DISCOORDINATION IN STROKE MEASURED DYNAMICALLY USING THE ACT-3D ROBOT

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INTRODUCTION

Abnormal synergy patterns, or pathological coupling of joint torques, have been shown to constrain functional reaching in patients beyond that which can be explained by simple muscle weakness [1]. These synergies have also been explored dynamically using an air bearing device. It was found that when a subject's limb was fully supported, they were able to reach targets that were well outside of their active range of motion, which was measured when they were required to lift their arm against gravity [2]. But this leaves to question how stroke subjects are able to do so well under the supported condition. The hypothesis for the current work is that they were simply working into the extension synergy and coupling elbow extension with a great deal of shoulder adduction (i.e. pushing into the table) in order to reach the target. For the first time, we measure the amount of adduction used to reach targets within the workspace under dynamic conditions.

METHODS

In the current study, we use a modified HapticMASTER robot (FCS Control Systems, The Netherlands) which has been integrated with a Biodex experimental chair (Biodex Medical Systems, Shirley, NY) to form the first generation Arm Coordination Training 3-D (ACT ^{3D}) device. The advantage of this system is that it incorporates the ability to measure 6 degrees of force and torque measurements while allowing the subject to move in 3-D workspace, features unavailable in the previous protocols. Here, the ACT ^{3D} is used to explore how shoulder adduction is coupled with reaching and retrieval motions when the arm is fully supported on a haptic table. A series of 5 targets were presented to each subject such that both single joint and multi joint movements in elbow and shoulder flexion and extension were tested, as described previously [3]. Online feedback was given via a 3 dimensional arm on a computer screen, and the subject was instructed to move as quickly as possible to the target without regard to specific endpoint accuracy. By examining only the first 100 ms after movement onset, we focused on the open loop control portion of the movement. Force and torque information in 3 dimensions (JR3 load cell, Woodland, CA) as well as angles recorded by the instrumented gimbal on the ACT ^{3D} were recorded during trials and saved for later analysis.

RESULTS AND DISCUSSION

For each trial, HM position arm angles were used to calculate the torques at the shoulder and elbow using inverse dynamics and a Jacobian matrix. Here, we compare a severely impaired stroke subject (Fugl-Meyer upper extremity score 30 out of 66; Chedoke-McMaster arm score 3 out of 7) and a healthy control subject whose speeds of movement to the target were similar. For the elbow extension target (target placement required 30° of elbow extension in order to reach it), the stroke subject coupled the elbow extension movement with a significantly greater amount of shoulder adduction ($p = .002$), compared to the healthy control subject. These results are shown in Figure 1.

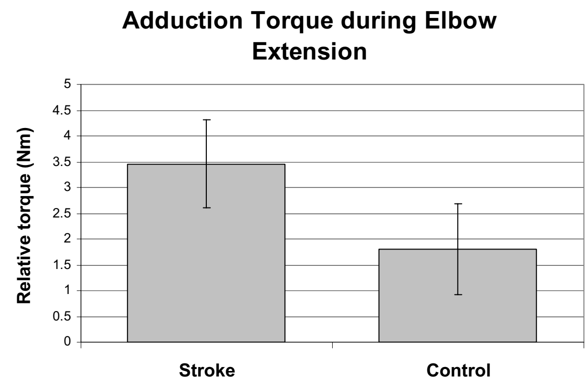

Figure 1: Relative adduction torque (that beyond limb weight) measured during elbow extension task.

CONCLUSIONS

Results indicate that subjects need to use much larger amounts of adduction torque in order to produce the same amount of elbow extension torque when compared to healthy subjects. This information supports the hypothesis that they are simply working within their extension synergies in order to accomplish the elbow extension task when supported by the haptic table. With the current setup, we can also vary the amount of limb support that is given to the subject during arm movements, so a greater resolution can be achieved between supported and unsupported conditions. This will allow us to gain a better understanding of the dynamic expression of synergies and their effect on the reduction of workspace as a function of limb support, and is the subject of ongoing investigation in the lab.

REFERENCES

1. Dewald JPA, Beer RF. *Muscle & Nerve* **24**: 273-283, 2001.
2. Beer RF, et al. *Exp Brain Res* **131**(3): 305-19, 2000.
3. Beer RF, et al. *Exp Brain Res*. **156**: 458–470, 2004.

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