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The functional effect of a distal rectus femoris tenotomy in adults with cerebral palsy

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ABSTRACT

The purpose of this study was to determine the effect of a distal rectus femoris tenotomy on function and gait in adults with cerebral palsy who had diminished knee flexion during swing. A stiff knee gait pattern is commonly seen in individuals with cerebral palsy and frequently leads to tripping and falling. Five subjects, 25–51 years, (34.6 ± 10.3 years) participated in the study; each individual had the surgery after the age of 18. Four of the five subjects underwent bilateral distal rectus femoris tenotomies for a total of nine limbs being studied. Four of the five subjects had a single procedure of a distal rectus femoris tenotomy and one subject also had bilateral adductor tenotomies. All individuals underwent a pre-operative and post-operative, (3.28 ± 1.6 years) three-dimensional gait analysis. Pre-operative gait revealed diminished peak knee flexion and out of phase rectus femoris activity with a quiet vastus lateralis during swing in all subjects. Significant findings after a distal rectus femoris tenotomy included: improved peak swing knee flexion, improved peak stance hip extension, and increased total knee excursion without loss in knee extension strength. During swing, knee flexion angle improved on average 11° which correlated with subjective report of less shoe wear, tripping, and falling due to improved clearance. In conclusion, a distal rectus femoris tenotomy should be considered a surgical option for adults with cerebral palsy and a stiff knee gait pattern to improve mobility, function, and quality of life.

1. Introduction

During normal gait, the rectus femoris muscle is active in terminal swing and loading response to decelerate and prevent excessive knee flexion during loading; it also assists with limb advancement by flexing the hip during terminal stance and early swing phases of gait [1]. The rectus femoris is not active during mid-swing to allow for knee flexion and foot clearance. However, in individuals with cerebral palsy (CP) and a spastic rectus femoris, the muscle contracts during the mid-swing phase of gait [2–5]. This limits knee flexion and can result in poor clearance, toe drag, tripping, or falling.

The presence of a stiff knee gait pattern in individuals with spastic CP, specifically the pediatric population, is well researched compared to adults in regards to improving gait [2,4,6,7]. A rectus femoris transfer (RFT) is a common surgical option for stiff knee gait in the pediatric CP population with the goal of improving swing phase clearance and functionally diminish the amount of tripping and falling. Moreau et al. [8] found a significant improvement of 11° of knee flexion during swing following a RFT, with no significant knee flexion changes in the non-RFT group. Improved and maintained knee flexion during swing has been noted in several studies without a significant difference between RFT surgical attachment sites [9–11]. Long term benefits of RFT, as part of multilevel surgery, has been shown to have the best results when done to correct diminished peak knee flexion during swing and not as a prophylactic procedure [12].

In the literature, various surgical procedures are compared to the RFT such as, rectus femoris lengthening or release, each procedure has the same goal of working toward improving knee flexion kinematics during the swing phase of gait. Sutherland et al. found significant improvements in swing peak knee flexion in both the proximal rectus femoris release group (9°) and RFT group (16°) [6]. However, a significant change in timing in peak knee flexion was found only in the RFT group. Literature does not support a significant change in pelvic or hip position following a proximal rectus femoris release [6,13,14]. Chambers et al. [15] compared a RFT to distal rectus femoris release in 70 children with CP and stiff knee gait and found improved swing peak knee flexion of 8° in the

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RFT group, but no change in the release group. Similarly, Ounpuu et al. compared the effect of a RFT and a distal rectus femoris release and found no significant changes in the distal rectus femoris release group [16].

These studies found mixed results after proximal rectus femoris release and no effect following distal rectus femoris releases in children as part of a multilevel surgery. However, a retrospective study by Presedo et al. [17] noted significant changes in swing phase timing and peak knee flexion (11°) in subjects who had a distal rectus femoris tendon resection. Cruz et al. also suggests a rectus femoris intramuscular lengthening may be an alternative to RFT with results of improved timing of peak knee flexion, less crouch, and maintained peak swing knee flexion in 42 patients [18]. Results by Cruz and Presedo [17,18] are promising in the pediatric population, however it is unknown if these results can be applied to the adult CP population.

The previously cited studies involve individuals with CP under the age of 20 who underwent multilevel surgery. Specific changes in adults with CP and stiff knee gait is lacking in the literature. Westwell et al. [19] did study RFT on adolescents and young adults ages 14–34 finding a significant increase in knee flexion of 8° and no change in timing. Namdari et al. [20] is the only all adult study with a stiff knee gait pattern in individuals following a stroke or traumatic brain injury. They found improved clearance and knee flexion following a distal RFT with fractional lengthening of vastus muscles. However, these results, by Namdari, were based on observational gait analysis versus 3D gait analysis for exact kinematics. In the majority of literature, the RFT is done as part of a multilevel surgery. This current research aims to study a single procedure of a distal rectus femoris (DRF) tenotomy in adults with CP. Furthermore, no studies address an individual's perception of change in function post-operatively in the adult CP population.

The objective of this study was to determine the effect of a DRF tenotomy on gait in adults with CP; specifically effects on: knee extensor strength, subject perceived change in function, changes in peak swing knee flexion, peak stance hip extension, total knee excursion, and timing of peak swing knee flexion. A DRF tenotomy was selected over a RFT for adults with CP because of the relative simplicity of the operation and a quicker return to function. It was hypothesized that a DRF tenotomy would improve gait in adults with CP by increasing swing knee flexion, stance hip extension, and total knee excursion as well as improving the timing of peak knee flexion to earlier during swing. It was also hypothesized that subjects will maintain knee extension strength and be satisfied with their perceived change in gait and function.

2. Methods

2.1. Participants

Eight individuals with CP underwent a DRF tenotomy, seven of the eight met the inclusion criteria, and five of the seven enrolled in this research study. The five participants (9 limbs) were ages 25–51 years, (34.6 ± 10.3 years). Four of the five subjects had a single procedure of a DRF tenotomy and one subject also had bilateral adductor tenotomies (Table 1). Inclusion criteria for the study included: ambulatory individuals over 18 years of age, diagnosis of CP, pre-operative gait analysis completed with delayed and diminished peak knee flexion and documented out of phase rectus femoris swing activity with quiet vastus lateralis on electromyography (EMG). Individuals also needed to be at least one year post-operative DRF tenotomy at the time of the second gait analysis. Following hospital institutional review board (IRB) approval, the charts of one surgeon were reviewed to identify individuals who met the inclusion criteria. The DRF tenotomy surgery was performed on eight individuals all of whom were contacted and invited to participate in the study. Five participants were available and consented to participate by an IRB approved informed consent. The other two adults were unable to participate due to increased travel distance and one subject was 16 years of age.

2.2. Surgical procedure: distal rectus femoris tenotomy

Spinal or epidural aesthesis was preformed in all patients. A pneumatic tourniquet was inflated to provide hemostasis during the procedure, and deflated after the tenotomy was performed. A longitudinal incision, 5 cm in length was made on the distal anterior aspect of the femur approximately 10 cm proximal to the superior pole of the patella. The fascia over the rectus femoris tendon was incised. At this level the tendon was separated from the vastus medialis, intermedius, and lateralis muscles. The tendon was transected and not sutured. The tendon of the rectus femoris was bluntly isolated and then transected before it became incorporated with the combined quadriceps tendon. The knee was fully flexed to allow the rectus femoris tendon to retract. The subcutaneous tissue and skin were closed in a standard fashion. A dressing was applied and held in place by an elastic bandage.

2.3. Post-operative rehabilitation

On the first post-operative day, physical therapy (PT) was initiated including walking with full weight bearing and passive knee flexion as tolerated for 1–2 PT sessions. Patients were discharged on post operative day one walking with a rolling walker. PT was continued in an outpatient setting for approximately six weeks to achieve full knee range of motion (ROM) and independent baseline level of walking. Outpatient PT progression was determined by the treating therapist using general PT guidelines.

2.4. Clinical measures

Testing for all subjects included: a PT examination, completion of a questionnaire, and 3D gait analysis testing.

2.5. Physical therapy examination

The PT examination included the measurement of supine knee flexion range of motion (ROM) with a universal goniometer using a standard protocol [21]. Knee extension strength was tested with manual muscle testing [22]. The Ely test measured the spasticity of the rectus femoris muscle. The Ely test was performed with the subject prone and the subject's knee was rapidly flexed. The

Table 1
Subject demographics.

GMFCS*	Gender	Age at post-op visit (years)	Surgical procedure	Years post-operative
I	Male	28	Bilateral DRF tenotomy	2.5
II	Female	51	Bilateral DRF tenotomy and adductor tenotomy	2.3
II	Male	31	Bilateral DRF tenotomy	1.7
III	Female	25	Bilateral DRF tenotomy	5.4
III	Female	38	Right DRF tenotomy	4.5

* Gross Motor Function Classification Scale (GMFCS) [24].