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## Can biomechanical variables predict improvement in crouch gait?

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### ABSTRACT

Many patients respond positively to treatments for crouch gait, yet surgical outcomes are inconsistent and unpredictable. In this study, we developed a multivariable regression model to determine if biomechanical variables and other subject characteristics measured during a physical exam and gait analysis can predict which subjects with crouch gait will demonstrate improved knee kinematics on a follow-up gait analysis. We formulated the model and tested its performance by retrospectively analyzing 353 limbs of subjects who walked with crouch gait. The regression model was able to predict which subjects would demonstrate 'Improved' and 'Unimproved' knee kinematics with over 70% accuracy, and was able to explain approximately 49% of the variance in subjects' change in knee flexion between gait analyses. We found that improvement in stance phase knee flexion was positively associated with three variables that were drawn from knowledge about the biomechanical contributors to crouch gait: (i) adequate hamstrings lengths and velocities, possibly achieved via hamstrings lengthening surgery, (ii) normal tibial torsion, possibly achieved via tibial derotation osteotomy, and (iii) sufficient muscle strength.

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### 1. Introduction

Crouch gait, a walking pattern defined by excessive flexion of the knee during stance phase, is a debilitating problem that affects the population of children with spastic cerebral palsy. Many patients benefit from treatments for crouch gait, including hamstrings lengthening surgeries [1–4], tibial derotation osteotomies [5–7], and multi-level surgery [8,9]; however, treatment outcomes are unpredictable.

Clinical decision-making is challenging, in part because there are no standardized protocols for determining which surgeries a patient should receive. Three-dimensional gait analysis helps clinicians identify which gait abnormalities should be targeted with treatment [10–12], but there are no uniform guidelines for interpreting the wealth of information provided by gait analysis. For example, two clinical teams might examine the same set of patient data and develop two different treatment plans [13].

Several studies have utilized biomechanical modeling and simulation of the musculoskeletal system to objectively identify the contributors to an individual's crouch gait. For example, the

work of Arnold and colleagues [14,15] suggests that a subject's hamstrings lengths and velocities during gait may provide information to more effectively prescribe hamstrings surgery. Several investigations have demonstrated that excessive tibial torsion reduces the capacity of muscles to extend the knee [16–18], suggesting that subjects with crouch gait and excess tibial torsion may benefit from a tibial derotation osteotomy. Sufficient strength of the extensor muscles may also be a key component in achieving normal knee motion. Analyzing the dynamics of normal and crouch gait has demonstrated that the gluteal muscles, plantarflexors, and vasti all play a crucial role in extending the knee during stance [18–20].

These biomechanical modeling studies have examined individual mechanical contributors to excess knee flexion for small, specialized groups of subjects, yet a typical patient has many possible contributors to his or her crouch gait. Further, there may be other variables, such as the severity of a subject's gait pathology or the presence of concomitant gait abnormalities, that affect how crouch gait progresses over time.

To improve clinical decision-making and address the limitations of past biomechanics research, we developed and tested a multivariable linear regression model that used biomechanical variables to predict subjects' improvement in crouch gait. We retrospectively analyzed subjects with moderate to severe crouch gait to determine if data from a subject's initial visit to the gait analysis laboratory could predict the change in the subject's knee

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subjects with crouch gait, in particular hamstrings lengthenings and tibial derotation osteotomies. The methods used to build the regression model in this study could be used to develop similar predictive models for other patient populations and gait pathologies. For example, we are currently investigating a linear regression model to predict improvement in overall gait kinematics after multi-level surgery. As demonstrated here, retrospective statistical analysis of patient data and biomechanical modeling are powerful and complementary tools to improve the treatment of movement disorders and make outcomes more predictable.

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### Conflict of interest statement

The authors declare that they have no competing interests.

### Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at [doi:10.1016/j.gaitpost.2011.04.009](https://doi.org/10.1016/j.gaitpost.2011.04.009).

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