EXPLORING HUMAN ADAPTATION USING ULTRASONIC MEASUREMENT TECHNIQUES AND OPTIMIZED, DYNAMIC HUMAN NECK MODELS

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INTRODUCTION: The purpose of this project is to introduce a new body motion data acquisition technology and incorporate the function with a sophisticated computer model of the human neck. The ultrasonic device captures the changing of the length of the skin between sets of sensors during movement. By strategically placing the sensors on the human body, the skin motion can be translated to body segment motion through a calibration procedure or by applying the data to actuators in a computer model of the human neck. The computer model of the neck can provide insights into the biomechanical behavior of the cervical spinal column by producing data on disk pressure during certain activities.

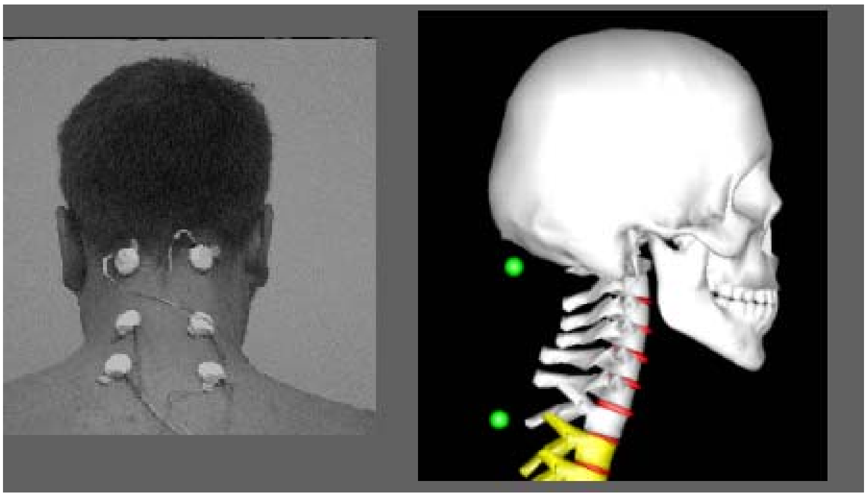

Figure 1. The sensor setup and the equivalent computer model with actuators.

METHODS: The data collection device (Orthoson), which is portable on the body, assesses body movements with an ultrasonic measurement method. For this purpose, four small ultrasonic sensors are applied to skin points with a distance changing during body movements. The changes in distance are measured with an accuracy of 0.3 millimeter. Both ultrasonic sensors are attached to the skin with stick rings. The ultrasound is coupled on the body under a flat angle to the skin surface.
Detection of body movements/positions is performed using an ultrasonic distance measuring device with sensors which are applied to the skin. The device operates with four channels and six sensors each consisting of one transmitter and one receiver. The ultrasonic sensors are applied to suitable body regions detecting skin

dilatation or contraction occurring movements. The distance measurement is based on the nearly constant spreading velocity of ultrasound in body tissue.
Since the device captures the nonlinear skin stretch distance the sensors must be placed strategically on the body to record joint rotation. Figure 1 displays the arrangement of the sensors on the back of the neck. The first pair are located at the base of the neck with the nearest vertebrae being the atlas, the second pair is located at the location of the C3 and the third pair is located at the C7 vertebrae. Data for the flexion/extension neck motion is recorded at 10 hz. for a motion duration of 6 seconds.
Figure 1 displays the computer model of the cervical spine and head. The computer model of the cervical spine is developed using the ADAMS (Mechanical Dynamics Inc.) mechanical simulation software system complete with 8 parts representing C1-7 and the skull. The parts are modeled as rigid bodies and coupled together with hinge joints since the motion is strictly in the sagittal plane for this flexion/extension example. MRI scan data of the bones are imported into the model. To determine mass properties for the model basic anthropometric data (Baughman) are used for the head and the neck mass and inertial properties are distributed about 7 equally dimensioned cylinders representing slices of the neck. For the present study, the ligament forces are represented as spring/damper elements to prevent bone impingement. Rotational spring/damper elements are used at the hinge joints to represent the composite stiffness of the stabilizing musculature in the neck. Data for these forces were derived from (Kelps). Contact forces at the anterior side of the vertebrae provide the compliance properties of the disks using force/deflection data from (Matyjewski).
To drive the dynamic model using data from the ultrasonic device, an actuator arrangement is coupled to the neck/skull model. The actuator model consists of 4 translational joints attached to the bones in the model at the locations of the sensors on the test subject. The attachment of the actuators to the underlying bones is via spring bushing elements. These attachments allow for error between data collection and the model. The position data for each of the 4 sets of markers from the ultrasonic device us used to drive the translational joints in the model.
Data retrieved from the simulation includes cervical joint kinematics, contact forces and disk pressures for the flexion/extension motion of the neck.

RESULTS: The intention of this study is to create a computer model of the head and spine which closely parallels the human experiment using the Orthoson device. This arrangement produces the internal forces of the neck based on skin deformation of the test subject. The disk contact force profiles produced by the simulation are show in Figure 4. These data are in agreement with the general profiles reported in (Begeman). Some over-prediction occurs in the model with the use of basic hinge joints representing the intra-vertebrae constraint. In reality, the intra-vertebrae joint is a six degree-of-freedom joint permitting 3 axes of translation and rotation. The model presented here will overly compress the disk by forming a lever arm between the vertebrae and sandwiched disk.

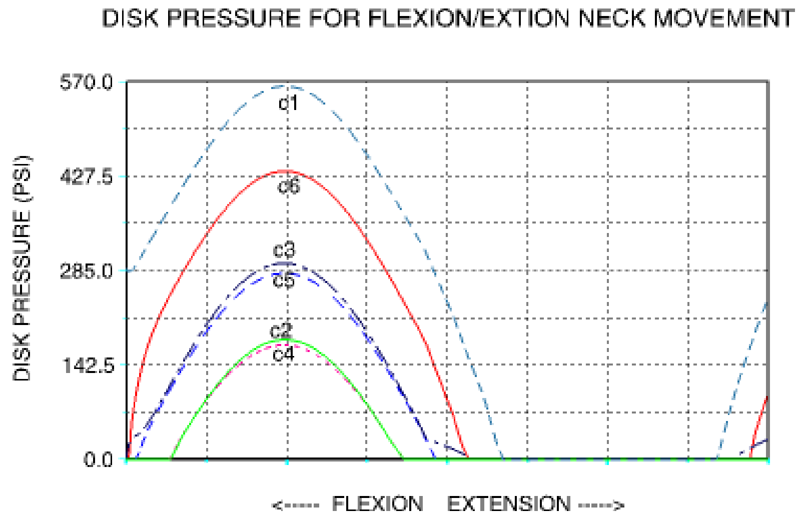

Figure 3. The Disk Contact Pressures for Flexion/Extension Movement

The model in its present form is useful to predict disk compression trends for flexion-extension, internal-external rotation and side flexure of the neck. Various marker configurations of the Orthoson device have been explored to drive the model to produce these motions. Future plans call for reducing the assumptions in the model including: 1. Replacing the hinge joints with 6 degree-of-freedom contact joints, 2. Disk forces capable of transmitting axial, shear and rotational forces. 3. Spring damper elements representing major stabilizers in the neck.

CONCLUSIONS: This study was intended to develop a methodology to generate the internal reactions of the neck based on skin deformation data from the Orthoson device. A new data collection instrument and computer model of the neck are introduced. The near-term practical utility of this work is to calculate range-of-motion in the daily work-space environment. This methodology can also be extended for cadaver tests to study automobile impact injuries to the spine.

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