THE EFFECT OF MOTION DYNAMICS IN CALCULATION OF EXTERNAL JOINT MOMENTS DURING LIGHT INDUSTRIAL HAND MOTIONS

CR Dickerson, DB Chaffin, K Kim, BJ Martin, N Womack

Center for Ergonomics, University of Michigan, Ann Arbor, MI, USA
E-mail: cdickers@umich.edu

INTRODUCTION

Detailed studies have investigated the dynamic effects of locomotion, as well as many fast-paced sports motions, on physiological loading. This study examines the significance of considering the dynamics of simulated industrial handwork when calculating external joint moments, for a demographically diverse population, and for an individual with a lumbar spinal cord injury.

METHODS

Twenty healthy subjects (10 male, 10 female Age 18-80, 43.6 +/- 16.0 years), and one individual with a spinal cord injury (Age 28) participated in the study. Detailed anthropometric dimensions were obtained. Strength testing was performed implementing a previously used protocol (Chaffin, 1975). Subjects performed a sequence of seated tasks that required the lifting and placing of a light hand weight (20% of maximum lifting strength with the arm abducted 90 degrees) on to specified targets located at 0, 45, and 90 degrees clockwise from the anterior sagittal plane, and which varied vertically, as shown in Figure 1. This included over 500 studied motions.

Motion of the upper extremity was sampled at 25 Hz using a combination optical/electromagnetic recording system (MacReflex^{TM}, Flock of Birds^{TM}). Regression algorithms were applied to locate the relevant joint centers.

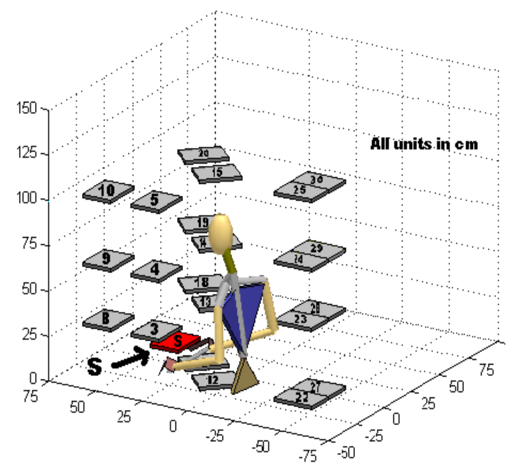

Figure 1. 3-D locations of task terminal targets. All tasks begin at point S.

Both inverse dynamic and quasi-static algorithms were designed to compute external shoulder joint torques using a top-down 3-D model. Kane's Method (Kane, 1983) was employed to obtain angular velocities and accelerations of segments. Figure 2 shows the local coordinate systems created. Segment inertial properties were calculated using scaling techniques in Chaffin (1993).

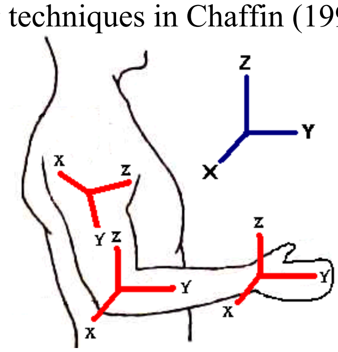

Figure 2. Local (light) Arm Coordinate Systems, Global System Frame (dark).

External moments were calculated for each task using both paradigms.

Comparisons were made between the methods for trapezoidal integration of the vector norm of the moment, as well as the peak external moment prediction.

RESULTS AND DISCUSSION

A representative task performed by both populations is shown in Figure 3. While the curves share the same general form, the static paradigm fails to capture peaks visible in the dynamic calculation. This is more pronounced for the unique subject, suggesting the dynamics differ.

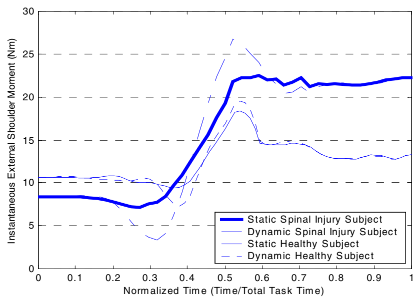

Figure 3. Typical Shoulder External Moment about local upper arm x-axis for two populations, by both methods.

While there are visible differences in each task (up to 22% of the mean moment for healthy, nearly 43% for spinal injured), comparison of the total moment for the exertion shows close linear similarity (Figure 4).

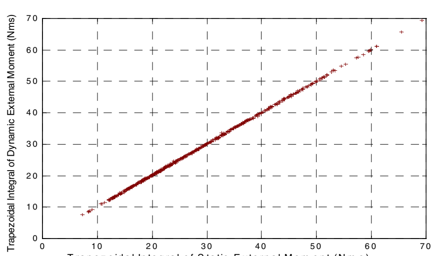

Figure 4. The integrated trapezoidal moment norm derived by two methods, (individual trials (+) [$R^2 > 0.9$].

For the relatively light load reaching motions studied in this experiment, the overall dynamic external shoulder moment was statistically significantly higher than that derived by the static method, ($p < 0.01$). However, as a percentage of the average of the two moments, this difference had a value of 0.70 +/- 0.52 %. To study the overall physical cost of certain types of normal work motions performed at industrial reaching speeds, static analysis may suffice, but peak external moments cannot be characterized well with static measures. Biomechanical analysis of the importance of these peaks continues.

SUMMARY

Careful examination of the nature of a task should precede the selection of an appropriate biomechanical analysis technique selection. Both identification of peak moments and analysis of high-speed motions require dynamic models, but static models can also provide a simple method to obtain important biomechanical information for analysis of the cumulative effects of many work tasks. Special attention should be paid to the impact of the dynamics of higher speed activities (i.e. the spinal injury subject) on moment calculations.

REFERENCES

Chaffin (1975). *AIHA J*. 35:505-510.

Chaffin, Anderson, Martin (1999). *Occupational Biomechanic,(3rd).* Wiley.

Kane, Likins, Levinson (1983). *Spacecraft Dynamics*. McGraw-Hill.

ACKNOWLEDGEMENTS

The Automotive Research Center and the partners of the HUMOSIM consortium (GM, Ford, Daimler-Chrysler, TRW International Truck, TACOM, Johnson Controls, EAI) provided funding for this experiment.