INTRODUCTION

Past studies of muscle strengthening in healthy adults have reported that greater effort leads to higher gain and that the first significant change occurs in central nervous system as shown by increases in motor unit recruitment rate and firing rate [1]. Muscle weakness has been indicated in past studies as a primary factor for disability after stroke [2]. Intuitively one would expect significant outcome from strength training that uses the similar protocol developed in strength training of healthy adults. However, past studies using strength/resistance training in stroke rehabilitation have reported inconsistent results [3]. Various intensities of resistance have been tried in strength training of stroke survivors, but it is unclear whether there exits an optimal effort level for a specific sub-group of stroke survivors. Therefore, we set forth a study to investigate the effect of different effort levels on the elbow joint torque production and upper limb muscle activation using a sense of effort testing protocol in chronic stroke survivors and healthy adults.

METHODS

Five young healthy subjects (26.4±2.8 years) and thirteen chronic stroke survivors (64.2±6.3 years) > 3 months after stroke were enrolled. The subjects after stroke were classified into sub-categories based on severity of motor impairment (moderate n=4, mild n=9) using the Fugl-Meyer upper limb motor score. The testing of the torque production and upper limb muscle activation occurred in 2 sessions on two different days (Figure 1). During the first session, the maximum isometric voluntary elbow joint torque contraction (MVC) and maximal muscle activation (EMG) for biceps brachii, triceps, and auxiliary muscles (Anterior Deltoid, Middle Deltoid, Posterior Deltoid, Upper Trapezius, Pectoralis Major, and Lattisimus Dorsi) was established for flexion and extension motions on the unaffected side of the stroke survivors and the dominant side of the healthy subjects using the Biodex dynamometer. The subjects were then asked to contract elbow muscles in flexion and extension at different effort levels of MVC (30%, 50%, 70%, and 90%). During the second session, the affected side (stroke survivors) or non-dominant side (healthy subjects) was tested at different effort levels and the subjects were instructed to reproduce the effort levels.

The MVC and maximal muscle activation for biceps brachii, triceps, and auxiliary muscles in both flexion and extension were tested and recorded first. After that, the torque production and muscle activations at different effort levels were tested on both sides and the recorded data was normalized to MVC/maximal muscle activation to interpret the trends in both groups.

Figure 1: Experimental set-up using Biodex Dynamometer
RESULTS AND DISCUSSION

Healthy subjects demonstrated an expected pattern of linear increases in torque and agonist EMG activation with minimal co-activation of auxiliary and antagonistic muscle groups in isometric elbow flexion contraction (Figure 2). Stroke subjects with mild impairment demonstrated the similar pattern. Stroke subjects with moderate impairment differed from a linear progression in recorded torque and agonist EMG. There were no significant increases in activity levels of antagonist and auxiliary muscle groups as the effort level increased. Similar trends were observed for elbow extension.

The results of our study indicate that stroke survivors, depending on their levels of motor impairment, may/may not be able to scale their motor command according to a desired effort level. In this type of task, the stroke survivors with mild impairment showed similar behavior as healthy adults, while individuals with moderate impairment presented with abnormal behavior. This may be due to differences in the severity of disrupted motor neuron pathways after stroke.

We originally hypothesized that inability in accurately scaling force output in stroke survivors with moderate/severe impairment may come primarily from increased activity of either antagonist muscle or auxiliary muscles, as the literature indicated the increased co-contraction and abnormal muscle/movement synergy in stroke survivors in their attempt to compensate for their motor impairment. However, our data indicated no increase in activities of either antagonist or auxiliary muscle groups in company with the increase in effort level. The cause for the abnormal torque production scale in stroke survivors with moderate impairment in our data appeared to be a lack of accurate motor control on the agonistic muscle.

CONCLUSIONS

Our data indicate that the torque production and EMG activation in stroke subjects may differ from healthy subjects, depending on their impairment levels. Motor training with high resistance/high level of effort may benefit stroke survivors with mild impairment, but not necessary beneficial in individuals with moderate/severe impairment.

REFERENCES


Figure 2: Trends in torque and muscle activation at different effort levels of elbow flexion for healthy and stroke patients.