A PROCEDURE TO PERSONALIZE A MUSCLE FATIGUE MODEL FOR SOLVING THE MUSCLE RECRUITMENT PROBLEM

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Introduction

Determination of muscle forces is of great interest to extract the principles of the central nervous system control (diagnosis of neuromuscular disorders), or to estimate the loads on bones and joints (prevention of injuries in sports/work tasks, surgical planning to reconstruct diseased joints) [1]. The redundancy problem of the muscle recruitment, the uniqueness of each human being and the difficulty to extract some subject-specific parameters are the main issues to solve for obtaining good results. The aim of this study is to propose a procedure to include a personalized muscle fatigue model in the optimization-based solution of the muscle recruitment problem.

Methods

Muscle activation, fatigue, and recovery under a variety of loading conditions can be represented by a three-compartment model, fully explained in [2], corresponding to the three muscle states: resting, activated, or fatigued. This model can be implemented to constraint the muscle forces within the optimization problem, thus offering a valid approach for the calculation of the redundant muscle forces in the presence of muscular fatigue, as stated in [3].

However, in [3], the authors did not apply the resulting model to a real case, and consequently did not address some issues. In order to use the full muscle model considering fatigue, it is required to calibrate some subject-specific parameters. While some parameters depend directly on the musculoskeletal geometry (musculotendon length, musculotendon velocity, and moment arms), and others can be indirectly scaled from it (optimal muscle fiber length and slack tendon length), maximum isometric force (*Fm0*) as well as fatigue and recovery coefficients (*F* and *R*, respectively) require additional calibration measurements. The latter play an essential role for an accurate fatigue simulation because they introduce muscle force constraints. If they are not calibrated, the task-related loss of force will not be reflected.

For this reason, to assess muscles forces considering fatigue, the authors propose a protocol consisting of two main steps (Figure 1):

1. Muscle force and fatigue calibration.
2. Determination of muscle forces with fatigue.

A right upper extremity model of the elbow joint with seven muscles adapted from [4] was used in an inverse dynamics analysis perspective for two subjects (one male and one female).

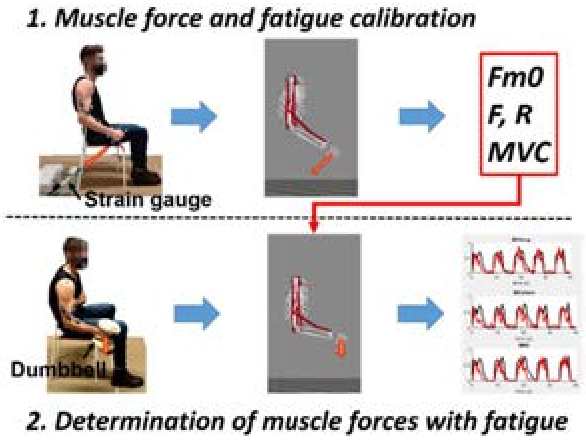

Figure 1: Protocol steps (MVC: Maximum Voluntary Contraction).

Results

In this work, the process is applied to a benchmark case: the force quantification of the elbow flexor and extensor muscle sets engaged in weightlifting and performing cycles of forearm flexion/extension. Results are compared to those obtained without considering fatigue, showing good correlation with experimental measurements (surface electromyography).

Discussion

Results were observed for two subjects, and subject-specific parameters showed differences. In order to highlight the inter-subject variability and validate the procedure, the approach will be applied to more subjects in a future work.

References

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