Development of a computational musculoskeletal model of the cat hind limb

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1. Introduction

One of the challenging problems in the field of biomechanics is to determine the individual muscle forces by noninvasive and theoretical approaches. To provide a solution to this problem, some computational musculoskeletal modeling and simulation software packages were released [1]. Computational models and simulation of musculoskeletal systems enable researchers to gain insight into the motor control mechanisms of human and animals. In this study, a musculoskeletal model of a cat hind limb was developed and simulated for a wide range of locomotor conditions in Opensim software. To evaluate the model, muscle force predictions obtained from the simulation software were compared with the experimentally recorded muscle forces. Results indicate that although the theoretical muscle forces are highly sensitive to the configuration parameters, which are needed to construct the musculoskeletal model, realistic muscle force predictions can be obtained from the simulation software.

2. Musculoskeletal model of cat hind limb

To create the solid body model of the skeletal system of cat hind limb, computed tomography (CT) images of a male, adult cat were recorded. Then, three dimensional skeletal model was obtained by converting the CT data using a image processing program (3D Doctor, Able Software Corp., USA). The modeled cat skeletal system with 13 degrees of freedom (DoF) was consisted of five rigid bodies: the pelvis, thigh, shank, foot, and the digits (Fig. 1a). Furthermore, 25 Hill-type muscles were added to the Opensim skeletal model by taking the anatomically correct origin and insertions sites into account (Fig. 1b). The muscle physiological parameters, which are needed to be predefined in order to create a muscle model in Opensim, such as pennation angle, optimal fiber length, maximal isometric force and tendon slack length were drawn from literature sources [2]. The musculoskeletal model was then modified so that the muscle moment arms fitted the given literature data [2]. Individual muscle forces obtained from Opensim were compared with those that were experimentally measured for different locomotor conditions. In the experiments, forces of the cat soleus (SOL) and medial gastrocnemius (MG) muscles were measured using surgically implanted tendon force transducers. Joint angles and ground reaction forces were also recorded [3].

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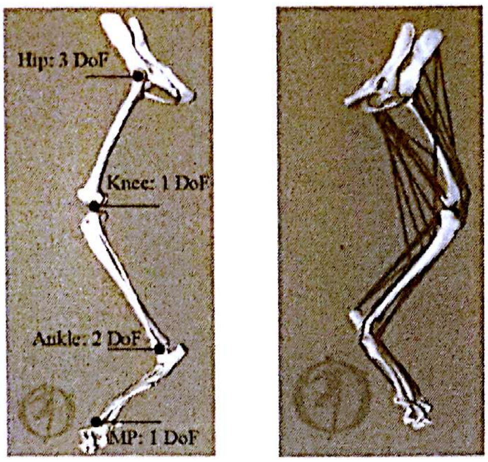
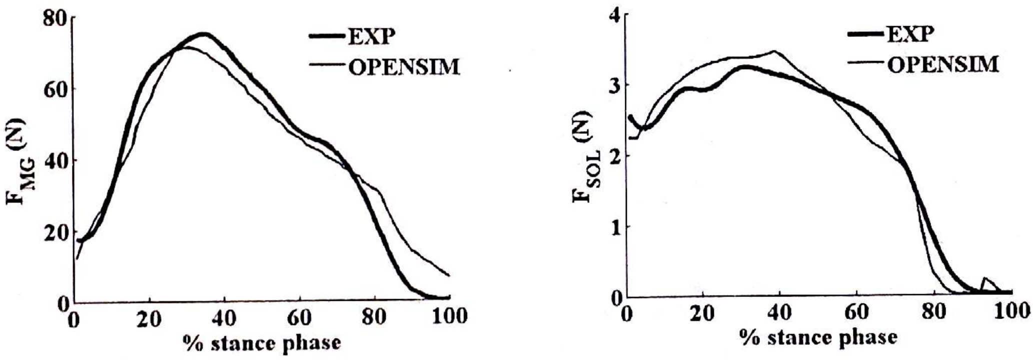


(a) (b)

Fig. 1. (a) Skeletal model of cat hind limb b) Hill-type muscle models integrated model.

3. Results and discussions

The comparison of theoretical and experimental muscle forces over stance phase was given in Fig. 2. It can be seen from the figure that simulation and experimental forces are in good agreement. On the other hand, calculated muscle forces showed a high sensitivity to the configuration parameters, such as tendon slack length and optimal fiber length which requires a close attention should be given to the modeling phase of the musculoskeletal system in Opensim.



(a) (b)

Fig. 2. Comparison of the experimental (EXP) and theoretical muscle forces obtained by Opensim for (a) medial gastrocnemius (MG), (b) soleus (SOL).

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