Journal of Biomechanical Engineering

Letter to the Editor

Dear Editor:

In the recent issue of the *Journal of Biomechanical Engineering*, Kromodihardjo and Mital [1] describe a biomechanical analysis of manual lifting tasks. Their analytical approach is based on the description of the upper limb and lower limb as a two-link system, and hence-using eight links to describe the extremities. Two more links are used to describe the trunk and the pelvis – for a total of ten links for the model.

The force and moment analysis presented in the paper is based on the assumption that ". . . the human body model formed an open linkage system during lifting motion and forces at the distal segment (i.e., foreare/wrist joint) were known. These forces were the weight of the load being lifted and its inertial force due to linear acceleration." I maintain that in order to extract the forces (and moments) transferred through the wrist joint to the forearm, one needs additional assumptions or additional measurements.

Since both hands are in contact with the box – both apply generalized interaction forces (i.e. forces and moments), making it a *closed linkage system*. The interaction forces need to be extracted in order to proceed with the force and moment analysis for the individual link. If the only information available includes the weight and the linear acceleration of the box (as stated in the paper), the system is dynamically indeterminate and the generalized interaction forces for each hand cannot be extracted.

The same point can also be illustrated for the lower extremity: in order for the analysis to proceed from the trunk to the legs – the solution of the dynamic equation for the pelvis link would require additional information (or assumptions) on the forces and torques at the hip joints. The analysis could then proceed to calculate the *individual* knee and foot/floor interaction forces and moments, and thus predict the average ground reaction forces (shown in Fig. 3).

The dynamic indeterminacy described above can be alleviated by lumping both upper extremities into one "virtual" upper extremity, and similarly lumping the lower extremities, thus indeed transforming the model into a six-link *open-linkage* system. It could also be alleviated by placing additional assumptions on the nature of the interaction forces between the box and the hands, and the joint forces at the hips (which is possibly the approach taken by the authors). Clearly, the authors should have specified their solution to the indeterminacy issue.

1 Kromodihardjo, S. and Mital, A., "Biomechanical Analysis of Manual Lifting Tasks," ASME Journal of Biomechanical Engineering, Vol. 109, No. 2, pp. 132–138.

Zvi Haden