MUSCLE-TENDON LENGTHS AND VELOCITIES OF THE HAMSTRINGS AFTER SURGICAL LENGTHENING TO CORRECT CROUCH GAIT

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INTRODUCTION

Crouch gait, one of the most prevalent and troublesome movement abnormalities among children with cerebral palsy, is characterized by excessive knee flexion during the terminal swing and stance phases. The reputed cause of the excessive knee flexion is abnormally "short" or "spastic" hamstrings that restrict knee extension; thus, crouch gait is commonly treated by hamstrings lengthening surgery. Unfortunately, it is difficult to predict which patients will benefit from these procedures, in part, because the biomechanical factors that contribute to crouch gait and the mechanisms responsible for patients' postoperative improvements are unclear. Many individuals achieve dramatic improvements in knee extension and stride length after surgery, while others show little improvement or get worse. We believe that treatments for crouch gait could be designed more effectively if the mechanisms responsible for patients' postsurgical improvements were better understood.

This study tested the hypothesis that surgical lengthening enables the hamstrings of persons with crouch gait to operate at longer muscle-tendon lengths or lengthen at faster muscle-tendon velocities during walking. We reasoned that the surgery may improve knee extension by *(i)* decreasing the passive forces generated by hamstrings with abnormally short muscle fiber lengths, thereby enabling "short" hamstrings to operate at longer muscle-tendon lengths, or by *(ii)* attenuating the exaggerated, velocity-dependent resistance of the hamstrings to stretch, thereby enabling "spastic" hamstrings to lengthen at greater muscle-tendon velocities. Previous studies have confirmed that some children with crouch gait walk with hamstrings that are shorter than normal (e.g., Delp et al. 1996), while others walk with hamstrings that are activated at lengthening velocities slower than normal (Crenna 1998). However, no study has examined whether surgical lengthening allows patients' hamstrings to operate at greater muscle-tendon velocities or longer muscle-tendon lengths. The aim of this study was to investigate this issue.

METHODS

The muscle-tendon lengths and velocities of the semimembranosus were determined for 69 subjects with favorable surgical outcomes by combining kinematic data from gait analysis with a 3D computer model of the lower extremity (Arnold et al., 2001). The subjects' "peak" lengths and velocities during walking were identified, since these measures correspond to times in the gait cycle when abnormally short or spastic hamstrings may restrict knee extension. Log-linear analyses were performed to assess whether the subjects' hamstrings operated at increased muscle-tendon lengths and/or velocities after surgery. A test statistic was considered to be significant for p-values less than 0.05.

RESULTS AND DISCUSSION

The subjects who walked with abnormally short semimembranosus muscle-tendon lengths preoperatively tended to walk with longer peak lengths following hamstrings lengthening surgery (21 of 29 subjects, $p < 0.01$, Table 1), suggesting that surgical lengthening may have slackened these subjects' tight hamstrings. The subjects who walked with abnormally slow muscle-tendon velocities preoperatively tended to walk with faster peak semimembranosus velocities postoperatively (30 of 40 subjects, $p < 0.01$, Table 2), suggesting that, in most of these cases, surgical lengthening may have diminished the spastic response of the subjects' hamstrings to stretch. Approximately one third of the subjects walked with muscle-tendon lengths and velocities that were neither abnormally short nor slow preoperatively (22 of 69 subjects), and the hamstrings of most of these subjects did *not* operate at longer peak lengths or faster peak velocities postoperatively. In these subjects, spasticity or contracture of the hamstrings may not have been the source of the excessive knee flexion, and the improvements in knee extension exhibited by the subjects after treatment may not have been related to the hamstrings surgery.

SUMMARY

Analyses of muscle-tendon lengths and velocities during crouch gait may help to distinguish individuals who have abnormally "short" or "spastic" hamstrings from those who do not, and thus may augment conventional methods used to describe patients' neuromusculoskeletal impairments and gait abnormalities.

REFERENCES

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ACKNOWLEDGMENTS

NIH, The Whitaker Foundation, and the United Cerebral Palsy Foundation.

Table 1: Subjects who walked with longer semimembranosus muscle-tendon lengths after surgical lengthening, cross-classified by their preoperative muscle-tendon lengths and velocities

		Change in Muscle-Tendon Length	
Preoperative Length	*Preoperative Velocity*	Longer	Not Longer
Short	Slow	15	7
	Not Slow	6	1
Not Short	Slow	7	11
	Not Slow	8	14

Likelihood ratio χ^2 (3 degrees of freedom) for 2-way interactions = 16.15, $p < 0.01$

Table 2: Subjects who walked with faster semimembranosus muscle-tendon velocities after surgical lengthening, cross-classified by their preoperative muscle-tendon lengths and velocities

		Change in Muscle-Tendon Velocity	
Preoperative Length	*Preoperative Velocity*	Faster	Not Faster
Short	Slow	16	6
	Not Slow	2	5
Not Short	Slow	14	4
	Not Slow	8	14

Likelihood ratio χ^2 (3 degrees of freedom) for 2-way interactions = 18.61, $p < 0.01$