Validation of a Clinically Useful Kinematic Model for Upper Limb Motion Analysis in Hemiplegic Cerebral Palsy and Brachial Plexus Palsy

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Background

Reliability of 3-dimensional upper limb kinematics during simple functional tasks has been established for individuals with hemiplegic cerebral palsy (CP), however an upper limb kinematic model has not been validated. The purpose of this study was to introduce a new upper limb (UL) kinematic model as well as present early validation work to establish its accuracy and clinical usefulness. We present a six degree-of-freedom model using clinical angles, after extensive testing in individuals with cerebral palsy (CP) and brachial plexus palsy (BPP).

Methods

Kinematic upper limb data were collected bilaterally from 50 individuals including 32 with hemiplegic CP ages 3.6-26.1 years (mean 12.0 years, SD 5.2), and 18 with BPP ages 1.6-12.2 years (mean 8.1 years, SD 2.9). Visual 3D software (C-Motion, Inc.) and a 6-camera Motion Analysis Corporation™ system were used for data capture. The kinematic model included the head, arms and trunk using a 41-marker set with 16 static markers, 7 tracking triads, and 4 head markers. Triads were placed on the 1) superior sternum *or* upper thoracic spine, 2) distal-most humeral segment posteriorly bridging the epicondyles and olecranon, 3) distal-most forearm segment dorsally over the ulnar and radial styloid processes, and 4) dorsal hand segment over the metacarpals. In the CP group, kinematics were collected during 5 trials each of full active reciprocal elbow flexion-extension, forearm supination-pronation, and wrist flexion-extension, and during a modified Jebson-Taylor Test (JTT) of Hand Function. For the BPP group, kinematic data were collected during 5 trials of each Mallet scale maneuver, performed unilaterally with each upper limb to document compensatory strategies of the head and trunk. Active range of motion (AROM) measures of all upper limb joints were performed by a skilled pediatric physiotherapist. Pearson product moment correlations were calculated for specific AROM measures and peak kinematic magnitudes.

Kinematic Example

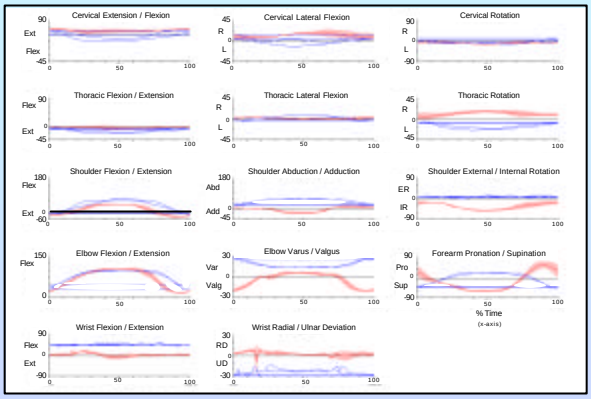
- 8-year-old with brachial plexus birth palsy - entire arm involvement (C5-C6 rupture, C7-C8 avulsion, T1 traction injury)
- s/p 6 surgical procedures (two primary; four secondary)
- Evaluation for surgical planning to improve hand function

Mallet	II	III	IV
Hand to Mouth	 "large clarion" Impossible	 "small clarion" Difficult	 Easy

I = Absent movement; V = Normal movement

Right Normal UL

Left Involved UL



Results

	Peak Kinematic Magnitude vs. Active Range of Motion	Pearson Correlation Coefficient (r)
CP n = 32	Elbow Extension	.74 *good*
	Forearm Supination	.41 *fair*
	Forearm Pronation	.42 *fair*
	Wrist Extension	.85 *excellent*
	Wrist Flexion	.73 *good*
BPP n = 18	Shoulder Flexion	.87 *excellent*
	Shoulder Extension	.75 *good*
	Shoulder Abduction	.76 *good*
	Shoulder Adduction	.47 *fair*
	Shoulder External Rotation	.76 *good*
	Shoulder Internal Rotation	.67 *good*
	Elbow Flexion	.93 *excellent*
	Forearm Supination	.53 *fair*
	Forearm Pronation	.60 *fair - good*
	Wrist Extension	.99 *excellent*
	Wrist Flexion	.98 *excellent*

Discussion

A 3-dimensional kinematic model for the upper limb must accurately quantify movement in a clinically useful way in order to enhance the management of individuals with movement dysfunction. Kinematic graphs that display excursion of joint movements should correspond with known goniometric standards (familiar to clinicians) for kinematics to be helpful in treatment planning, especially for surgery. Eleven out of 16 variables examined revealed good to excellent correlations between AROM and peak kinematic magnitude supporting the validity of this model. Further investigation is warranted to establish test-retest reliability, as well as intra- and inter-rater reliability. Kinematic evaluation of individuals with CP and BPP during specific functional tasks encouraging maximal supination, such as those used in the SHUEE*, may improve our fair correlation values.

**SHUEE = Shriners Hospital Upper Extremity Evaluation*