Force changes in Vastus Medialis during gait: Relationship with EMG and impact on co-contraction estimates – A proof of concept.

Kumar D[3], Rudolph KS[1,3], Manal K[2,3]
1.Dept of Physical Therapy, 2.Dept of Mechanical Engineering, 3.Biomechanics and Movement Sciences (University of Delaware)

Background and Significance: People with knee osteoarthritis (OA) have been shown to have higher muscular co-contraction between opposing muscle groups during walking. Investigators have speculated that higher muscle co-contraction, calculated from electromyographic (EMG) signals during walking can lead to higher joint loading that may exacerbate OA progression. However the force generated during the co-contraction is unknown. During dynamic activities estimates of muscle force from EMG must take into account characteristics such as electromechanical delay, muscle force-length and force-velocity relationships and the type of contraction (eccentric or concentric) all of which can influence the magnitude of the force produced per unit EMG. Although the EMG-force relationship has been studied previously, no study has validated the changes in muscle force and co-contraction as predicted by EMG during gait. Computational modeling can provide estimates of muscle force that would broaden and greatly enhance the interpretation of EMG data during dynamic activities such as walking.

Purpose: In this presentation we compare EMG data presented as %max EMG, to muscle force estimated with an EMG driven musculoskeletal model and discuss the difference in interpretation of muscle activation during walking in a subject with medial knee OA.

Methods: A 63 year old female with Knee Osteoarthritis walked at a self-selected speed while kinematic data was captured with 8 camera VICON motion system @ 120 Hz, kinetic data @ 1080 Hz with 2 Bertec force plates and EMG @1080 Hz using bipolar, surface electrodes over lower extremity muscles. EMG linear envelopes were created by full wave rectification and filtering the EMG with a 6Hz low pass filter, and normalized to the peak EMG during a maximum voluntary contraction. The EMG-driven model includes 12 muscles crossing the knee and is sensitive to subject specific joint kinematics and neuromuscular activations. The normalized EMGs were transformed to neural activation and used as inputs to a Hill-type muscle model. Parameters specific to each muscle included: optimal fiber length, tendon slack length, maximum isometric force, pennation angle and maximum fiber contraction velocity. Simulated annealing optimization was used to determine muscle parameters that minimized the difference between the model-estimated and the net moment computed using inverse dynamics. Muscle parameters were constrained to be within physiologic ranges reported in the literature. The details of this method have been described elsewhere (Buchanan et al., 2004).

Results: Figure 1 illustrates a vastus medialis EMG activation profile that, as expected, shows increasing activity during early stance with decreasing activity from late midstance to toe off.

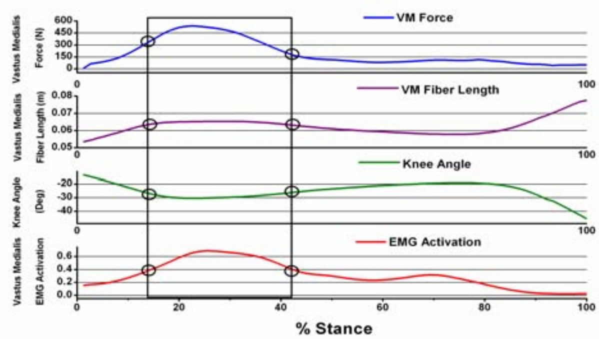

Figure 1. Vastus Medialis (VM) Force, fiber length, knee flexion angle, and VM activation during stance.

The model also appropriately identifies muscle fiber lengthening during the eccentric contraction in early stance and shortening during the concentric phase in mid-stance.

At 15% and 42% stance, the muscle activation and fiber lengths were approximately equal, however the force generated by the VM was higher during the eccentric contraction around 15% stance than at 42% stance where the contraction was concentric. The higher muscle force during the eccentric than concentric phases despite equal EMG levels, illustrates that interpreting EMG without knowing the force level that the EMG actually represents can lead to erroneous conclusions.

Discussion: The data show that muscle activation does not accurately represent the level of force that is generated by the muscles at all points in the gait cycle. It also shows the effect of muscle contraction type (concentric vs. eccentric) on EMG during gait. The results underscore the importance of accounting for characteristics of muscle that influence force during dynamic contractions when interpreting EMG data. The force that was calculated by the musculoskeletal model clearly indicates that the same level of EMG does not always produce the same force. This illustrates the importance of choosing intervals that represent the same type of contraction if EMG alone is used to study neuromuscular control. This computational model improves the interpretation of muscle activation in studies of people with knee OA by allowing comparison of muscle forces rather than speculating about how muscle co-contraction might influence joint degeneration.