CAN AN INVERSE DYNAMICS APPROACH PREDICT AGONIST AND ANTAGONIST ACTIVATION OF A SQUAT?

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Introduction

The prediction of muscle activation (a_m) is essential when estimating muscle force (f^m) using an inverse dynamics approach. Adjusting the polynomial (P) of the cost function and complexity of the model used may improve these estimates. This study sought to determine the ability of the inverse dynamics approach to accurately predict the magnitudes and patterns of a_m for a closed kinetic chain dynamic task and whether model complexity or P value altered the ability in agonist and antagonist muscle groups.

Methods

Five healthy young adults stood on a force plate with their dominant leg and performed three one-legged squats. Kinematics, kinetics, and electromyography (EMG) were recorded. Maximum voluntary isometric contractions (MVIC) were recorded on an isokinetic dynamometre. In the *AnyBody Modeling System*, the lower extremity model [Klein Horsman et al, 2007] was used to predict a_m in lateral (LG) and medial (MG) gastrocnemius, vastus lateralis (VL) and medialis (VM), rectus femoris (RF), semitendinosus (ST), biceps femoris (BF), and tensor fascia lata (TF) using either a simple or Hill-type actuator. The simple actuator included the contractile element defined by a_m and maximum isometric force (f^{max}). The Hill-type actuator included the contractile element, defined by a_m, f^{max}, length-tension and force-velocity relationships. a_m was defined as [Damsgaard et al, 2006]:

$$Simple\ Actuator: a_m = \left(\frac{f^m}{f^{max}}\right) \quad (1)$$

$$Hill-Type\ Actuator: a_m = \left(\frac{f^m}{f^n}\right) \quad (2)$$

where f^n was instantaneous muscle strength. Then a_m was determined through minimizing the cost function [Damsgaard et al, 2006]:

$$J_{COST} = \sum(a_m)^P \ (P = 1, 2, 3, 4, 5) \quad (3)$$

EMG and model-predicted a_m were normalized to the measured MVICs. Standard error of the estimate (SEE) and coefficient of determination (r^2) were calculated to determine the respective accuracies of magnitudes and patterns in the model-predicted a_m relative to the EMG.

Result

The ability to predict activation was muscle, actuator, role, and P dependent (Fig 1). The simple actuators predicted similar a_m magnitudes and patterns of VM (P=4, 5) and RF (P=3 to 5) compared to EMGs (SEE ≤ .10; $r^2 \geq .95$). For VL, the simple (P=1) and Hill-type (P=2 to 4) actuators predicted a_m magnitudes and patterns similar to the EMG (SEE ≤ .09; $r^2 \geq .94$). However, for LG, MG, ST, BF, and TF, the simple and Hill-type actuators could not accurately predict a_m.

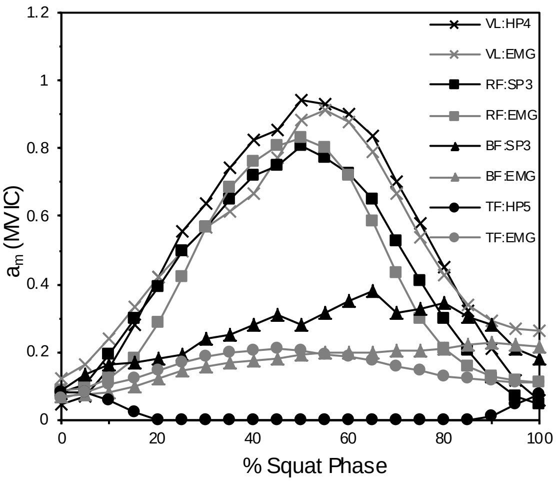

Fig. 1. Mean experimental and model-predicted a_m of VL, RF, BF, and TF by simple (S) and Hill-type (H) actuators.

Discussion

Our results demonstrated that, with different combinations of muscle models and P, the inverse dynamic's approach can predict a_m characteristics in the major knee uni-and biarticular extensors similar to real-life a_m, but only if they function as dominant moment-generating (agonistic) muscles for this squat task. The stabilizing (antagonistic) muscles were not well predicted regardless of the approach for our task. A better approach to increase model predictions is required and being explored based on these muscle roles.

References

Damsgaard *et al*, Simulat Model Pract Th, 14, 1100-1111, 2006.
Klein Horsman *et al*, Clinic Biomech, 22, 239-247, 2007.