DETERMINATION OF KINEMATICS OF THE UPPER EXTREMITY.

George Rab M.D., Kyria Petuskey, M.S., Anita Bagley, Ph.D.
Motion Analysis Laboratory, Shriners Hospitals for Children, Northern California, Sacramento, California, U.S.A.
E-Mail: abagley@shrinenet.org

Introduction

Technical and conceptual issues make measurements of 3D upper limb motion difficult to collect and interpret. Modeling of the wrist and elbow can be simplified using two degree-of-freedom joints. The shoulder complex, however, has two separate articulations, scapulothoracic and glenohumeral, and a simple, non-invasive way of locating the scapula is lacking. We suggest that measurement of upper arm position relative to the trunk is a practical approach to model shoulder motion.

There is no consensus on local coordinate systems or on the sequence of movement to describe upper limb position. We describe a 3D system of upper extremity analysis utilizing retroreflective skin markers that follows philosophical and computational principles borrowed from lower extremity kinematic analysis. Its advantages are ease of use, reproducibility, and familiarity to clinicians.

Materials and Methods

The biomechanical model consists of ten segments whose local coordinate systems are used to calculate upper extremity motion relative to anatomical reference planes. All joints are assumed to have fixed centers of rotation. The wrist joint allows flex/ext and ulnar/radial deviation. The elbow joint is a flex/ext hinge with a pronation/supination axis along the forearm. The shoulder joint is modeled as a ball and socket joint between the humerus and the trunk, with the joint center at the geometric center of the humeral head. Scapular contribution to shoulder motion is ignored.

We used a standard 3D video-based technique with retroreflective markers over prominent bony landmarks (Fig. 1). Joint positions were calculated as displacement offsets from selected surface markers, expressed as a fraction of segment lengths. Segments were defined by proximal and distal joint centers, and a third non-collinear point. Rotation sequence was flexion-abduction-axial rotation.

Figure 1: Surface markers and calculated segment joint centers (fine line).
Results

Accuracy of measurement was tested using an articulated rigid aluminum model of the shoulder girdle and upper extremity. Calculated and measured angular displacements were equal, with maximum standard deviations less than 1°. Sensitivity analysis demonstrated that shoulder angle measures were not significantly affected by perturbation of the shoulder joint center.

We have recorded 3D upper extremity movement during a variety of daily living activities on over 30 subjects, and routinely perform pre- and post-operative studies on children with abnormal movement patterns secondary to brachial plexus birth palsy. The method is practical and flexible for subjects with a wide range of height, weight, and ability to cooperate with data collection.

Summary

A method of three-dimensional kinematic analysis of the upper extremity is presented, using surface markers and current video data collection techniques. The rotation sequence is similar to methods used in lower extremity movement analysis, and is logical and easy to remember. It is our hope that a trend toward standardization of analytic techniques leads to an increase in communication and learning about upper extremity kinematics. The minimum requirement for reporting should be a clear description of axes (preferably with pictures), rotation sequences, and model assumptions.

Acknowledgement

The authors wish to express their appreciation to Larry Lamoreux for his help with the aluminum frame shoulder model.

References


Figure 2: 3D data collected from a normal 40-year-old subject placing hand on head and returning arm to the side (thick line).