COMPARISON OF MODULE QUALITY AND WALKING PERFORMANCE OF HEMIPARETIC SUBJECTS PRE AND POST LOCOMOTOR REHABILITATION THERAPY

Rebecca L. Routson¹, David J. Clark², Mark G. Bowden³,⁴, Steven A. Kautz³,⁴ and Richard R. Neptune¹

¹ Department of Mechanical Engineering, The University of Texas at Austin, Austin, TX
² Department of Aging and Geriatric Research, University of Florida, Gainesville FL
³ Ralph H. Johnson VA Medical Center, Charleston, SC
4 Department of Health Sciences and Research, Medical University of South Carolina, Charleston, SC
email: rebecca.routson@gmail.com, web: http://me.utexas.edu/~neptune

INTRODUCTION

In healthy subjects, electromyography (EMG) reveals that well-coordinated walking can be produced by exciting four co-activation modules: Module 1 (hip and knee extensors) in early stance, Module 2 (ankle plantarflexors) in late stance, Module 3 (tibialis anterior and rectus femoris) during swing, and Module 4 (hamstrings) in late swing and early stance [1]. These modules, comprised of timing and composition matrices that define muscle activity (Fig. 1), may reflect a neural strategy of co-activation through a reduced set of patterns.

Persons with post-stroke hemiparesis typically have fewer modules that are less well organized than healthy subjects [2]. Even in those subjects who had four modules post-stroke, the modules differed in composition and timing from those of healthy subjects. Since recent simulation analyses found modules have specific biomechanical functions during unimpaired walking [1], altering their timing or composition could adversely affect walking ability. Thus, interventions that restore normal module organization could significantly improve locomotor performance.

Studies investigating EMG throughout the post-stroke recovery process have proposed that improved walking performance can be accomplished by relying on an individual’s own compensatory muscle activation patterns, rather than trying to improve muscle timing towards healthy patterns [3, 4]. However, the effect of rehabilitation on muscle activation timing, reflected by module organization, and hemiparetic walking performance has not been assessed. We propose that such an assessment would provide justification for selecting specific rehabilitation approaches that target improving module quality. Therefore, the goal of this study was to examine the influence of a locomotor rehabilitation therapy on module organization and post-stroke hemiparetic walking performance. Specifically, we assessed whether those subjects who had four modules pre-therapy improved their module quality post-therapy.

METHODS

Twenty-eight individuals with chronic post-stroke hemiparesis participated in a 12-week, 36 session locomotor training program including stepping on a treadmill with body weight support and manual assistance. Kinematics, ground reaction forces and EMG were collected pre- and post-therapy for each subject. Data were also collected from 19 age-matched healthy subjects walking at self-selected speeds. Using a non-negative matrix factorization algorithm (NNMF) [2], the number of modules required to account for the variability of EMG recorded from eight muscles bilaterally were assessed.

Module quality was determined by comparing both module composition and timing in the hemiparetic subjects to average respective values in healthy subjects. Composition was assessed by comparing weighting factors for individual muscles using Pearson’s correlation coefficient. Timing quality was calculated as the difference in timing peaks of the hemiparetic subjects as compared to the control group average. Biomechanical measures including self-selected speed (SS), paretic step length, paretic pre-swing leg angle and propulsion asymmetry as well as module quality measures were compared pre- and post-therapy using paired t-tests.
RESULTS AND DISCUSSION

Nine of the 28 hemiparetic subjects had four modules pre- and post-therapy. When comparing the magnitude and timing of the four modules of these nine subjects pre- and post-therapy, the only statistically significant change was that timing improved for the ankle plantarflexor module (Module 2; \( p=0.005 \)). The post-therapy timing peak of this module was more defined and occurred later in stance, which more closely resembled the control group (compare Figs. 1b and 1c to 1a). Of the four biomechanical measures compared in these subjects, three were statistically (\( \alpha=0.05 \)) or marginally (\( \alpha=0.10 \)) significantly improved post-therapy. Those measures were SS speed (\( p=0.004 \)), propulsion asymmetry (\( p=0.072 \)), and pre-swing leg angle (\( p=0.022 \)). Improvements in these measures (i.e., a faster speed, greater propulsion symmetry, and more extended leg angle) were likely directly related to the improved Module 2 timing since the plantar flexors have been shown to be important contributors to these biomechanical functions [1].

CONCLUSION

In subjects with four modules pre- and post-therapy, locomotor training resulted in improved timing of the ankle plantar flexor module (Module 2) and more extended paretic leg angles that allowed the hemiparetic subjects to walk faster and with more symmetrical (i.e., greater paretic leg) propulsion. Future work will investigate module quality post-therapy in those subjects who started with less than four modules pre-therapy to assess whether they are more or less likely to achieve a normal module organization.

REFERENCES


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