README

This file describes the formatting of the data in the "Cervical vertebra kinematics during a controlled motion task database" and the data collection in brief.

The database provides the data in two forms:

1. One MATLAB (.mat) file which contains the participant pseudonyms, vertebral body positions, participant demographics and effective radiation dose from the fluoroscopic imaging from which this motion analysis is derived.
    a. NB. Vertebral body positions are derived from bespoke image tracking of the cervical spine in motion during fluoroscopic recordings. (1024x1024 16bit Images were acquired and analysed at 15fps).
2. Excel files which contain a file with participant demographics and separate files which contain common spinal kinematic measures derived from the vertebral body positions. These include:
    a. Vertebral Angles relative to image x-axis (C0= McGregor line C2= inferior endplate of C2, C1 and C3 though C7 = midplane of vertebrae)
    b. Intervertebral Translation, using the Frobin method (Frobin et al. 2002a)
    c. Intervertebral Disc Height, using the Frobin method (Frobin et al. 2002b)

Motion and Imaging protocols In Brief:

For a more detailed account of the methods see Branney, Jonathan, Breen, Alexander, du Rose, Alister, Mowlem, Philip, and Breen, Alan (2024). Disc degeneration and cervical spine intervertebral motion: a cross-sectional study in patients with neck pain and matched healthy controls.

Participants were seated with their shoulder next to a motorised guided motion frame in a position that was judged to be a 'neutral' sitting position by the operator, using the infraorbital meatal line as a reference. The motion frame was adjusted to align the centre of rotation to the C3-C4 disc space of the participant under low-dose radiographic guidance.

Participants' shoulders and torso were constrained to minimize lateral motion and keep the cervical spine within the imaging field. A support plate was pressed against the participant's sternum and thoracic spine (at approximately the T5 vertebra). The positioning of the participant and equipment were recorded for duplication at follow-up visit.

Participants were trained on the motion protocol, guided by the motion frame. This consisted of two bending protocols, "Neutral to maximal Flexion and return to Neutral position" and "Neutral to maximal Extension and return to Neutral position". The motion frame accelerated and decelerated at a rate of $6°/s^2$ and otherwise moved at a consistent speed of 6°/s. During imaging the participant was guided by the motion frame to a maximum of 60^o of flexion or extension from their neutral position.

During each bending trial, fluoroscopic images were acquired in the lateral view at 15 frames per second. Anonymised images were exported in DICOM format (16bit 1024x1024 pixels). Fluoroscopic images were enhanced for brightness, contrast, and vertebral edge detection. Four-point templates were used to manually identify the corners of each cervical vertebral body in the first image of each fluoroscopic sequence. This was repeated five times for each image sequence. An automatic image tracking system then identified the positions of the vertebrae in subsequent images. Following visual inspection of the tracking algorithm outputs, any templates which were deemed not to follow the vertebra were removed, and if possible, replaced with alternative tracking. The mean positions of the remaining four-point templates per vertebra (maximum of five iterations per vertebra) were calculated and added to a database under the structure "`Database.Templates`".

Descriptor of 4-point templates location on vertebral landmarks

Each of the 4-point templates indicate the positions of the occiput (C0), each cervical vertebrae (C1-C7) and the first Thoracic vertebrae (T1) if it was visible in the imaging field.

The 4-point templates were marked in a clockwise direction around each vertebra. 1-Top left, 2-bottom left, 3-bottom right, 4-top right.
NB: Participant orientation should be taken into account when deriving kinematic measures from template positions. Participant orientation can be found in "`Database. orientation`" of the MATLAB file . This indicates participant orientation in imaging L= Anterior side on left of image, R= Anterior side on right of image.

As the morphology of the upper cervical spine differs significantly from the region C3 to C7, and the inferior border of T1 was rarely visible in imaging, definitions of template positions differ across the tracked vertebrae. This is to aid in calculations of vertebral and inter-vertebral angles, translation displacement and disc height and align with the Methods defined in Frobin et al 2002a & 2002b. **NB**: Point labelling. The template corner point labelling indicated above differs from that used in Frobin et al 2002a & 2002b.

For C3 to C7, the 4 points were positioned over the 4 vertebral corners of the vertebral body as seen in the lateral view.

For C0, points 2 and 3 indicate the McGregor line, a line connecting the posterior edge of the hard palate to the most caudal point of the occipital curve. Points 1 and 4 are located superior to this line but not overlaying any specific anatomy.

For C1, the left (1 & 2) and right (3 & 4) most points are placed cranially (1 & 4) and caudally (2 & 3) over the marrow cavities of C1. With the mid points of the left and right most points indication the centre of the marrow cavities positions.

For C2, points 2 and 3 indicate the caudal corners of the C2 vertebra. Points 1 and 4 are located superior to these 2 points on the anterior and posterior aspects of C2 and not intersecting with the C1 template.

For T1 (and C7 if there is obstruction by participants shoulder), points 1&4 indicate the cranial corners of the vertebra. Points 2 and 3 are placed caudally at the estimated location of the caudal corners of the vertebra. Unlike C3-C6 the caudal aspects of the C7 and T1 vertebrae are rarely visible throughout motion due to overlying anatomy in the image field.

Outputs

All data is anonymized.

MATLAB file (.mat)

The "`Cervical Database.mat`" is the database in its most raw anonymised form.

Structure

- Each subfield is a cell structure. Each row corresponds to a participant visit ("Image Event"), the row location for each participant is uniform across all fields.
- Pseudonym: "`Database.ImageEvent`"
  - Cell structure with participant identifier per row.
    - Prefix, HV=Healthy Volunteer, P=Patient
    - Suffix, a=baseline observation, b=4-week follow-up observation
- Sex "`Database.Sex`"
  - Cell structure,
    - Each row is an imaging event which corresponds with the row number of "`Database.ImageEvent`"
    - Contains participant Sex (M/F)
- Age "`Database.Age`"
  - Cell structure,
    - Each row is an imaging event which corresponds with the row number of "`Database.ImageEvent`"
    - Contains participant Age (years)
- Population group "`Database.PatientOrControl`"
  - Cell structure,
    - Each row is an imaging event which corresponds with the row number of "`Database.ImageEvent`"
    - 'C'=Healthy control
    - 'P'= Patient recruited with neck pain at baseline
- Vertebral body positions "`Database.Templates`"
  - Cell structure,
    - Each row is an imaging event which corresponds with the row number of "`Database.ImageEvent`"
    - Column 1= Flexion, 2=Extension
    - Substructure,
      - Contained within these cells are sub-cells. Each sub-cell consists of 9 rows and 4 columns
      - Each Sub row indicates the vertebra in sequential order C0-T1
      - Each Sub column indicates a corner of the template
        - These cells contain the X and Y coordinates of these corners (column 1 and 2 respectively) where each row indicates a recorded position at 15 recordings per second
  - Missing or incomplete data
    - Empty cells suggest this level was not tracked. "NaN" values denote where tracking had failed, and these results were removed.
- Fluoroscopy imaging Dose to participant "`Database.Dose`"
    - Cell structure,
    - Each row is an imaging event which corresponds with the row number of "Database.ImageEvent"

- Column 1= Flexion, 2=Extension
- Unit of measurement is millisieverts (mSv)

Excel files

There are 7 excel files in this database. This consists of one file providing the demographics data (Participant Identifier, Age, Sex & Population group) and two files for each of the calculated kinematic measures for flexion and extension bending trial protocols respectively.

The kinematic measures are calculated from the vertebral body positions indicated in the "`Database.Templates`" structure of the "`Cervical Database.mat`" MATLAB file. Data is presented at the imaging rate of the Siemens Arcadis Avantic VC10A digital fluoroscope (CE 0123, Siemens, Germany) (15Hz). The manner by which each of these kinematic measures was calculated is briefly described below along with the file structure.

To reduce noise in the output, each output was smoothed by Tikhonov regularization (Eilers PH. 2003).

The McGregor line for C0, the Inferior endplate margin for C2, the midplane of C1 & C3 to C7 and the Superior endplate margin for T1 were extracted from the "`Database.Templates`" structure.

Vertebral angular measures ("Vert-Angle") are the angles of these lines in degrees with respect to the horizontal axis of the image (dimensions 1024x1024 pixels). This method of calculations is further described, with figures in Frobin et al. 2002a.

Intervertebral posteroanterior displacement ("Translation") and Intervertebral Disc Height ("Disc Height") are calculated using the Frobin methods (Frobin et al. 2002a 2002b respectively). In brief these use the previously detailed lines per vertebra, their calculated mid-point (for translation measures), the adjacent anterior vertebral body corners per intervertebral pair point position (for disc height measures) and a "bisectrix" (An average of the two adjacent lines) to calculate the Translation and Disc height in a manner that corrects for radiographic distortion, variation in stature and alignment errors of patients. The unit of measurement in which they are presented is as a fraction of the inferiorly adjacent vertebral body depth (VBD). 1 VBD = the anterior-posterior depth of the inferiorly adjacent vertebral body.

Structure

Each Excel workbook consists of multiple worksheets. The "Table" worksheet provides the raw angular positions of the motion frame which guided participant motion. The following worksheets "C0", "C1", "C2", "C3", "C4", "C5", "C6", "C7" & "T1" relate to the vertebra being presented. The top row of each worksheet details the protocol and participant details. For example, "Flex WB C F HV01a": "Flex WB" = Flexion Weight Bearing (Ext = Extension), "C" = Control participant (P=Patient), "M"= Male participant (F=Female), "HV01" = Unique identifier for this participant, "a" = baseline data collection ("b" = Follow-up data collection 4 weeks after baseline).

The vertebral and "table" angles in these workbooks have been synchronized at 15 samples per second.

Any blank cells represent uncaptured data. These data may not have been captured because 1) the participant did not perform this particular motion protocol, 2) image resolution or image artifacts made it impractical to track the positions of the vertebrae accurately, or 3) the vertebra moved out of the imaging field of view.

All data is anonymized.

References

Branney, J., Breen, A.C. Does inter-vertebral range of motion increase after spinal manipulation? A prospective cohort study. *Chiropr Man Therap* 22, 24 (2014). https://doi.org/10.1186/s12998-014-0024-9

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