IDENTIFICATION OF MUSCLE SYNERGIES DURING HIGH KNEE FLEXION SQUATTING

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INTRODUCTION

Currently, there is no activation waveform data available for the lower limb muscles during high knee flexion activities. Without foundational electromyographic (EMG) data our understanding of muscular control strategies is limited for these postures. Synergistic analysis has emerged as a tool which can be used to reduce data dimensionality in muscle activation waveforms and outputs are theorized to represent central command patterns [1]. This study aimed to determine if muscle activity during high flexion squatting can be reduced to a small number of synergies and to determine the robustness of the identified synergies to a change in external load during high flexion squatting.

METHODS

Sixteen participants (8M/8F) participated in this study. Surface EMG was recorded (Wireless Wave Plus™, Cometa srl, MI, Italy) from 8 lower limb muscles while synchronous kinematics and kinetics were recorded (Optotrak Certus/3020™, NDI, ON, Canada; OR6-7™ force plates (AMTI Inc, MA, USA).

Forty symmetric squats (4 sets of 10) were performed in each of two load conditions: unloaded (holding a 1.5kg crate) and loaded (20% of participant's body weight) in a randomized order. Squats were divided into descending and ascending phases for analysis. EMG data were normalized to flexion angle—as opposed to time-series—from 0-135º in 1º increments. Non-negative matrix factorization (NMF) was used to extract a selected number of synergies [2].

Two criteria were used to determine adequate signal reconstruction from the extracted synergies. Variability accounted for (VAF) in all muscles combined [3] and RMSD for all individual muscles were ≥ 90% and ≤ 1% MVC respectively. The NMF algorithm was iteratively run with the *a-priori* number of synergies increasing by one until both criteria were satisfied.

RESULTS

Four synergies were required to satisfy both the VAF and RMSD criteria across all phases of movement and conditions. During descent in unloaded squatting, knee extensor musculature weighted heavily on synergy 3 (67.3% VAF) which had a large magnitude from 70-120º of knee flexion. Similarly during ascent extensor musculature weighted heavily on synergy 3 (56.3% VAF) from 100-135º, but flexors were best represented by synergy 1 (15% VAF). Loaded trials had similar outcomes, but the shapes and respective VAF score trends between synergies 1 and 2 were reversed.

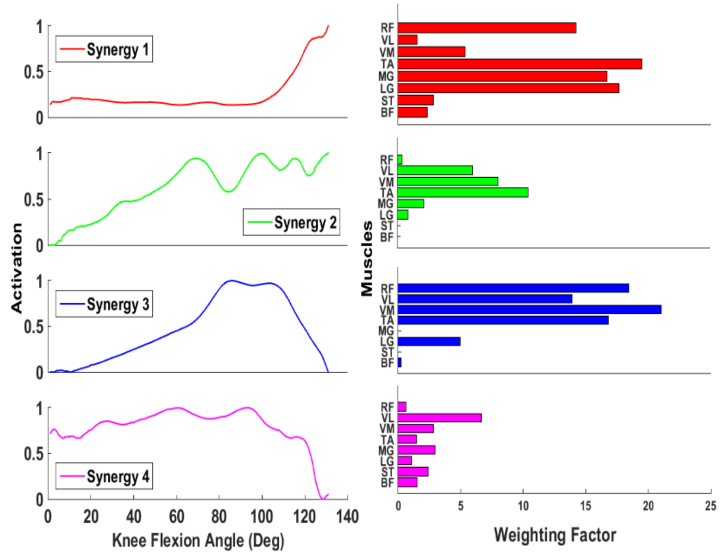

Figure 1 Synergy activation waveforms (left) and respective weightings (right) for each muscle during unloaded descent. Rectus femoris (RF), vastus lateralis (VL), vastus medialis (VM), tibialis anterior (TA), medial gastrocnemius (MG), lateral gastrocnemius (LG), semitendinosus (ST), and biceps femoris (BF). Synergy activations are normalized to the maximum waveform value across all muscles.

DISCUSSION AND CONCLUSIONS

For this high knee flexion movement a small set of muscle synergies was able to reconstruct the original signal within 1% MVC. For each synergy, the most heavily weighted muscles tended to be grouped by inferred anatomical functions, providing support for the theory that synergies represent a common neural drive [1]. Adding a hand-held mass did not change the number of synergies needed. This approach provides an objective means of grouping muscles based on co-activation and allows signal reconstruction with half of the original data dimensionality. These synergistic profiles may be used to improve muscle force estimates in optimization routines [3].

REFERENCES

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