

## **Calf Muscle Length in Equinus Gait**

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**Introduction:** Equinus is one of the most common deformities in children with cerebral palsy (CP). Though equinus is dynamic initially, it often develops into a fixed deformity that requires surgical correction. Two operations commonly performed to correct fixed equinus include gastrocnemius recession (GR) and tendo-achilles lengthening (TAL). Surgical decision-making between GR and TAL is often based on the Silfverskiöld test under the assumption that lack of dorsiflexion with the knee flexed indicates soleus contracture while lack of dorsiflexion with the knee extended indicates gastrocnemius involvement. However, it is not currently known if muscle contracture measured during static examination translates into decreased muscle length during gait. The effects of surgery on dynamic muscle lengths are also not known. This study uses computer modeling to examine gastrocnemius and soleus lengths in children with CP and equinus gait to determine whether either muscle is abnormally short, whether dynamic muscle length is limited by muscle contracture, and whether GR and TAL provide adequate correction of dynamic muscle lengths.

**Statement of Clinical Significance:** Abnormal muscle length contributes to equinus gait in children with CP. A thorough understanding of dynamic muscle lengths during equinus gait is necessary to optimize therapeutic intervention.

**Methodology:** Pre- and post-operative ( $18 \pm 6$  mo) gait kinematics were retrospectively reviewed for 10 limbs from 8 children who underwent GR and 5 limbs from 4 children who underwent TAL without concomitant bony surgeries. GR was generally performed if the ankle could be dorsiflexed to at least  $0^\circ$  with the knee flexed, and TAL was performed if this dorsiflexion could not be achieved. Kinematics were also reviewed for 10 limbs from 8 children who had equinus gait without fixed contracture ( $>0^\circ$  dorsiflexion with knee extended) and 10 limbs from 5 able-bodied children. Medial gastrocnemius (MGAS) and soleus (SOL) muscle lengths were calculated from the kinematic data using the Software for Interactive Musculoskeletal Modeling (SIMM) gait module (Musculographics Inc., Chicago, IL). This module uses a generic musculoskeletal model [1] scaled to the subject's body proportions. To account for differences in size between subjects, all muscle lengths were normalized by muscle length in the anatomic position. Pre-operative ratios of peak muscle length during the stance phase of gait to maximum static muscle length were also examined. For this analysis, one GR limb was excluded because static measurements were not available, and 4 additional limbs that had pre- but not post-operative data were added to the TAL group. Maximum SOL length was calculated with the knee flexed to  $90^\circ$  and the ankle dorsiflexed to the maximum achieved during physical examination. MGAS length was calculated similarly but with the knee fully extended at  $0^\circ$ .

**Results:** Preoperatively, subjects in all groups had abnormally short MGAS and SOL lengths throughout the gait cycle (Fig 1). Surgery greatly improved dynamic muscle length,

particularly in stance. MGAS and SOL lengths during stance became normal after TAL. After GR, stance-phase MGAS length was normal, but SOL length remained slightly shorter than normal in 7 of 10 subjects.

During gait, subjects in the surgery groups used close to their maximum static muscle lengths, while subjects in the dynamic equinus group used shorter muscle lengths (Table 1). For all groups, MGAS operated closer to its maximum static length than SOL.

	MGAS	SOL
<b>GR</b>	$0.999 \pm 0.037$	$0.985 \pm 0.039$
<b>TAL</b>	$1.005 \pm 0.019$	$0.987 \pm 0.029$
<b>Dynamic</b>	$0.976 \pm 0.015$	$0.967 \pm 0.019$

Table 1: Pre-operative ratios of peak dynamic (stance phase) to maximum static muscle length.

**Discussion:** Equinus gait is characterized by abnormally short gastrocnemius and soleus lengths in most subjects with CP. The muscles operate at a shortened length whether the equinus is fixed or dynamic. This contrasts with crouch gait, which often does not involve abnormally short hamstrings [2] except in children selected for hamstring lengthening surgery [3].

The calf muscles operate closer to their maximum static lengths when fixed contracture is present than when contracture is absent. This indicates that factors other than contracture (e.g., spasticity) contribute to dynamic equinus. Because MGAS operates closer to its maximum length than SOL, gastrocnemius contracture may influence equinus gait more than soleus contracture.

GR and TAL both increase muscle length during gait, particularly in stance when peak dorsiflexion is normally achieved. However, GR often fails to fully correct dynamic soleus length. Despite greater static dorsiflexion with the knee flexed in subjects selected for GR, dynamic SOL length did not differ pre-operatively between subjects selected for GR versus TAL. Consideration of dynamic muscle lengths in addition to static range of motion measurements could improve the treatment of equinus gait in children with CP.

**References:** [1] Delp et al., IEEE Trans Biomed Eng, 37(8):757-67, 1990. [2] Delp et al., J Orthop Res, 14(1):144-51, 1996. [3] Olsen et al., GCMAS 2002:170.

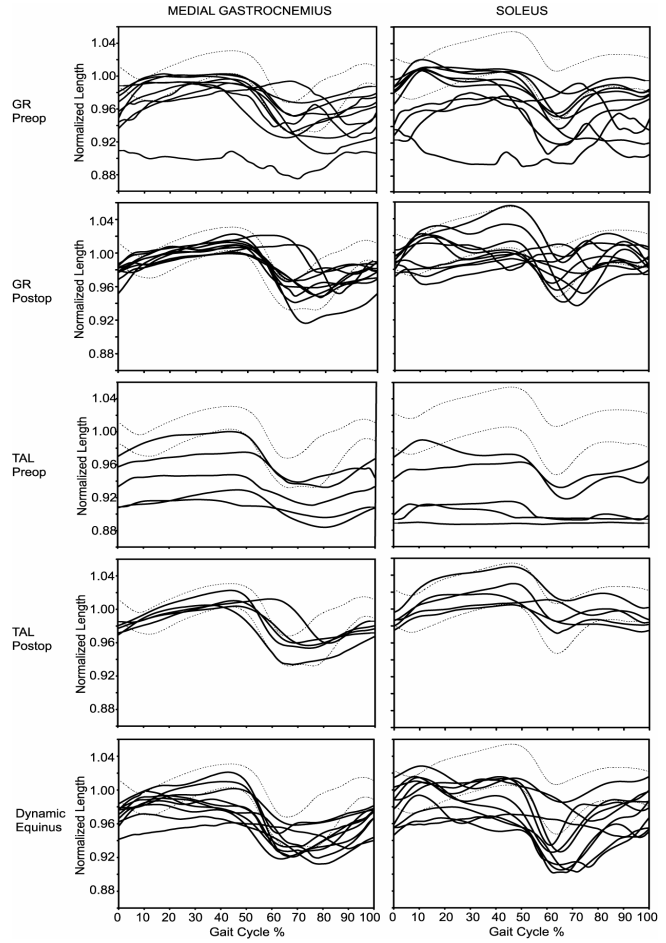


Figure 1: Muscle lengths before and after surgery. Dotted lines indicate normal range ( $\pm 2SD$ ).