A Preliminary Musculoskeletal Model of the German Shepherd Lumbosacral Spine

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Abstract

German shepherd dogs (GSD) are commonly utilised in police and military forces, where they undertake physically demanding working roles. These duties, combined with the typical GSD musculoskeletal conformation, consequently result in a high incidence of degenerative lumbo-sacral stenosis in this breed. This debilitating condition compromises the welfare of the animal and often results in premature loss from service.

A preliminary mathematical musculoskeletal model was developed in the AnyBody Modelling System software platform from computed tomography imagery and muscle dissection. Positions of hard and soft tissue elements were recorded from the specimen to construct this patient-specific model. Inverse dynamics simulations were run with incremental alterations of two muscle input parameters: muscle fibre length and sarcomere length. The effect of these parameters was found to be extremely sensitive on the model output values, with minor input variations resulting in major output variations.

Histology data was obtained from muscle excised in the dissection, and indicated variability in muscle sarcomere length up to 0.681 μm within the muscle and an average of 0.389 μm between GSD muscles. The sensitivity analysis indicated a 0.1 μm variation in sarcomere length exceeded the set threshold of ± 2.5 % from the measured sarcomere length output value of strength for the muscle sacrocaudalis dorsalis medialis. Muscle length sensitivity indicated a 1 mm input variation remained within the strength output threshold, while a 2 mm variation exceeded the threshold.

This research resulted in the development of a preliminary and functional biomechanical model of the GSD lumbo-sacral spine capable of simulation studies. The results of the inverse dynamics sensitivity analysis identified the critical effect of variation of muscle fibre length and sarcomere length as muscle input parameters, and emphasised the requirement of precise muscle measurement, specific to each individual muscle.

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List of Abbreviations

AMS	AnyBody Modeling System
AR	Axial rotation
CT	Computed tomography
DLSS	Degenerative lumbosacral stenosis
eps	strain
FE	Flexion and extension
GSD	German shepherd dog
k	stiffness
LB	Lateral bending
Lf_{nom}	Nominal muscle fibre length (cm)
Lf_{opt}	Optimal muscle fibre length (cm)
Lm_{nom}	Nominal muscle length (cm)
Lmt	Muscle-tendon element length (cm)
Ls_{nom}	Nominal sarcomere length (μm)
Ls_{opt}	Optimal sarcomere length (μm)
$Ls_{opt\ (canine)}$	Optimum canine sarcomere length (2.5 μm)
Lt_{nom}	Nominal tendon length (cm)
NZ	New Zealand
ρ_{canine}	Uniform canine muscle tissue density (1.059 g/cm^3)
PA	Pennation angle (°)

PCSA	Physiological cross-sectional area
PDS	Police Dog Section
ROM	Range of motion
TLEM	Twente Lower Extremity Model
USMWD	United States military working dog
Vol	Volume (cm^3)
2E	Two-element muscle