnemius, Soleus and Tibialis Anterior) are taken into account. Our cost function J is a weighted mean of three usual cost functions J_i (square sum of muscle forces, of muscle stresses, and of muscle activations computed through Hill's model [Van Soest and Bobbert, 1993]), plus a new one J_{new} taking into account the square sum of contact forces at the joints:

$$J = \omega_1 J_1 + \omega_2 J_2 + \omega_3 J_3 + \omega_4 J_{new}, \qquad (1)$$

where the ω_i are the weighting parameters. The moment arms and the positions of the muscles origin and insertion points are taken from OpenSim [Delp *et al.*, 2007]. In order to validate the results, EMG data have been measured using eight EMG surface sensors Biometrics SX230 and specialized software eBiom (LabSid S.L.).

Results

Muscle activations are being qualitatively analyzed and compared with EMG data. Figure 1 shows EMG data of four muscles acting on the knee during one gait cycle (starting at the left toe off).

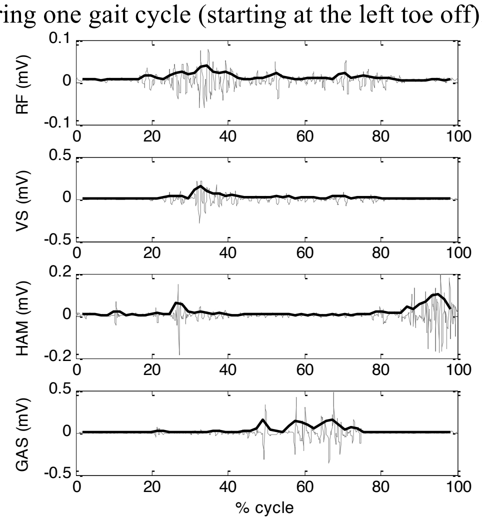

Figure 1. EMG during the gait cycle.

Discussion

The optimization criterion followed by the CNS of an injured patient when activating the muscles differs from that of a healthy one. The knowledge of such criterion may be helpful to predict muscle forces in patients suffering from joint injuries. This works deals with the identification of the corresponding cost function.

References

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