Computers in Biology and Medicine 35 (2005) 373–387
Computers in Biology and Medicine
http://www.intl.elsevierhealth.com/journals/cobm

Comparison between two muscle models under dynamic conditions

R.T. Raikova*, H.Ts. Aladjov

Bulgarian Academy of Sciences, Centre of Biomedical Engineering, Acad. G. Bonchev Str., Bl. 105, 207A, Sofia 1113, Bulgaria

Received 4 November 2003; accepted 1 March 2004

Abstract

One fundamental problem when trying to calculate the force developed by one muscle during a motor task is the muscle model. Usually, one control signal is juxtaposed to one musclotendon unit. The question is how is this signal connected to the activation of the motor units (MUs) that compose the muscle and fire differently. The aim of the paper is to compare a Hill-type muscle model to a model composed of MUs. A fast elbow flexion performed by only one muscle is considered. The activation necessary for performing the motion and the corresponding frequencies are calculated for cases of fast and slow muscles using Hill-type model. Then the muscle is modelled as a mixture of 774 MUs with uniformly distributed twitch parameters. Using MotCo software the moments of impulsation of all MUs and their mechanical responses are predicted. The activation characteristics obtained by the two muscle models are compared. It is concluded that there are two essential parameters for proper muscle modelling: the lead-time and the MUs composition.

Keywords: Motor control; Muscle model; Motor units; Hill-model; Muscle forces; Genetic algorithm; Neural control

1. Introduction

When modelling the control of the human limb motions, the final aim is to estimate the individual muscle forces. The scientific problem is how shall the necessary joint moments be satisfied by the synchronous contribution of so many muscles. A fundamental issue here is the muscle model [1]. The muscle force is usually considered a simple design variable when the external joint

* Corresponding author. Tel.: +3592-80-05-27; fax: +3592-72-37-87.
E-mail address: rosi.raikova@clbme.bas.bg (R.T. Raikova).

0010-4825/$ - see front matter © 2004 Elsevier Ltd. All rights reserved.
doi:10.1016/j.compbiomed.2004.03.001

Nomenclature

φ	flexion angle in the elbow
M_{ext}	external moment in the joint
d	lever arm of a muscle equivalent
F	muscle force
F_{max}	maximal muscle force
l	current length of the muscle normalized to the optimal length
V	contraction velocity of the muscle
$FL(l)$	force–length relationship
FL_s	calculated force–length relationship during the motion if the muscle is slow
FL_f	calculated force–length relationship during the motion if the muscle is fast
$FV(l,V)$	force–velocity relationship
FV_s	calculated force–velocity relationship during the motion if the muscle is slow
FV_f	calculated force–velocity relationship during the motion if the muscle is fast
$F_{PE1}(l)$ and $F_{PE2}(l)$	forces in the passive elements
F_{PE1s} F_{PE2s}	calculated forces in the passive elements if the muscle is slow
F_{PE1f} F_{PE2f}	calculated forces in the passive elements if the muscle is fast
α	muscle activation
alfa-fast	calculated activation in case of fast muscle
alfa-slow	calculated activation in case of slow muscle
alfa-motco	"activation parameter" calculated by MotCo software in case of uniformly distributed parameters of the motor units
alfa-motco with Tlead	"activation parameter" calculated by MotCo software in case of uniformly distributed parameters of the motor units but shifted forward with 100 ms
alfa-motco-fast	"activation parameter" calculated by MotCo software in case when all motor units are fast-like
f	stimulus frequency
l_{eff}	muscle effective length
Y	yielding
f-fast	calculated frequency during the motion in case of fast muscle
f-slow	calculated frequency during the motion in case of slow muscle
fef-fast	calculated frequency during the motion in case of fast muscle accounting for the yielding and using the muscle effective length
fef-slow	calculated frequency during the motion in case of slow muscle accounting for the yielding and using the muscle effective length
f-motco	average frequency of the motor units firing calculated by MotCo software in case of uniformly distributed parameters of the motor units
f-motco-fast	average frequency of the motor units firing calculated by MotCo software in the case when all motor units are fast-like