COMPENSATORY GAIT MOVEMENTS POST STROKE: THE INFLUENCE OF SYNERGIES

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INTRODUCTION

Although most patients regain the ability to walk after stroke, several sagittal plane impairments (i.e. reduced paretic knee flexion, hip flexion, and ankle dorsiflexion) compromise toe clearance during swing. Compensatory frontal plane movements, including circumduction and hip hiking, may be employed to facilitate toe clearance (Perry 1992; Kerrigan, Frates et al. 2000). Despite the recovery of walking, persistent gait disorders are linked to increased energy expenditure (Olney and Richards 1996; Chen, Patten et al. 2005), which can negatively impact endurance and rehabilitation. Given this clinical significance, the goal of this study is to quantify the differential effects of sagittal and frontal plane joint strength measures on compensatory kinematics. Additionally, the frontal and sagittal plane deviations in gait kinematics suggest that abnormal multi-joint synergistic torque coupling previously observed in the lower limbs of stroke subjects may contribute to overground gait behaviors (Cruz and Dhaher 2008). We hypothesize that paretic hip sagittal plane weakness and abnormal across-joint coupling will relate to gait deviations. Delineating the effects of these impairments may improve future rehabilitation therapies.

METHODS

Eighteen stroke subjects (>12 months post monohemispheric CVA) and eight age-matched controls were tested. Data collection consisted of two parts: gait analysis and isometric strength measures. Overground gait analysis was performed using standard procedures and equipment (Cleveland Clinic marker set and an eight camera Motion Analysis Corp, data sampled at 120 Hz). Subjects walked with comfortable shoes on a 10m walkway at a self-selected walking speed for a minimum of five trials. Stroke subjects were tested without ankle-foot-orthoses (AFOs) and canes when possible. Given that walking is a dynamic task influenced by many factors, the rates of change of compensatory movements at the initiation of the swing phase were selected as outcome measures. Specifically, the deviations from the normal rate of change of hip abduction/adduction angle and hip pelvic obliquity angle at toeoff were used.

For the isometric data collection, stroke subjects' lower limbs were secured in an instrumented exoskeleton locked in the standing toeoff posture (Cruz and Dhaher 2008). Subjects were instructed to produce maximum hip frontal and sagittal plane torque and hold for 200ms, while receiving real-time visual feedback. Subjects were unaware that knee flexion/ extension torque measurements were recorded simultaneously, providing a measure of across joint coupling. Paretic knee and ankle sagittal plane strength was measured using a Biodex® chair.

To determine which strength measures were related to compensatory kinematics, multiple linear regression models were used as follows:

$$\Delta = \beta_i \alpha_i + \varepsilon,$$

where Δ is the deviation in the rate of change of the kinematic variable, β_i are the coefficients for the α_i variables and ε is the error.

RESULTS AND DISCUSSION

The groups significantly differed in pelvic joint angle at toeoff ($p = 0.005$, see Figure 1), but not in frontal plane angle ($p = 0.44$). The stepwise regression procedure found four of the ten variables to be related to the deviation from normal in the rate of change of pelvic obliquity angle at toeoff in the stroke group, including hip flexion and extension strength, knee flexion strength, and abnormal hip adduction\knee extension hip\knee coupling. As expected, the regression model revealed that abnormal coupling resulted in increased deviations from normal, while increases in paretic hip extension and flexion, and paretic knee flexion strength reduced the deviations from normal, see Table 1. The regression algorithms were unable to find a relationship between the strength variables and the deviation from normal in the rate of change of hip frontal plane angle at toeoff. These findings reveal that proximal joint sagittal plane strength measures are the most important factors when determining abnormal pelvic frontal plane compensatory kinematics.

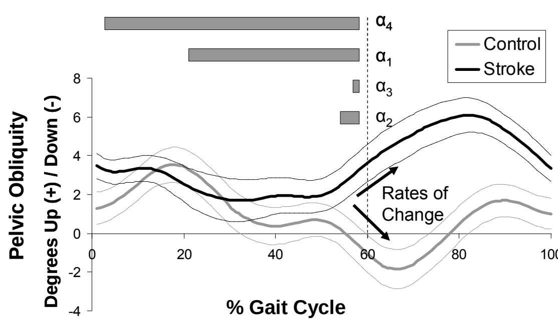

Figure 1: Mean (SE) pelvic frontal plane angle for one gait cycle (heelstrike= 0% and toeoff = 60%) and mean strength measures from Table 1.

Table 1 – ANOVA for Multiple Regression Model for Pelvic Obliquity

Source (α_i)	**Coefficient (β_i)**	R^2	**Probability Level**	**Power 5%**
Hip Flexion (**α_1**)	-0.01		**0.002**	.966
Hip Adduction/Knee Extension Ratio (**α_2**)	-0.08		**0.000**	1.00
Knee Flexion (**α_3**)	-0.31		**0.000**	.993
Hip Extension (**α_4**)	-0.02		**0.000**	1.00
Model (Intercept)	1.38	.957	**0.000**	1.00

SUMMARY/CONCLUSIONS

This study suggests that given the relationships among abnormal across joint coupling, single joint strength, and gait kinematics, task specific training may improve the quality of gait following stroke. The subsequent reduction of compensatory movements is anticipated to lessen energetic costs and improve rehabilitation potential. These findings also support the hypothesis that pelvic movement is a major compensatory strategy post stroke.

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