An Experimental Design for Measuring Neck Reflex Function

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Introduction
The human neck is modeled as a biological, second order, inverted pendulum. The central nervous system can change the properties of this system (stiffness and damping) by activating muscles. We wish to study the reflex response of the neck in flexion and extension (forward and backward rotation of the head). In order to accomplish this, four goals were setup:

1. Develop an experimental setup which will allow for perturbations to be safely applied to a seated subject's head in any direction in the horizontal plane
2. Test the natural frequency of the frame
3. Use the system to test a second order system
4. Use this system to study the reflex response and characterize the stiffness of the head/neck system

Methods

Experimental Setup
We built a free-standing frame to support an electric motor which will apply the perturbations to the subject's head through a load cell (Figure 1). The frame allows force to be applied at any direction in the horizontal plane. We will use an OptoTrak 3D-motion analysis system (Northern Digital, Waterloo, Ontario) to record the motion of the subject's head with respect to the trunk. Electromyographs (EMG's), which measure the electric activity within muscles, will be recorded from four neck muscles.

Natural Frequency
In order to determine whether the frame was stiff enough for our experiments, we tested its natural frequency using both accelerometers and positional markers attached to the frame (Figure 2). Using a pendulum device, we applied perturbations to the frame at various locations in various directions. We then performed Fast Fourier Transform (FFT) analysis on the data to determine the natural frequency.

\[ I\theta + B\dot{\theta} + K\ddot{\theta} + C\dot{\theta}^2 = \int Mdt^2 \]

Human Subjects
Our final tests will involve human subjects. We will apply positional markers and EMG's to the subjects. We will then seat the subject in the dental chair shown (Figure 1) and use the straps to hold their torso stationary. The subject will wear a helmet with a spike protruding from the top. Our motor will apply a force to the spike and we will record the head angular position and EMG data. We will fit the angular data as in the second order identification to determine the stiffness. The EMG data will yield the amplitude and onset latencies of the muscles' reactions.

Results

Natural Frequency
We performed an FFT on the accelerometer data to determine the natural frequency of the frame. Comparing with baseline FFT's resulted in a natural frequency for the frame of about 10 Hz (Figure 5). This is well above our expected value of 5.5 Hz (Horak et al 1994) for the human head/neck system and should not interfere with our tests.

Discussion
These studies will help us to gain a greater understanding of how the human head/neck system works. Identifying the system parameters will improve mathematical models of the neck. This has clinical applications in neck injuries such as whiplash.

Future investigators will use the device we built to test the neck system in different directions to further quantify its properties. They may also look at clinical populations such as whiplash injury patients or even stroke patients.

Future Work
We have completed the natural frequency section of our experiment. In the next few months, we will perform all of the second order tests as well as the human subjects tests.

References
Horak, Shupert, Dietz, and Horstmann; Exp. Brain Res. (1994) 100:93-106

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