ADAPTATIONS TO TASK MECHANICS ALTER STRETCH REFLEX GAIN BUT NOT INTERMUSCULAR COORDINATION

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INTRODUCTION

The human motor system regulates arm mechanics to produce stable postures during interactions with different physical environments. This regulation occurs partly via involuntary mechanisms, including stretch sensitive reflexes. For example, single joint studies have demonstrated that reflex sensitivity increases during interactions with more compliant environments, suggesting that reflex gain increases to enhance limb stability when that stability is not provided by the environment (Dietz et al. 1994). Although such studies demonstrate the adaptability of stretch reflexes to changes in environmental mechanics, they have focused on individual joints. In contrast, most functional tasks require the coordinated activity of multiple joints within a limb, and it remains unclear how reflexes coordinating actions of muscles throughout the limb are modulated by the mechanical requirements of a task.

The purpose of this study was to quantify multijoint stretch reflexes as humans use their arms to interact with stiff and compliant environments. Our hypothesis was that stretch reflex sensitivity increases within muscles throughout the limb during interactions with compliant environments. In addition, we quantified reflex coordination across muscles to determine if any observed sensitivity changes were accompanied by changes in muscle recruitment patterns.

METHODS

Data were collected from 8 subjects. Reflexes were elicited by perturbing the dominant arm with a 3 degrees of freedom (DOF) robotic manipulator. [HapticMaster; FCS Control Systems]. The robot was configured as a critically damped 2nd order system with an isotropic stiffness of 10 N/m (compliant) or 10kN/m (stiff) to determine how reflexes were altered by the mechanical properties of the human-environment interface. Randomly occurring perturbations with an amplitude of 30mm and a velocity of 500mm/sec were applied along the three axes illustrated in Fig. 1. Perturbation amplitude and velocity were matched in the stiff and compliant environments. Subjects exerted constant, voluntary flexion or extension forces during each experimental trial (±0, 5, 10% MVC; X-axis).

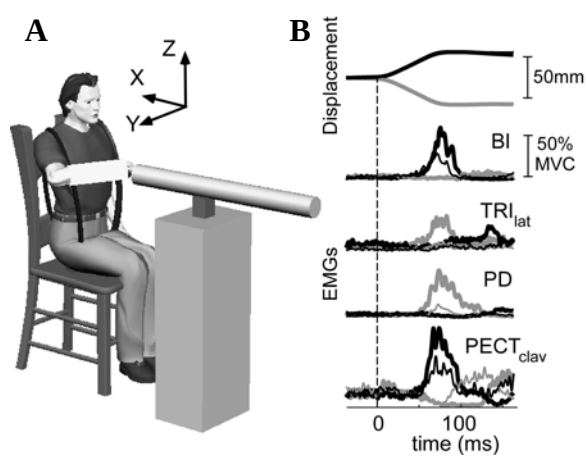

Figure 1: Experimental setup and typical reflexes elicited by Y-axis perturbations.

Electromyograms (EMGs) were recorded from 8 muscles representing the major elbow and shoulder muscles accessible via surface EMG: brachioradialis (BRD), biceps (BI), triceps long head (TRI_{long}), triceps lateral head (TRI_{lat}), anterior, middle and posterior deltoid (AD, MD, PD) and clavicular pectoralis ($PECT_{clav}$). Reflex magnitude was quantified by the average rectified EMG 50-100ms after perturbation onset. Reflex coordination was assessed using independent components analysis (ICA) to look at common muscle activations across all tasks (Tresch et al. 2006).

RESULTS AND DISCUSSION

Stretch reflex sensitivity increased during interactions with the compliant environment. Typical subject responses are shown in Fig. 1B. Thin traces correspond to data collected in stiff environment and thick traces to data from compliant environment. Color corresponds to perturbation direction, as shown in first row. Increased reflex sensitivity in the compliant environment occurred in all muscles and all subjects ($p<0.05$), and was not due to changes in background muscle activity.

Similar reflex coordination patterns were observed during interactions with stiff and compliant environments. Fig. 2 shows the coordination patterns estimated using ICA performed on data from a single subject; 4 ICs accounted for > 90% of the reflex variance in all subjects. Each group of 8 bars shows a single coordination pattern (one IC). Bar height indicates relative activation of each muscle. Coordination patterns estimated from stiff environment (left) are similar to those from compliant environment (right) for this subject. Cross-validation was used to assess similarity of the ICs estimated from data in each environment. Across all subjects, there was no significant difference in the accuracy of the reflexes predicted from ICs in either environment ($p>0.15$).

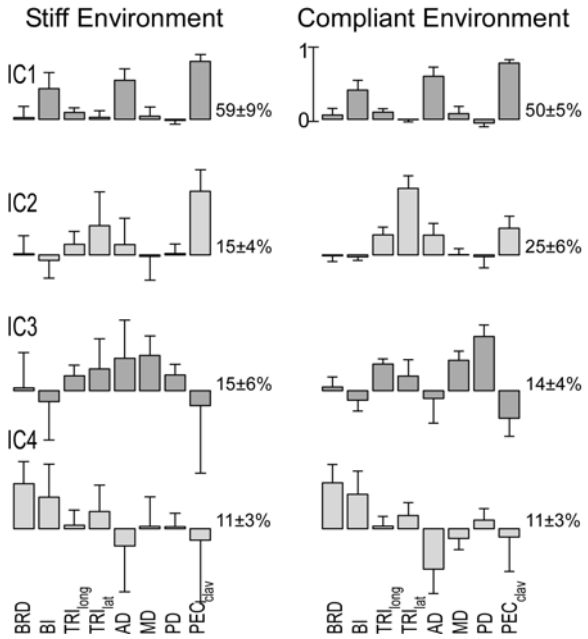

Figure 1: Single subject reflex coordination patterns. Numbers give relative IC variance.

SUMMARY/CONCLUSIONS

Our results are the first to demonstrate stretch sensitive reflexes throughout the arm modulate with the mechanical requirements of a task. The observed modulation did not represent a change in reflex coordination, suggesting that modulation for this task occurred through altered use of fixed muscle coordination patterns rather than through a change in the strategy of coordination.

REFERENCES

Dietz V et al. (1994) *Electroencephalogr Clin Neurophysiol* **93**: 49-56

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ACKNOWLEDGEMENTS

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