DYNAMIC LOADING AND EFFORT PERCEPTION DURING ONE-HANDED LOADED REACHES

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INTRODUCTION

Currently, analysis of occupational shoulder loading and potential discomfort is based upon models that use static worker postures as their input. These models provide useful information about working postures, however, they do not address the overall effect of performing a task. Cumulative joint and tissue loading are dependent upon the motions and postures associated with all aspects of performing a task. Fidelity of task analysis could be improved through a dynamic loading model. This study seeks to determine if the amount of effort perceived while performing a reach is more closely related to overall joint loading, rather than to the loading occurring during commonly studied 'extreme' static postures. It also addresses the utility of shoulder torque as a predictor of perceived effort.

METHODS

Ten Subjects (six male [Age 38 +/- 21], four female [Age 23 +/- 5]) participated in this study. Subjects were asked to perform a randomized series of one-handed reaches to specified targets. The target locations were varied for each subject according to the maximum reach distance that subject. Targets were arranged in the work envelope of the right arm, with targets located along five azimuths. Targets were also distributed along three elevation angles from the hip point. Further, targets were placed at two distances along these projections (Figure 1). Reaches were performed to each target using three hand weights (0%, 25%, and 50% of extended arm abduction strength). Some trials were repeated to examine intrasubject variability. During each trial, a combination optical/electromagnetic position tracking system was used to record a set of surface markers placed on body landmarks. After each trial was completed, the subjects reported their perceived effort score using an input device. Scores were calibrated to pre-experimental exertions of known muscular effort. A continuous modified Borg scale (0-10) was used to report shoulder effort.

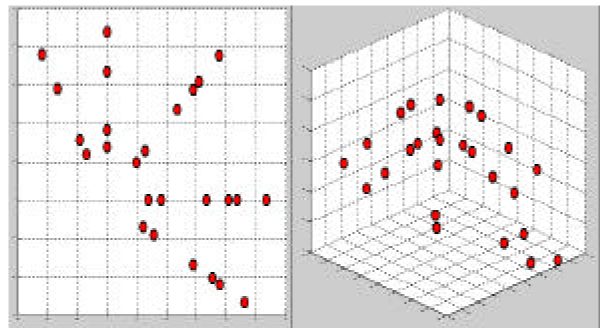

Figure 1: Target Locations. A. Top View; B. Perspective View

The recorded motions were translated into joint center locations using an existing algorithm (Nussbaum & Zhang, 2000). Dynamic shoulder moments were calculated using a custom software program (Dickerson et al, 2001). These data were used to predict perceived effort through a multiple regression statistical model that included as factors: age, gender, stature, target location, and cumulative shoulder torque loading. Peak shoulder torque loading (i.e. a 'worst posture' scenario) was also used in place of cumulative loading for comparison. A model that relied solely on subject and task information (age, gender, stature and target location) was also made.

RESULTS AND DISCUSSION

It was immediately clear that task and subject characteristics alone do not predict perceived effort adequately across subjects. The resulting model explained a minimal portion of the data's variability ($R^2 = 0.15$).

Similarly, cumulative shoulder torque data alone did not create a model of compelling accuracy ($R^2 = 0.32$).

Inclusion of subject and task variables in the analysis improved the prediction accuracy dramatically (R^2 rose from 0.32 to 0.67). The leverage plot of this combined model is shown in Figure 2. The composition of the factors of this model suggests that mental evaluation of the difficulty of a reaching task may be a multifactorial event, which combines both physical loading, as well as mediating task and subject characteristics.

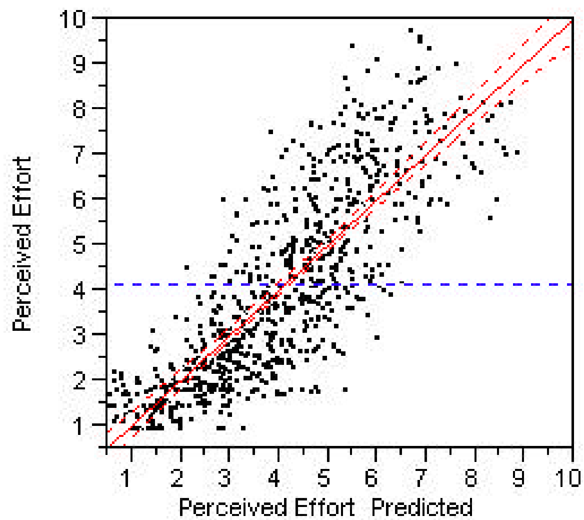

Figure 2: Combined Whole-Model Leverage Plot using cumulative loading and task and subject characteristics.

There was a minimal difference between the quality of prediction achieved using the cumulative and maximum torque values in the regressions ($R^2 = 0.67$ and $R^2 = 0.66$, respectively). This suggests that static and dynamic models could provide comparable task effort predictions, if they are able to identify the positions when maximum torques occur.

SUMMARY

This investigation has affirmed several characteristics of perceived effort for loaded reaches. First, subject and task data can not produce a model that is sufficient to explain the variability in perceived effort data. Second, shoulder torque data alone cannot produce an adequate predictive model of perceived effort. Third, when the two data sources are combined, a more accurate prediction model is produced. Finally, it was shown that both cumulative and maximum shoulder torque loading exhibit the same predictive ability in a combined regression model. Care should be taken, however, when using static postures to evaluate working tasks, in that the postures used represent maximum torque situations. The relationship between internal muscle forces and perceived effort ratings is also being investigated in a related study, which may provide a stronger predictive ability.

REFERENCES

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