A Comparison of Gastrocnemius Muscle Length During Gait Using MRI and Cadaveric Models

Tracy Yuen, and Michael Orendurff*, Department of Bioengineering, University of Pennsylvania, and *Motion Analysis Laboratory, Rehabilitation Research & Development, Veterans Administration Puget Sound Health Care System

Introduction: Several methods of calculating muscle length are available in literature, and all estimate the changes in muscle-tendon unit length resulting from the movements of the joints they cross. With recent developments in clinical gait analysis and interactive musculoskeletal modeling, new insights into outcomes of surgical muscle lengthening are possible, but only if accurate muscle lengths are known. Most muscle length estimation methods have been based on cadaveric models; other methods have employed more anatomically based estimates, using non-invasive in vivo techniques such as MRI to develop models to estimate muscle lengths. The purpose of this investigation was to compare cadaveric and MRI based models of gastrocnemius length calculation during gait.

Statement of Clinical Significance: Computing the length of a specific muscle is often of interest both in the study of human movement and in optimizing surgical techniques.

Methodology: Three methods of calculating gastrocnemius length were compared. All methods utilized ankle and knee kinematic data. Grieve et al. (1978) studied changes in gastrocnemius length upon the examination of cadaveric specimens. Following the dissection and isolation of the knee and ankle joints, one joint was held stationary while the other was manipulated through a range of angles. Changes in the length of a gap cut in the Achilles tendon were then measured. Hawkins & Hull (1990) obtained anthropometric data and then simulated different joint flexion angle combinations using computer software. Eames et al. (1997) employed MRI data to estimate the length of the gastrocnemius from sagittal views of the muscle's line of action at the knee and ankle. Using these three methods, the gastrocnemius length was calculated from the sagittal kinematics of the knee and ankle of 20 normal adults who were walking at their self selected speed. For this study, all lengths were normalized to percent of anatomic neutral length, with 100% of gastrocnemius length being full knee extension and neutral ankle plantar-dorsiflexion. A repeated measures ANOVA with Scheffe's tests post hoc was conducted to determine statistical significance among the three methods.

Results: Gastrocnemius values are shown in figure 1. The methods of Grieve and of Hawkins showed more variability than that of Eames, most noticeably during push-off. Gastrocnemius length calculated using the methods of Grieve and of Hawkins appears more closely related to ankle motion than knee motion. This contrasts with the method of Eames et al., which appears closely related to knee motion. The differences are most profound in mid-stance phase, where all methods showed statistical differences from each other ($p < 0.01$). Total gastrocnemius length change during gait was 9.7% ANL by Grieve's method, 10.6% by Hawkins and Hull, and 7.2% by Eames.

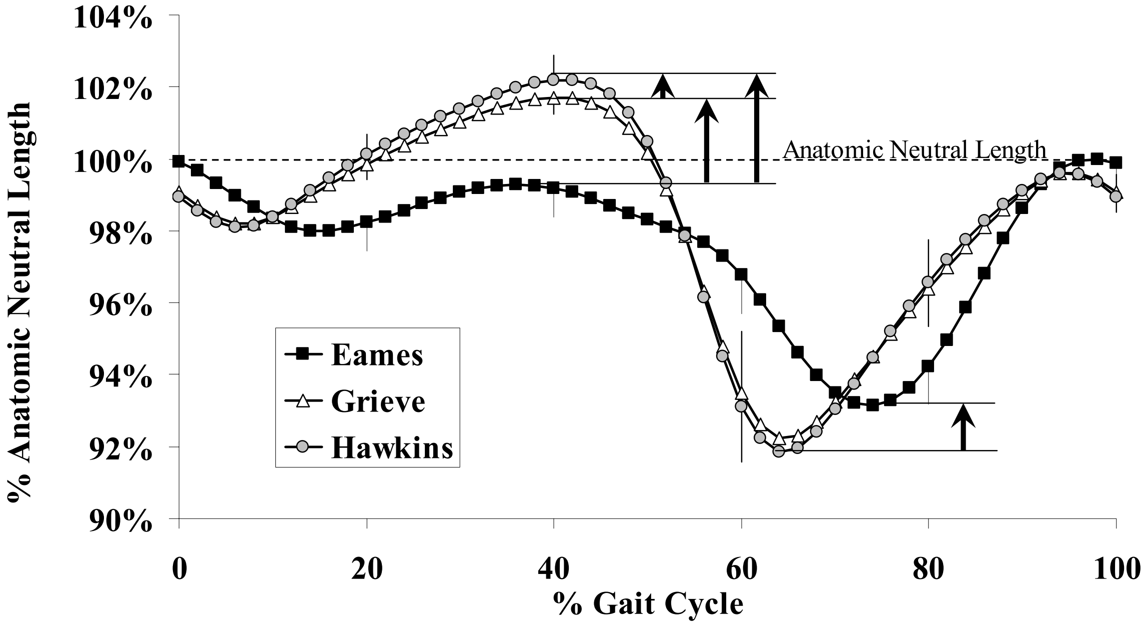

Figure 1. Mean gastrocnemius length during gait for 20 normal adults estimated by MRI (Eames) and cadaveric (Grieve, Hawkins) methods. Length is normalized to % anatomic neutral length (muscle length at full knee extension and neutral ankle position). Standard deviations are shown every 20% of the gait cycle. Arrows indicate statistically significant differences between methods at maximum and minimum lengths ($p<0.01$).

Discussion: The lack of agreement between methods, with no gold standard, suggests that muscle length estimates calculated from kinematic data should be interpreted with caution. The biarticular action of the gastrocnemius may result in a profound or negligible influence of knee motion upon gastrocnemius length, depending which method is used to estimate muscle length changes. The differences in cadaveric and MRI models may be due to differences in viscoelastic properties of muscle and tendon *in vivo* versus *exanimus*. The moment arm of the gastrocnemius is larger at the knee than at the ankle, and the knee goes through a larger range of motion during gait. However, this influence of the knee on gastrocnemius length is only reflected in the MRI based model. Additional work is needed to validate a model of gastrocnemius length.

Surgical lengthening of the gastrocnemius to correct equinus should be undertaken with caution since the effect of this muscle on ankle motion is not objectively known. This is especially true when simultaneous surgical procedures to increase knee extension such as hamstring or iliopsoas lengthenings are performed.

References:
1. Grieve DW, Cavanagh PR, Pheasant S (1978) *Biomechanics* VI-A:405-412.
2. Hawkins D, Hull ML. (1990) *Journal of Biomechanics,* 23(5):487-94.
3. Eames NWA, Baker RJ, Cosgrove AP (1997) *Gait and Posture* 6(1):9-17

Acknowledgements: This work is funded by Dept of Veterans Affairs #A0806C