

THE RELATIONSHIP BETWEEN INTERJOINT COORDINATION DURING GAIT AND STRENGTH, SPASTICITY AND SELECTIVE VOLUNTARY MOTOR CONTROL IN CHILDREN WITH SPASTIC DIPLEGIC CEREBRAL PALSY

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INTRODUCTION

Inadequate terminal knee extension during the swing phase of gait is common in spastic diplegic cerebral palsy (CP), frequently manifesting as a shorter stride length and decreased walking speed. Hamstring spasticity or contractures may contribute to inadequate knee extension (Tuzson et al., 2003); however, not all patients who undergo hamstring lengthenings walk with improved knee extension post-operatively (Thometz et al., 1989). Muscle weakness has also been proposed as a contributing factor (Arnold et al., 2007). The influence of selective voluntary motor control (SVMC) on terminal knee extension has not been examined. Patients with impaired or absent SVMC are often unable to move the hip, knee and ankle joints independently of one another and may rely on gross flexion and extension synergy patterns to varying degrees (Perry, 1975). Patients with good SVMC may be more capable of using non-synergistic patterns to simultaneously flex the hip and extend the knee during the swing phase of gait. The purpose of this study was to examine the relationship between the coordination of the hip and knee during the swing phase of gait and spasticity, strength and SVMC in children with spastic diplegic CP.

METHODS AND PROCEDURES

Fifteen subjects were recruited for this study. Subjects met the follow inclusion

criteria: (1) diagnosis of spastic diplegic CP, (2) minimum of twelve months post orthopedic or neurological surgery, (3) minimum of 6 months post baclofen pump implantation and (4) ability to walk independently indoors for short distances, with or without assistive devices (Levels I-IV of the Gross Motor Function Classification System (GMFCS)). Subjects with “stiff-knee” gait were excluded due to limited knee motion. The mean age of the subjects was 11.5 years (SD = 4.7, range = 5-20). Each subject was evaluated for his or her lower extremity SVMC ability using the UCLA Selective Voluntary Motor Control Assessment of the Lower Extremity tool (SCALE). A total score between 0 and 10 (0 = poor SVMC, 10 = normal SVMC) was given for each limb. Clinical assessments of spasticity and strength were performed using the Modified Ashworth Scale and the Manual Muscle Test, respectively. Spasticity and strength indexes were calculated for each limb by summing the individual scores throughout the lower extremity. Gait data were collected using an eight-camera system (Motion Analysis Corp.), and kinematics were computed using Orthotrak.

Dynamic Systems Theory methods (Stergiou, 2004) were used to quantify interjoint coordination of the hip and knee during gait. Joint velocity versus joint angle was plotted for the hip and knee. Phase angles were then computed (phase angle = $\arctan(\text{velocity}/\text{angle})$). The relative phase (i.e., the difference between the hip and knee

phase angles) was calculated throughout the gait cycle. A relative phase angle close to zero indicated that the two joints were moving in phase (synergy); a relative phase angle approaching ± 180 degrees indicates that the joints were moving out of phase (non-synergistic). A positive value indicated that the hip was leading the knee in the phase space. A negative value meant the knee was leading the hip. The minimum relative phase during swing (MRP) was correlated with the SCALE score, spasticity index and strength index using Pearson correlations (r) for the right limb of each subject. We evaluated the impact of SVMC, spasticity and strength on MRP using stepdown regression methods with a liberal $p < 0.15$ retention criterion.

RESULTS

Significant correlations ($p < 0.05$) were found between the MRP and SCALE score, spasticity index and strength index (Table 1). The strongest correlation was that of the SCALE score ($r = -0.81$) (Figure 1), as subjects with high SCALE scores tended to demonstrate more out-of-phase movement during swing (i.e., flexing the hip while extending the knee). In the stepdown regression model, SVMC remained the most important predictor, but spasticity was a factor and modified this relation ($R^2 = 0.75$).

	Pearson r	p
SCALE Score	-0.81	0.0001
Spasticity Index	0.67	0.0045
Strength Index	-0.57	0.0203

Table 1. Pearson correlations (r) between MRP and SCALE score, spasticity index and strength index.

DISCUSSION

The results of this study indicate that SVMC is a stronger predictor of hip and knee coordination during the swing phase of gait

than spasticity or strength. While CP is a multifaceted disorder, the ability to perform purposeful voluntary movement appears to be a key determinant in achieving non-synergistic movements during gait. Patients with poor SVMC ability may be constrained by their neurological capability and unable to dissociate hip and knee movement during swing regardless of hamstring length. Patients with good SVMC ability, initially constrained by biomechanical factors, may be able to utilize their increased range of motion following hamstring lengthenings. An understanding of influence of SVMC on swing phase mechanics during gait may help establish appropriate goals for interventions, in particular hamstring lengthenings.

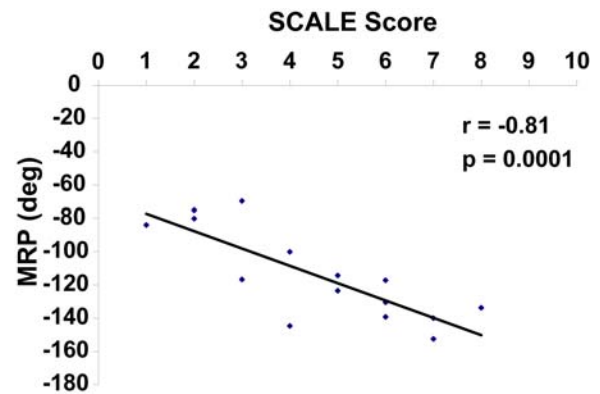


Figure 1. SCALE scores versus MRP for the right limb.

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