

P. E. Bourret, D. Rancourt, S. Martel and E. A. Clancy, "Prediction of Elbow Mechanical Impedance with Surface EMG," *Proceedings of the Sixteenth Congress of the International Society of Electrophysiology and Kinesiology*, Torino, Italy, pp. 72-73, June 29-July 1, 2006.

PREDICTION OF ELBOW MECHANICAL IMPEDANCE WITH SURFACE EMG

Bourret PE¹, Rancourt D¹, Martel S¹, Clancy EA²

1) Laboratoire Perseus, Université de Sherbrooke, Sherbrooke, Canada

2) Worcester Polytechnic Institute, Worcester, MA, USA

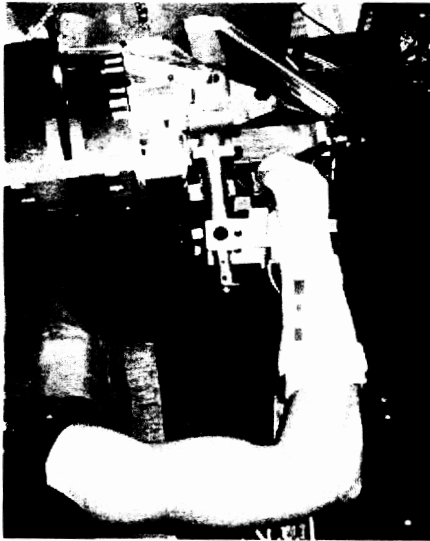
AIMS: The long-term objective of this research effort is to relate surface EMG signals to the mechanical impedance of the human elbow. Mechanical impedance of the musculo-skeletal system has been measured for a number of joints, primarily during well-controlled laboratory conditions. Given its importance for motor control studies, there is a need to develop a technique capable of predicting joint mechanical impedance in more complex daily tasks. Our overall aim is to use surface EMG for that purpose. The specific goal of this study was to develop a mechanical apparatus and protocol to estimate the parameters of a linearized second order joint mechanical impedance model (i.e., inertia, damping and stiffness), for future use in EMG to mechanical impedance studies.

METHODS: Subjects were seated on a fixed chair, with their shoulder at 90 degrees abduction, and their elbow at 90 degrees flexion in almost full supination (as shown in Figure). The hand/forearm was strapped in a cast attached to a two DOF joystick which could shake their limb in the horizontal plane, over a ± 15 degree flexion range. Subjects were asked to maintain a fixed level of biceps activation, while a 1-6 Hz bandwidth perturbations pseudorandom force perturbation was exerted on the cast at the contact point with the joystick. The resulting motion of the forearm at the cast location was measured with a high resolution encoder. Using least squares techniques that related the angular to the applied torque perturbations, system identification of the elbow inertia, damping and stiffness was performed. In this preliminary investigation, tests were conducted with the subject passive (fully relaxed), and during low and high elbow constant

co-contraction levels. Tests were also conducted by replacing the human subject by a mechanical mass-spring system to validate the system identification process.

RESULTS: Results showed accurate estimates of the inertia and stiffness of the mechanical mass-spring system. The prediction of exerted force calculated from these impedance parameters showed excellent correlation with actual exerted force by the joystick ($r^2 > 0.95$). However, inertia estimates of the human subjects (apparent inertia about 0,8 Kg) were only valid for passive conditions ($r^2 = 0.90$). Stiffness values ranged from 580 N/m (low co-contraction level) to 850 N/m (high co-contraction level), while damping was 32 and 37 Ns/m, respectively. Mathematically removing inertial forces, so that only damping and stiffness needed to be estimated, increased stiffness values to 800 and 1250 N/m, respectively, while damping was unchanged. These damping and stiffness values are in the range of those already described in the literature. However, results showed medium correlation ($r^2 = 0.75$).

CONCLUSIONS: Relating surface EMG to elbow mechanical impedance may require a more complex dynamic model than a linear second order system.



Top view of forearm attached to two DOF joystick