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TRACKING OF THE FLEXION- EXTENSION MOVEMENT OF THE CERVICAL VERTEBRAE USING FLUOROSCOPY

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SUMMARY

The aim of this paper is to describe and quantify the entire flexion-extension motion of the cervical spine. To obtain the information required to describe and quantify the entire movement, fluoroscopy recordings of three healthy individuals were made. All of the test subjects had a record of their flexion-extension movement viewed in the sagittal plane.

The fluoroscopy recordings were analyzed by tracking the flexion- extension movement of the cervical vertebrae. The algorithm used mutual information to match the intensities between the analyzed frames in a multiresolution optimization framework to align the images. The kinematic parameter rotation, was extracted. The global rotation of each vertebra was measured and based on that, the intervertebral range of motion was calculated.

The data recorded during this study indicated that the movement pattern between subjects seem to be very different. However, having only three test subjects it is not possible to give a definitive answer.

INTRODUCTION

Previous work presented detailed musculoskeletal models of the cervical spine [1] based on inverse dynamics. These models require precise kinematics as input in order to estimate muscle and joint reaction forces. So far the intervertebral kinematics were literature based which gave an average distribution for a flexion-extension movement. Continuing this work the movement of healthy test subjects was tracked using X-Ray fluoroscopy. Fluoroscopy is a continuous recording of radiographic images that can capture the full range of movement [2].

The aim of this study is to develop a method for extracting individual kinematics of flexion-extension from the cervical vertebrae. In this study, fluoroscopy was used to track the vertebrae during the full flexion-extension movement of healthy subjects. An intensity based semi-automatic image tracking was proposed.

METHODS

To obtain the information required to extract translation and rotation fluoroscopy recordings of healthy individuals were obtained. The fluoroscope used was a Siemens Siremobile 2000, model year 1994. For the paper three test subjects with no neck pain were screened by a professional licenced chiropractor. The subjects were two men (subject A and B)

and one woman (subject C) between 40 and 50 year-old. All the test subjects had a fluoroscopy recording of their flexion-extension movement viewed in the sagittal plane. The test subjects were not constrained in any way in their movement. The recording started with the test subjects keeping their necks in a neutral position. Each of the subjects first flexed the neck to full voluntary flexion and afterwards moved the neck back to a neutral position. The subject then performed a full voluntary extension of the neck and moved the neck back to neutral position. The fluoroscopy device recorded 12 frames per second (fps), and the digital recorder recorded it as a 30 fps movie.

Due to the anatomical structures surrounding the cervical spine, the focus was on analyzing movement of the vertebral bodies of C3 to C6. To be able to track the vertebrae it was necessary to analyze the fluoroscopy images. This was done by manually selecting regions of interest (ROI) of C3 to C6 in the first frame of the recording (see Figure 1).

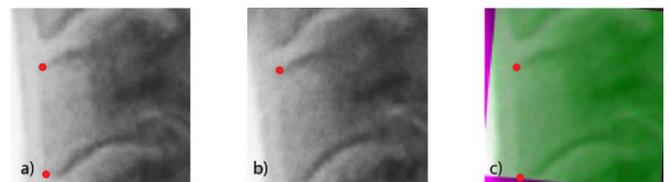


Figure 1: A ROI of one of the selected vertebrae. Image a) and b) shows the same ROI in an original frame a) and a moved frame b) eight frames later. c) shows the images matched. The red dots show the anterior corners of the vertebrae.

By manually selecting corners, the center of a mask was calculated and used to analyze the ROIs in every frame of the recording. Mutual information was used as similarity criterion to match the intensities between the segmented vertebrae in two after each other following frames. Multiresolution optimization was used to automatically align the images [3-4]. Translation and rotation information from the alignment of the ROIs was saved in a matrix structure. Also based on the translation and rotation information, the masks were moved to the center of the same vertebra in the next frame. This was done for each frame of the fluoroscopy.

To validate the results provided by the algorithm, a validation using manual selections of the vertebrae was proposed. A manual selection of the anterior corners of the

vertebral body was used to test the validity of the algorithm. The selection of the corners was done in collaboration with a professional chiropractor, to ensure the consistency of the selections.

RESULTS AND DISCUSSION

To reduce the noise produced by the conflicting frame rate between fluoroscopy device and digital recorder, the curves were smoothed in the results by applying an average filter. The figure (Figure 2) shows the validation of the intervertebral angles of subject A. The figures (Figure 3-5) show the extracted flexion extension of two male subjects A and B and a female subject C.

Looking at the validation and subject A (Figure 1 and 2) C4/C5 and C5/C6 have identical ranges of motion. However, there are over-rotations up to 3° in some points. Furthermore, the algorithm shows large rotation in extension of the C3/C4 while the C4/C5 and C5/C6 are stable. An important aspect is the fact that the validation has an error from the manually selected points. Due to the low signal to noise ratio (SNR), even after smoothing the influence is still visible. The results of the algorithm have a high repeatability.

The movement pattern of the subjects varies quite a lot. Trying to produce detailed musculoskeletal models of the cervical spine it is necessary to take this variation into account. Further studies are needed to investigate the flexion- extension movement, establishing if there are significant differences between healthy subjects.

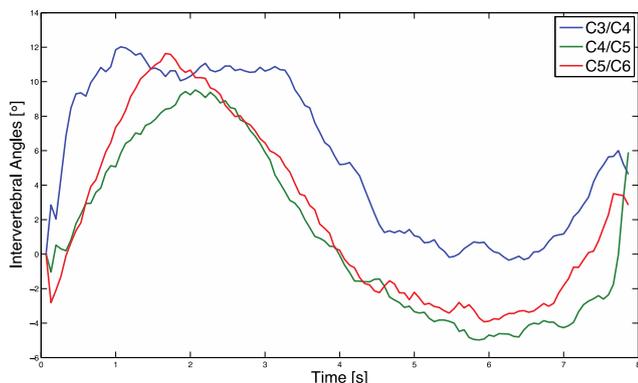


Figure 2: Validation by manual selection of subject A showing the intervertebral angles.

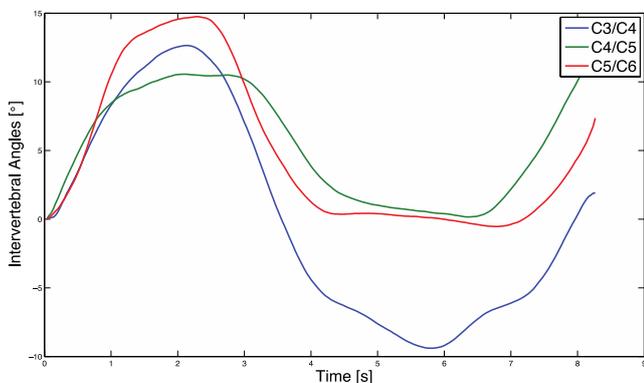


Figure 3: Intervertebral angles of rotation of subject A

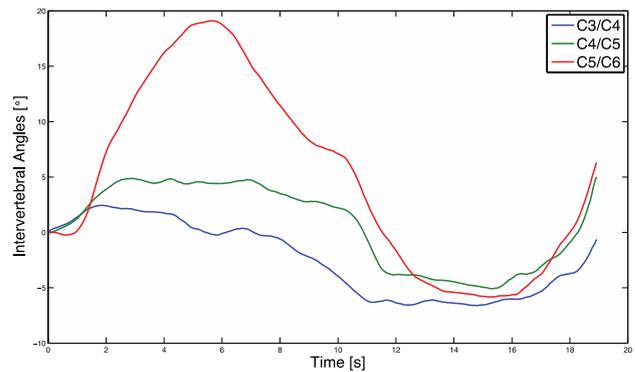


Figure 4: Intervertebral angles of rotation of subject B

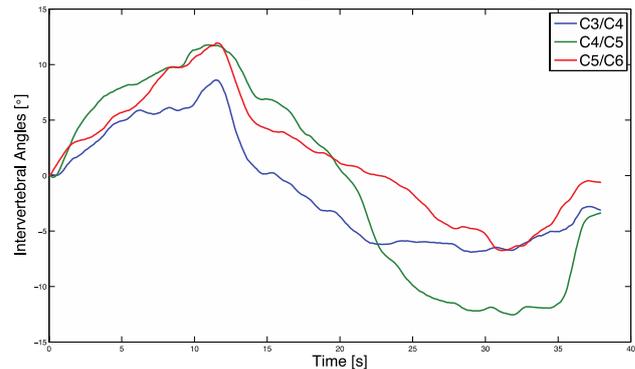


Figure 5: Intervertebral angles of rotation of subject C

CONCLUSIONS

The movement pattern of the test subjects indicates that the movement patterns between subjects are not the same, which has an important implication for musculoskeletal modeling. However, more subjects are needed to give a definitive answer.

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