Changes in Muscle Coordination Following Robot-assisted Gait Training in Hemiparetic Stroke

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VSHHG DQG D WR GHFUHDVH LQ WLPH WR FRPSOHWH WKH 7LPHG 8S DQG *R WHVWW
VKRZHG LPSURYHPHQWV LQ 6, DQG ,5 7KHVH UHVXOWV LQGLFDWH WKDW LQ DGGLWLRQ
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RI WKH ERG\ 7KHVH ILQGLQJV VXJJHVW WKDW WKH LPSURYHPHQWV LQ JDLW IXQFWLRQ
LPSURYHPHQWV LQ PXVFOH FRRUGLQDWLRQ 7KHVH FKDQJHV DUH OLNHO\ GXH WR SRVLWW
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Keywords: Surface electromyography (SEMG); Gait; Rehabilitation; Coordination; Locomotor training

Introduction

Recovery of ambulation is a key goal for many stroke patients with hemiparesis. Hemiparetic gait is typically characterized by slow walking speed, asymmetrical limb movements, short step length and reduced range of motion on the affected side. Long-term improvements in gait are possible through intensive locomotor therapy [1]. Robot-Assisted Gait Training (RAGT) is an alternative to manually-assisted treadmill training that is designed to alleviate the burden on therapists. RAGT provides external forces to the limbs of patients to mimic normal kinematics during locomotor training [2]. ...s on coordination of muscle activation patterns.

The idea that human locomotion is driven by oscillating neural circuits located in the spinal cord has been advanced for decades [5]. Locomotor training focuses on adaptation of the Central Pattern Generator (CPG), which is a largely autonomous neural circuit that produces cyclical bursts of pre-determined muscle activation signals [6,7]. The output of the CPG can be measured in the extremities using surface electromyography (SEMG), from which rhythmic patterns can be identified using a statistical classification technique [8]. This way, we can evaluate the degree to which multiple muscles act in a stable, rhythmic, coordinated manner. Furthermore, we can infer changes that take place in the central nervor ce¾γxQl' ' w m e evaluation at different after an intervention).

To date, most studies on RAGT in stroke evaluated locomotion using standard clinical scores, such as t' suI] previous 6 months, and it must have been their first stroke. Furthermore, they must have scored 4 or 5 on the locomotion

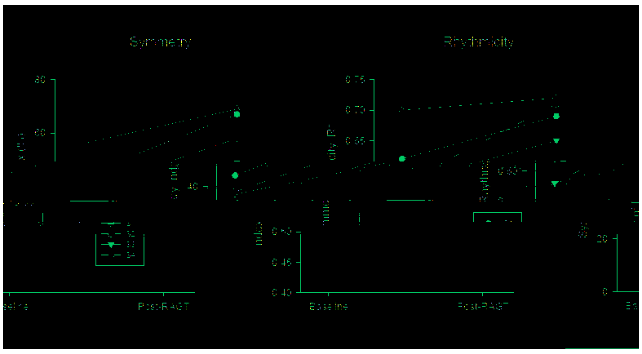

Figure 2: Evaluations of muscle coordination based on analysis of multiple SEMG signals

Discussion

Four individuals with hemiparesis due to stroke underwent an 8-week intervention of RAGT administered using a powered exoskeleton with partial body-weight support. All participants improved in terms of functional mobility assessments. These improvements were accompanied by increased symmetry of muscle activation during gait. That is, the muscle activation signals in the affected leg were more similar to those in the unaffected leg (180 degrees out of phase) after RAGT. Also, the combined muscle activation patterns of the lower extremities exhibited increased rhythmicity during gait. We can infer from these results that alterations occurred within the central nervous system such that locomotor activity is more coordinated and more consistent with a model of CPG control. This supports the idea that RAGT may affect positive adaptations in the central nervous system in hemiparetic stroke.

We assessed rhythmicity using a statistical model of CPG control that yielded values of IR between zero and one. In our previous work, we measured values of IR in normal, healthy adults between 0.70 and 0.80 [8]. Perfect rhythmicity (IR=1.00) represents a set of perfectly periodic SEMG signals with no deviations. Normal, healthy gait involves some variations from periodic muscle activity. According to the optimal variability hypothesis [10], a certain amount of variability is desirable in physiological systems to deal with perturbations and remain within a state of dynamic equilibrium. Three of the four hemiparetic subjects in this study had subnormal IR (less than 0.70), indicating some aberrant, “noisy” muscle activity during gait. Following RAGT, the aberrations were reduced, resulting in IR scores closer to the normal range. In our analysis, we applied the simplest interpretation of “improvement” as any change in IR greater than zero. We acknowledge that small changes that are greater than zero may not be clinically significant. Further study is needed to establish a threshold value that correlates to significance in this context.

The present study is one of the few analyses that deal with changes in coordination (synchronization and ryhthmicity) of multiple muscles following locomotor training.

Future work should involve experiments to compare changes in muscle coordination between patients who have undergone RAGT and other forms of locomotor training, such as conventional physical therapy and body-weight supported treadmill training with manual assistance.

Conclusions

Our data showed that muscle coordination improved following 8 weeks (24 sessions) of RAGT. This signifies the possibility that RAGT may affect fundamental alterations in locomotor control, a hypothesis that should be investigated via an experimental design. In our case series, we utilized a non-invasive method to identify how the central nervous system controls locomotion before and after a rehabilitation intervention. We believe that this is a practical method to measure changes in the central nervous system for any intervention for locomotor training.

Acknowledgement

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