Investigation of Shoulder Range of Motion Limits for Application to Ergonomic Analysis

Joshua S. Danker and Matthew P. Reed
University of Michigan - Ann Arbor,
email: danker@umich.edu, web: www.HUMOSIM.org

INTRODUCTION

Ergonomic analysis using human figure models requires detailed knowledge of worker postures. Because tendonitis, carpel tunnel syndrome, impingement syndrome, and other musculoskeletal disorders can result from awkward upper extremity postures, accurate simulation of upper-extremity postures is critical for job analysis. Posture-prediction algorithms used in digital human models include joint range of motion (ROM) limits, and these limits affect the ranges of postures that can be applied to the figures. Inaccurate or inappropriate joint ROM may result in inaccurate posture prediction.

Due to its complexity, versatility, and susceptibility to injury, the shoulder is of primary importance in any comprehensive ergonomic analysis of the upper extremities. This abstract describes the first steps of an investigation of the influence of shoulder ROM on work postures, beginning with a comparison of shoulder motions in seated reaching tasks with the ROM data provided by Tumer and Engin [2].

METHODS

Widely cited data on shoulder ROM [2] were compared with shoulder motions in seated upper extremity reaches measured in the laboratory using motion capture equipment. The experimental data contain the locations of the sternoclavicular and glenohumeral joints calculated from the position and orientation information obtained from electromagnetic transducers (Flock of Birds, Ascension Technologies). Data from 12 men and women seated in a truck seat reaching to a wide range of push-button target locations were used for the current investigation. Because the experimental data provide a single claviscapular segment to approximately the linkage of the thorax to the humerus, the data are not directly comparable to Tumer and Engin's three-segment model (clavicle, scapula, humerus) for which ROM data are provided. To facilitate the comparison, a composite ROM cone was created to define the combined motions of Tumer and Engin's sternoclavicular and claviscapular joint segments.

Figure 1 shows the joint sinus cones from Tumer and Engin along with the three-link shoulder system. A MATLAB simulation incremented the two joints independently through their ranges of motion. The endpoint of the claviscapular segment, the glenohumeral (GH) joint center, was stored for each increment. This cloud of roughly $5x10^5$ points defined a region of allowable glenohumeral joint center locations relative to the torso for the average joint ROM cones given by Tumer and Engin. The resulting simulated GH locations were compared to the measured GH locations, expressed with respect to an equivalent thorax coordinate system.

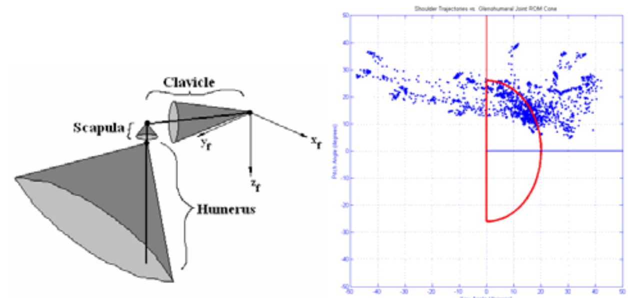

Figure 1: Diagram of the three-link shoulder complex used by Tumer and Engin [2] (left). Comparison of measured glenohumeral joint locations with respect to the thorax with the combined clavicle-scapula ROM (right).

RESULTS AND DISCUSSION

GH locations often deviated from the region defined by the Tumer and Engin clavicle and scapula ROM limits (Figure 1). The patterns of deviation persisted even when the data were normalized within subject to a neutral posture. Most of the deviations were in the upper right quadrant, corresponding to reaches to targets in front of and above the shoulder. The greatest GH excursions occurred in near-maximal reaches, precisely the reaches that are of greatest interest for ergonomic analysis. Perhaps unsurprisingly, given the large amount of inter-individual variability in shoulder ROM [1, 3], most of the population may have shoulder ROM that exceeds the average mobility provided by the Tumer and Engin joint sinus cones. The current investigation also suggests that the shape of the shoulder ROM used by individuals for seated reaches varies considerably.

More investigation will be necessary to determine how best to include the large amount of variability in shoulder ROM in ergonomic analyses. If an average ROM limit is used, the figure model may not be capable of motions that many or most people could perform, posing a model credibility problem. Moreover, because individuals with more limited ROM will not always be the individuals most at risk in a particular task, the utility of DHM figure models as a screening and evaluation tool may be compromised without improved methods for incorporating ROM limits.

REFERENCES

1. Dempster, WT. *Archives of Physical Medicine and Rehabilitation* **46**, 49-69, 1965.
2. Tumer ST and Engin AE. *ASME Journal of Biomechancial Engineering* **111**, 113-121, 1989.
3. Webb Associates, *Anthropometric Source Book* 1, NASA Ref. 1024, Chapters VI & VII, 1978.