INTRODUCTION
In the recent years, several rehabilitation robots had been built and under clinical trials [1,2,3,4]. A literature revealed that robot-aided rehabilitation for stroke patients could speed up recovery process in acute stage and continuously improve motor functions in chronic stage [5]. However, there is no effective and customized treatment exercise specifically designed for robot-aided rehabilitation. An analysis based on biomechanics and model simulation might be useful for constructing such treatment. This study augmented a biomechanical model of human upper limb, conducted a series of experiments by recruiting a stroke patient and twelve normal subjects, and compared experimental and simulation results between stroke patients and normal subjects when they interacted with the rehabilitation robot system.

METHODS
Twelve normal subjects and a stroke patient were recruited under documented agreement of human study. According to their acknowledgement, all the thirteen subjects were right-handed. As shown in Figure 1, the subject sat in a chair of the rehabilitation robot system and the trunk was fixed with two safety belts to reduce undesired motion. The subject was asked to guide the robot arm to perform horizontal circular tracking movements with palm fixed in a gripper at the end of the robot arm. To obtain muscle activation patterns of the subject, two surface electrodes were placed on muscle belly of biceps brachii, brachioradialis, or triceps brachii. From comparison of muscle activation patterns between experimental and simulation results, motor strategy of the subject for the tracking might be found.

The biomechanical model used in this study contained twelve muscles around elbow or shoulder joints [6]. A static optimization method was used to solve the load sharing problem [7]. Muscle length, muscle shortening velocity, and muscle activation etc could be obtained since joint angles and muscle forces were known.

RESULTS AND DISCUSSION
Figure 2 shows mean patterns of joint angles, EMG signals, and calculated muscle activations of the stroke patient when the subject performed the clockwise tracking. Contribution of submovements was not equal. Durations of submovements shoulder-flexion-elbow-extension (S_E) and shoulder-flexion-elbow-extension (S_E) were longer than the other two submovements shoulder-extension-elbow-extension (S_E) and shoulder-flexion-elbow-flexion (S_E). EMG signals indicated that biceps brachii was mainly activated in S_E and S_E and triceps brachii was mainly activated in S_E and S_E. Calculated muscle activations of biceps brachii and triceps brachii were consistent with the EMG signals. Consistency between EMG signals and calculated muscle activations suggested that the stroke patient might attempt to complete the clockwise tracking with minimum effort. For the normal subjects, comparison between EMG signals and calculated muscle activation indicated that one of two motor strategies was adopted according to personal preference.

REFERENCES

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