A PILOT STUDY ON IN VIVO JOINT ANGLE DEFINITION IN THE EQUINE CERVICAL SPINE WITH DIFFERENT METHODS

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SUMMARY

Musculoskeletal modelling is also the first step towards understanding dynamics of the equine neck. A common equine disorder (Wobbler syndrome) is cervical spinal cord compression characterized by malformation of the cervical vertebrae and stenosis of the vertebral canal. Techniques such as radiography are used to assess the cause. The aim of the study was to compare radiography, with the accuracy of the skin marker based model and thus validate the 3-dimensional simulation model.

In vivo measurements were taken in two horses; they were trained to reach the extended (head high, neck long) and flexed (head low, neck short) positions. The study was done with the calculating the maximum extension angle from the X-ray measurements, the kinematic measurements and the model using inverse kinematics.

The largest extension angle was found between the second and third cervical vertebrae in the X-ray, kinematic and model measurements. From these results it can be concluded, that the simulation model has a suitable accuracy to investigate equine cervical intervertebral motion.

METHODS

In vivo measurements were taken in two horses without clinical signs of neck and back pain. Clinical examination (palpation of the vertebrae and the musculature, as well as evaluation of passive and active neck movement) revealed no abnormal findings. Horses were without history of neck or back trauma or surgeries.

The horses were trained using clicker training to hold the required neck position for the measurements. The extended position of the neck was defined when the horse held the head high and the entire neck was maximally elongated.

X-ray measurements: digital laterolateral survey radiographs of the occiput, all the cervical vertebrae, and T1 were taken with the horse standing and the neck in a neutral, flexed and extended positions. Radiographic intervertebral angles were measured using the software OsiriX (v. 3.8.1. OsiriX Imaging Software, Geneva, Switzerland).

Kinematic measurements: Twenty-four reflective skin markers were attached to each horse using adhesive tape. Eighteen markers were placed on left and right side on the vertebrae from the first until the sixth cervical vertebrae. Additional markers were placed on the head (forehead, left and right crista facialis), on the highest point of the withers. The kinematic data were collected in a standard right-handed Cartesian coordinate system using ten digital infrared cameras (Eagle Digital Real Time System, Motion Analysis Corp., Santa Rosa, California, USA) recording at 120 Hz. Data collection continued until 3 trials (each 10 seconds) in all exercise had been recorded. The 3-dimensional coordinates of each marker during the time course of each experiment were calculated from the data by Cortex (1.3, Motion Analysis Corp., Santa Rosa, California, USA) software. The kinematic data has then been smoothed by use of a Butterworth low-pass filtered (cut-off frequency, 10 Hz).

Model measurements: The equine neck was modelled in SIMM (Software for Interactive Musculoskeletal Modelling), (SIMM 5.0, Motion Analysis Corp., Santa Rosa, California, USA) and further analysis was done in OpenSim (open source software for

INTRODUCTION

A common equine disorder (Wobbler syndrome) is cervical spinal cord compression characterized by malformation of the cervical vertebrae and (static or functional) stenosis of the vertebral canal [1]. If neck pain is suspected clinically, techniques such as radiography, ultrasound, scintigraphy, CT and MRI are used to assess the cause [2]. It should be noted that it is impossible to perform 3D imaging of the equine neck during motion, as the available techniques for this region require sedation or anaesthesia, making a model even more important.

A fully functional musculoskeletal model is therefore an important step towards understanding locomotor control of the neck, which can later be used as a scientific tool.

The aim of the study is to investigate the accuracy of the three different techniques and validate the three dimensional simulation model.
simulation), (OpenSim 2.2, Stanford University, Stanford, California, USA). The standard right-handed Cartesian coordinate system was applied, where the movements are defined as a rotation about the x, y and z axes respectively. Three degrees of freedom (DOF) were applied. Flexion-extension (FE) was defined as longitudinal bending in a vertical plane, which flexes or extends the spine, dorsoventral flexion-extension is rotation about the y axis. Maximum possible ranges of motion of every single DOF accepted for each joint in our model of the equine cervical spine were chosen in accordance with literature [3]. The model was scaled by the use of the OpenSim Scale Tool. Scaling was performed based on a comparison of experimental marker data with virtual markers placed on the model. For each horse the model was scaled individually by the marker data from the recorded motion. After that the inverse kinematic tool was used to calculate the joint angles.

RESULTS AND DISCUSSION
Maximum extension values were calculated with all three different techniques (see Figure 1).

X-ray measurements: the maximum extension angles ranged from 183.37° to 201.46° in all measurement trials. The largest extension was documented at C2-C3 joint.

Kinematic measurement: from all calculated trials we recorded the largest extension angles between the C3-C4 joint (ranged from 172.74° to 197.47°).

Model measurement: maximum extended angles were located at C2-C3, where they ranged from 181.53° to 204.45°.

Figure 1: Cervical intervertebral joint angles (degrees) in extended and flexed position in Horse 1.

CONCLUSIONS
The largest extended angle has been found between the second and third cervical vertebrae in case of the X-ray and model measurements. These results indicate the accuracy of the simulation model, which is following the physiological ranges. Similar results have been reported using a 2-dimensional model [4].

The kinematic measurement, which was calculated form the marker movement, showed the maximum extension angle between the third and the fourth cervical vertebrae. This difference was probably due to the relative movement of the skin markers over the vertebral bodies.

In the present study our simulation model was compared to two measurement techniques: flexion-extension radiographs and in vivo kinematic measurement. Similar techniques have been proven to be useful in human neck research [5]. The inverse kinematics calculation were based on the kinematic measurement and allowed an estimation of intervertebral motion in vivo. To conclude the combination of these techniques gives the possibility to record and evaluate the in vivo interactions between intervertebral joints in the equine cervical spine.

REFERENCES