Assessment of the Spastic Upper Limb with Computational Motion Analysis

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KEYWORDS

• SHUEE • Three-dimensional motion analysis • Coordination • Normative database
• Upper extremity

KEY POINTS

- Three-dimensional computerized motion analysis along with electromyography can quantify and augment clinical scales.
- Hand, wrist, forearm, and elbow function and motion are related to shoulder function and motion.
- The most optimum approach, currently, to assess upper extremity function is by combining a clinical examination, a diagnosis-specific clinical scale, and 3-dimensional data.
- It may be feasible to use the Shriners Hospital Upper Extremity Evaluation to evaluate upper extremity function for diagnoses other than hemiplegic cerebral palsy, such as obstetric brachial plexus palsy.

INTRODUCTION

There is consensus that quantifying hand and upper extremity (UE) function using 3-dimensional motion analysis (3DMA) is important.[1–5] It can facilitate clinical decision-making regarding the need and type of surgery, administration of pharmacological agents, and the focus of a therapy protocol. Furthermore, 3DMA preintervention and postintervention can quantify outcomes and assess treatment efficacy. These goals are accomplished by comparing pathological and normal movements, identifying primary and compensatory motor strategies during goal-oriented tasks, and by assessing movement quality relative to coordination. Nevertheless, there are challenges in establishing 3DMA as a means of quantifying UE function.

Although the use of 3DMA for the lower extremity (LE) during walking is an established procedure for the quantification of LE functional limitations, identifying a single, most relevant, repeatable, and cyclic activity of daily living (ADL) for the UE is difficult.[3,4] This diagnostic challenge is also compounded by the variable and complex nature of UE motion.[6]

In this article, the authors aim to provide an overview of the use of 3DMA in the evaluation of UE function to facilitate the clinical decision-making process regarding UE spasticity management. The authors also describe the approach used in their Computerized Motion Analysis (CMA) laboratory as a means of providing a more comprehensive UE clinical evaluation.

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CHALLENGES OF CLINICAL THREE-DIMENSIONAL MOTION ANALYSIS

Protocol

An established protocol for quantifying UE motion does not exist. There is variability in the functional tasks and ADLs selected for assessment and analysis.[1,3–9] The selected tasks must offer the ability to discern pathological from normal movement. Furthermore, they need to have validity, reproducibility, and sensitivity to clinically significant changes and they need to be predictive (ie, they need to be able to relate the 3D-based task results to the clinical findings and the outcomes of clinical assessment scales).[2]

Task variability is partly inherent in the marker-based 3DMA systems, which are considered the gold standard for computerized motion assessment.[2] For example, assessment of the fine movements of the finger joints and thumb simultaneous with other joints of the UE is difficult because of the required resolution. It is important, therefore, that all reports adequately describe the instrumentation used and the associated measurement errors. The authors' laboratory includes a 10-camera optical capture system (VICON, Los Angeles, CA, USA) with angular error of less than 1°. UE motion and analog data are captured at 120 Hz and 1080 Hz, respectively.

Biomechanical Approach

The biomechanical approach used varies between investigators. To evaluate the kinematics at a joint, one needs to start with a marker or sensor-based model. Markers are placed on specific anatomical positions to define body segments. Motion at the joint is then defined by a mathematical model determining the movement of the adjacent segments making up the joint. Some investigators select to focus on isolated UE joints,[9–11] which allows the flexibility of using mathematical models that are not applicable to all joints. Consequently, the specific mechanical approaches implemented in these investigations necessitate that the results of these studies, in conjunction with the tasks studied, may need further validation.

However, there is evidence that distal UE deficits need to be evaluated along with the other, more proximal, joints of the UE and trunk[12–14] (ie, all joints need to be assessed concurrently). In fact, Fitoussi and collaborators[12] suggested that, because of the significant effects of treatment of the distal UE on the proximal UE joints and trunk, treatment of proximal UE deficits should wait until the effects of distal UE treatment are considered. However, even among the investigators who have evaluated all joints of the UE concurrently, consensus is lacking in terms of the manner that motion is defined mathematically. This variability is, in part, due to the complexity of the joint structures. For example, some investigators have described motion at the wrist and elbow by modeling these joints as hinged or 2 degrees of freedom joints.[6,15] Others have approached them as 3D structures. However, when considering motion in 3 dimensions, the order of rotation about each axis of motion ultimately determines the position in space. In order to address this challenge, the International Society of Biomechanics (ISB)[16] offered guidelines to standardize biomechanical modeling and reporting[1,4] of UE joint motion; these are not followed by all investigators. Most of the controversy regarding modeling revolves around the shoulder joint. Some researchers describe movement at the shoulder as motion of the humerus relative to the trunk,[6,15] which neglects the contribution of the scapulothoracic joint (STJ) to the motion of the shoulder complex. Although motion of the scapula is difficult to track, some investigators have tried to account for it.[1,4,9] However, all current approaches seem to neglect the contributions of the acromioclavicular joint (ACJ) and sternoclavicular joint (SCJ) to the shoulder complex motion[17,18] by considering them part of trunk movement.

The authors' CMA laboratory uses 23 passive retroreflective markers, positioned at specific, easily identifiable and reproducible, anatomical landmarks according to the Vicon PluginGait marker model (**Fig. 1**). From the markers and anthropometric measurements, the authors define the segments that comprise the UE, trunk, pelvis, and head. Each UE segment is allocated to a bone and is defined by a proximal and distal endpoint located at the center of the joint along with a third non-collinear point to describe rotational orientation. The wrist joint center is located at the midpoint of the distance between the ulnar and radial styloid processes. The elbow joint center is located at the midpoint of the distance between the medial and lateral epicondyles. The glenohumeral joint center is defined through a dynamic joint centering procedure involving humeral abduction/adduction and anterior flexion to calculate the pivot point of the instantaneous helical axes from these movements. The trunk segment is defined by the markers on the 7th cervical and 10th thoracic spinous processes, the manubrium, and the sternal notch at the xyphoid process (see **Fig. 1**). This approach allows the contributions of the STJ, ACJ, and SCJ to humeral elevation to be reflected in the shoulder complex rather than in the kinematics of the trunk.

For the purposes of the authors' analysis (focused on the hand, wrist, forearm, and elbow

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