IMPROVED KNEE EXTENSION CAPACITY FOLLOWING DEROTATION OF THE TIBIA IN A SUBJECT WITH CROUCH GAIT

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Introduction

Tibial torsion deformities have been identified as one of the possible contributors to crouch gait in children with cerebral palsy [1]. Previous modeling studies based on normal gait kinematics have suggested that excess external tibial torsion can reduce the capacity of muscles to extend the hip and knee during stance by altering the relative orientations of the joint axes [2,3]. The extent to which tibial torsion limits the capacity of muscles to extend the joints has not been rigorously investigated for individual subjects with pathological gait. The purpose of this study was to quantify the muscle extension capacities of a specific subject with crouch gait before and after receiving surgery to correct an external tibial torsion deformity.

Clinical Significance

This is the first study to quantitatively link subject-specific changes in tibial torsion to changes in the capacity of muscles to extend the knee and hip before and after surgery. This study demonstrates how musculoskeletal modeling can be used to help identify the effect of bone deformities on the gait of individual subjects.

Methods

We retrospectively analyzed pre- and post-operative data for a 10 year-old subject with spastic hemiplegic cerebral palsy. Prior to surgery, the subject walked with excessive hip and knee flexion throughout most of the gait cycle (Fig 1). The subject's pre-operative thigh-foot angle was 25° and popliteal angle was 35°. The subject received an external tibial derotation osteotomy that corrected approximately 20° of excess external torsion and a medial hamstrings lengthening, both on the affected side.

We estimated the extent to which the tibial torsion deformity contributed to the subject's excessive hip and knee by flexion by calculating the extension capacities of four major limb extensors (gluteus maximus, posterior gluteus medius, vasti and soleus) in a series of analyses. Extension capacities were determined by taking an average over single limb stance of the potential of each muscle to accelerate the hip and knee towards extension per unit muscle force [2]. The pre- and post-operative extension capacities were calculated by positioning a model of the subject's pre- or post-operative tibial torsion with the subject's pre- or post-operative gait kinematics. The effect of excess tibial torsion alone on muscle function was assessed by positioning a model with normal tibial geometry using the subject's pre-operative kinematics.

Results

Following surgery, the subject showed significant improvement in knee extension during terminal swing and stance (Fig 1, top). The improvements during single limb stance were consistent with our assessment of the subject's pre- and post-operative muscle capacities at the knee (Fig 2, top). Pre-operatively, the capacities of the four muscles to extend the knee were only 20 to 50% of normal when averaged over single-limb stance. Between 5 and 20% of this reduction was due to torsion alone, while the rest was attributable to the subject's crouched gait posture. After surgery, the capacity of all muscles to extend the knee improved to between 50

and 80% of normal. We believe the subject's improvement during the single-limb stance phase can be attributed to the correction of the bone deformity, rather than the hamstrings lengthening. The subject's popliteal angle was not severe prior to surgery, and only improved by 5° post-operatively. Additionally, during the portion of the gait cycle examined, the hamstrings had an extension potential, suggesting that hamstrings tightness was not a major contributor to the subject's crouch gait during single-limb stance. Rather, modeling suggested that correcting the tibial torsion would improve the stance-phase capacity of muscles to extend the knee joint, and the surgical outcome is quite consistent with this finding.

The subject showed little change in hip extension after surgery (Fig 1, bottom); the modeling results also helped to explain this outcome (Fig 2, bottom). The capacities of all four muscles to extend the hip were reduced prior to surgery, but the tibial torsion deformity accounted for less than 6% of this reduction. After surgery, the soleus and vasti showed some improvement in extension capacity; however, the capacity of the gluteal muscles to extend the hip decreased. Based on the clinical exam, we hypothesize that the excessive hip flexion resulted from the subject's diminished hip extension strength, which was not improved postoperatively.

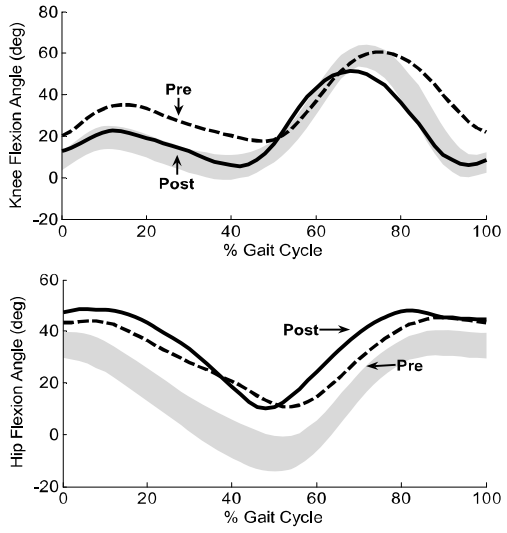

Figure 1 Pre- and post-operative gait kinematics for the knee (top) and hip (bottom)

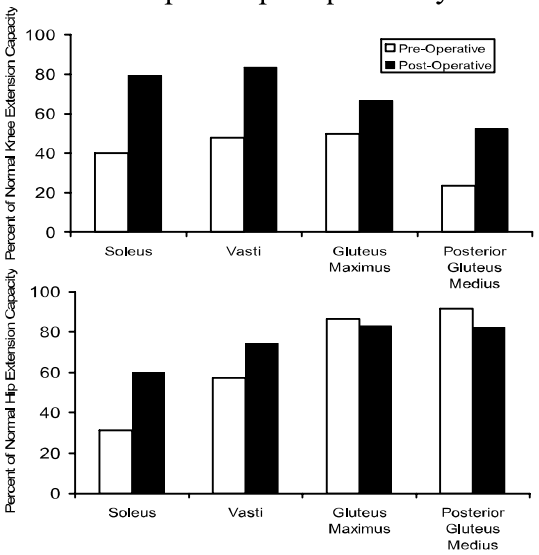

Figure 2 Pre- and post-operative muscle extension capacities as a percent of normal for the knee (top) and hip (bottom)

Discussion

We analyzed the muscle extension capacities of a specific subject with crouch gait before and after a tibial derotation osteotomy and hamstrings lengthening. We identified excess external tibial torsion as a contributor to the subject's pre-operative reduction in knee extension capacity. After surgery, this subject had improved knee extension during single limb-stance, which we believe can be attributed to correcting the excess tibial torsion. This study demonstrates how musculoskeletal modeling can be used to assess the effect of a bone deformity on an individual subject's gait. This approach can be integrated with standard gait analysis to help guide the treatment of subjects with gait disorders and bone deformities and assess the outcome of surgery.

References

[1] Gage, 2004, p45. [2] Hicks et al. (Accepted) *Gait Posture.* [3] Schwartz et al. (2003) *Gait Posture* 17, 113-8.

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