The Modelling of Different Dog Breeds on the Basis of a Validated Model

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Abstract. Based on our existing musculoskeletal models of the dog (Beagle & German Shepard) we have developed two additional ones. We have chosen the Dachshund and the Great Dane because they represent extreme body size values along dog breads. Models for the French Bulldog, the Whippet, and Malinois will follow. We are confident that our models will advance the analysis of the influence of body size, physique and mobility on locomotion and joint dynamics.

Keywords: Neuromechanical models · Dachshund · Beagle · German shepard · Great dane

1 Introduction

The domestic dog (*canis lupus* f. familiaris) is the only animal species with more than 400 breeds recognized worldwide [1]. Therefore, it represents an interesting study group due to its great variability in body size, body mass and physique. In recent years, the number of clinical studies on the musculoskeletal system of dogs has increased [2,3]. However, the relationship between body structure and joint loading during locomotion, as well as between joint loading and degenerative musculoskeletal diseases (e.g. dysplasia) and their effects on neural control, has not yet been adequately elucidated [4]. A combination of experiments, detailed musculoskeletal models, finite element modelling (FEM), neuromechanical models and bioinspired robotics can help to analyze these interactions. For this purpose, a flexible modular software kit has been designed that can be used to create canine models ranging from individual leg segments to a complete musculoskeletal model [4]. In addition, this building kit can be used to create different models for different breeds to understand the influence of morphological parameters on e.g., locomotion or joint dynamics and control.

2 Material and Methods

From the publication of Stark et al. [4] we had a validated three-dimensional model of a beagle at our availability. This model was based on a German Shepard

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dataset, so that the scaling algorithms (for e.g., mass, lengths, muscle parameters) were existent. To build new models, we used the scaling function of OpenSim [5,6]. It is implemented in the tool "Scale" and with it the individual segment masses, inertia, lengths, and muscle parameters, can be scaled uniformly or individually for all three axes. This made it easy to adapt the model to the different proportions of the dog breeds. However, the availability of the morphometric parameters is important.

We obtained these data from Fischer and Lilje [7]. For the different breeds, body lengths, wither heights and leg segment lengths in proportion to the leg length are there given. Note that the moments of inertia must be recomputed if the segment masses differ. The maximal muscle force must be manually scaled as well. For this, we used the relationships published by Stark et al. [4]. To generate the musculoskeletal models presented in this work, we selected the Dachshund and the Great Dane (see Fig. 1), They represent two extreme values of body size and the ratio between body length/wither height.

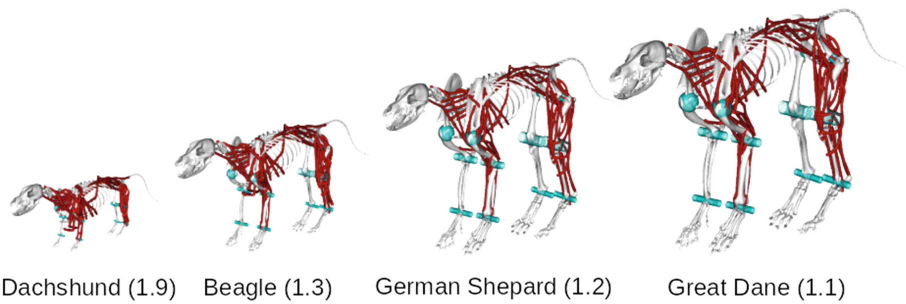

Fig. 1. Perspective view of the four modelled breeds (body length/withers height) for the simulation tool OpenSim [5,6]. The segments (bones) are shown in gray, the musculature in red and the joint constraints in cyan. (Color figure online)

3 Results and Discussion

The models presented here represent extreme values among dog breeds. The Great Dane is in average 3.3 times larger than the Dachshund. It is well known that body length and height influences life span and the occurrence of degenerative musculoskeletal deceases. The average life span for the Great Dane is quite low (median: 6 years) [8]. Despite the short life span, it shows a high relative frequency within musculoskeletal disease as the cause of deaths (0.217) [9]. As well as for other large breeds: the Saint Bernard (0.262), Great Pyrenees (0.255), Irish Wolfhound (0.221), and Greyhound (0.214). In contrast, the Dachshund has a longer lifespan (median: 13.5 years) but is in the group with the highest relative frequency for neurologic disease as the cause of death (0.404) [9]. This can also be shown for other small breeds: Miniature Dachshund (0.397), Dutch Pug (0.274), Miniature Pinscher (0.223), and Boston Terrier (0.222). In addition, several small dog breeds also show an increase in the incidence of medial patellar luxation (MPL) [10]. Both models thus represent two important groups for the study of degenerative disease affecting locomotion.

The scaling presented here represent a first step towards a tool for the analysis of dog locomotion/health. Further steps are necessary. For example, the joint actuators must be optimized for every model. In addition, muscle geometry and parameters must be adapted to the different breeds (extremes: Whippet vs. Boxer [7]). Simulations will require additional data regarding ground reaction forces and kinematics for the individual breeds, as shown in [11]. The combination of morphological and experimental data with our models will make be possible the comparison of joint loads among breeds. We hypothesize that morphological changes might induce differing muscle activation or even changes in muscles synergies. Further trade-offs will be analyzed by scaling our Beagle model for Whippets (built for speed) and French bulldogs (built for strength). We are confident that these additional models will help to improve the analysis of the influence of body size, physique, mobility and disease on neural control and joint loading during locomotion in dogs.

Data availability
The data that support the findings of this study are available from the authors on reasonable request. The OpenSim model can be downloaded https://simtk.org/projects/dogmodel.

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