MECHANICAL ANALYSIS OF CERVICAL SPINE OF GIRAFFE

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INTRODUCTION

Head and neck of largish giraffe reaches 2.5m long and weighs 150kg [1]. As such, musculoskeletal structure of the giraffes long and heavy neck must be subjected to large moments and forces, and in spite of this, giraffes can swing their necks in a highly flexible manner. So, mechanical adaptation is expected on musculoskeletal structure of giraffe's neck. Several anatomical studies of musculoskeletal system of giraffe's neck have been reported [2], however; to-date there has been no biomechanical studies. The purpose of this study was to evaluate the mechanical strength of giraffe's neck and to consider its mechanical adaptation.

METHODS

We created the finite-element model based on CT images taken from the skeletal specimen of giraffe owned by the Osaka Museum of Natural History. The cervical spine model was composed of skull, all cervical vertebrae, 1st and 2nd thoracic vertebra, vertebral disks and nuchal ligaments. Inhomogeneous material properties of vertebrae were given due to bone mass density obtained from CT value [3]. Material properties of vertebral disks and nuchal ligaments were assumed by using other animal data of past literature [eg 4]. A horizontally extended posture was analyzed as this was considered to be a posture where the neck would experience a large moment. Alignment of the vertebrae in the model was determined by referring anatomical charts of giraffe and other mammals. The FE model of giraffe's cervical spine is shown in Figure 1. Inhomogeneous density distribution of 5th cervical vertebra is shown in Figure 2.

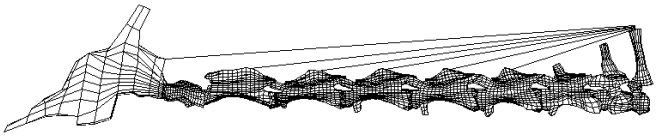


Figure 1: The finite-element model of giraffe's cervical spine. Total length of the model is 2m.

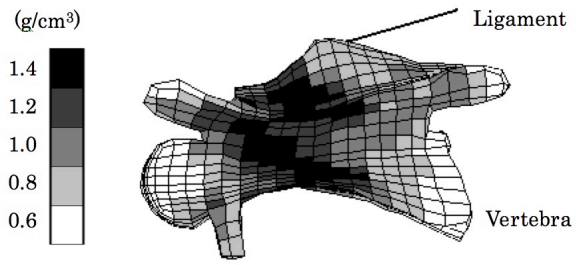


Figure 2: The finite-element model of 5th cervical vertebra and its density distribution.

Gravity loads correspond to the mass of head and each vertebra levels were applied. Mass of head and neck were assumed as 20Kg and 70Kg. The mass of neck was divided into each vertebra levels in according to their length. Posterior end of the 2nd thoracic vertebra (T2) was fixed, and the ligament was fixed at insertion point of spinous process of T2.

RESULTS AND DISCUSSION

FE analyses were performed for two cases to assess the influence of bone inhomogeneity. One was homogeneous bone case (case 1) and the other was inhomogeneous bone case (case 2). In case 1, average of bone densities were given separately for cortical shell (0.9g/cm^3) and solid (0.2g/cm^3) of the vertebrae. Figure 3 shows maximum value of tensile principal stress in the cervical vertebrae. Figure 4 shows tensile principal stress distribution of C5. Maximum tensile principal stresses of case 2 are lower than case 1 for C5 and C7. According to Figure 2 and 4, belt-like high density area at central part of C5 is effective to reduce large tensile principal stress occurred at anterior side, because nuchal ligament force is supported by the high density area.

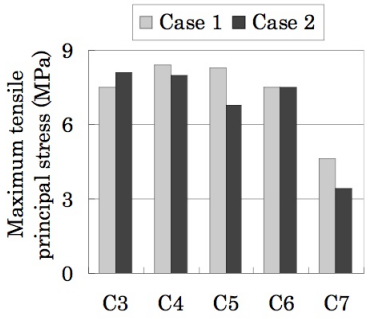
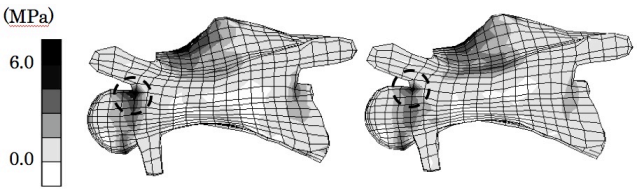


Figure 3: Maximum value of tensile principal stress of cervical vertebrae in homogeneous case (case1) and inhomogeneous case (case 2).



(a) Homogeneous (b) Inhomogeneous

Figure 4: Tensile principal stress distribution of 5th cervical vertebra in homogeneous and inhomogeneous case.

CONCLUSIONS

Finite-element models of giraffe's cervical spine were created based on CT images, and stress analyses were carried out. In the result, inhomogeneity of bone seemed to be effective to reduce tensile stress at anterior side of cervical vertebrae.

REFERENCES

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