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Image-driven subject-specific spine models: developing a novel tool to measure in vivo loading

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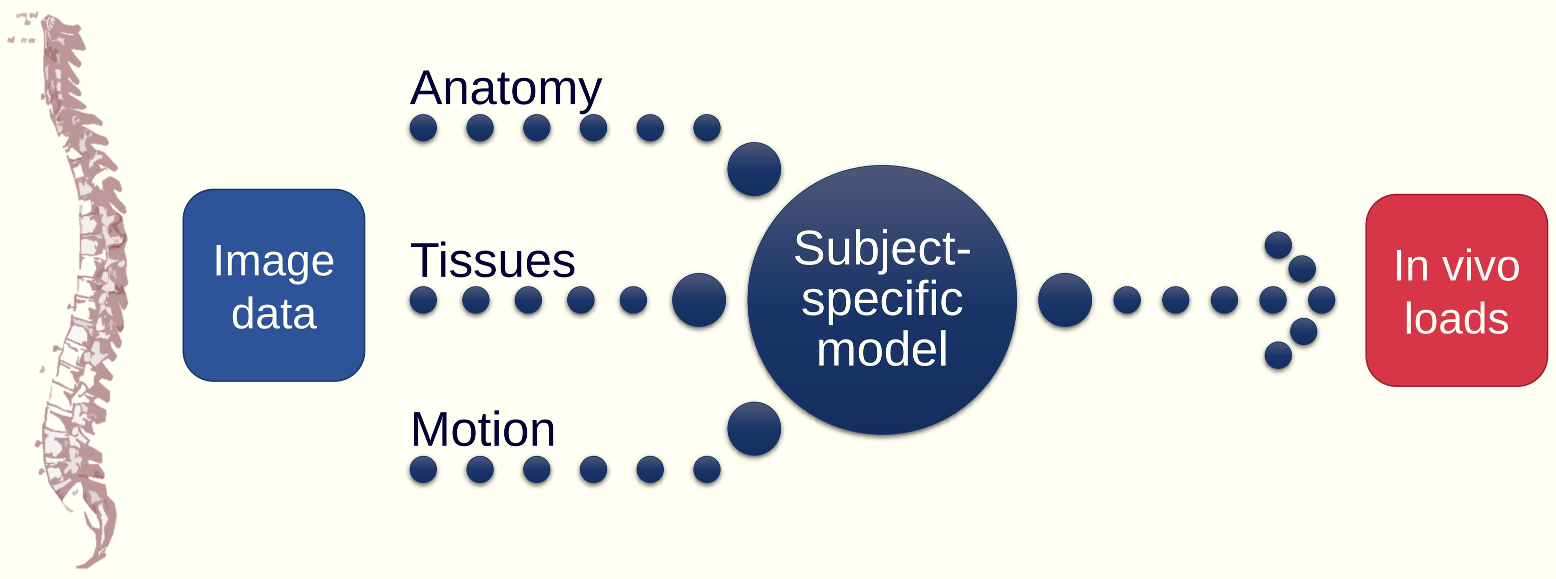
Introduction

Spinal disorders such as back pain incur a substantial societal and economic burden. Our understanding and treatment of these disorders are impeded by our limited ability to assess spinal forces in vivo.

Our project is addressing this challenge by developing and testing a novel image-driven approach that will allow us to create a fully subject-specific model of an individual's spine and assess the forces in them in vivo.

Project aim and plan

Our aim is to develop modelling methods and pipelines that incorporate subject-specific information acquired from multimodel imaging and use this to measure in vivo loads.

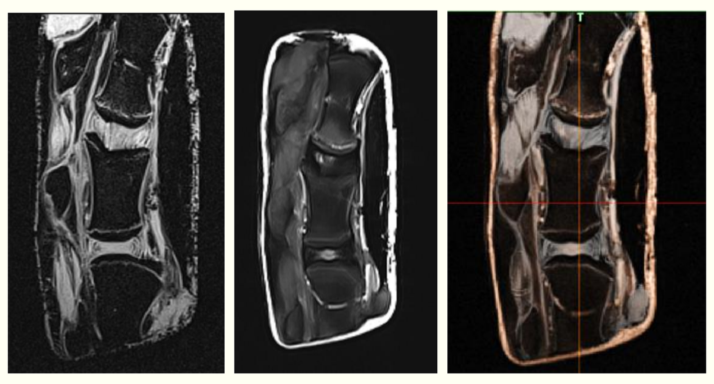


Anatomy and tissue data will be captured using 3T magnetic resonance imaging (MRI) and subject-specific motion will be assessed using biplane X-rays. Modelling will be performed using the finite element method.

Project progress

Anatomy

We have identified MRI sequences that provide high-quality image data for generating the geometry of our finite element models.



MR data from a bovine specimen used for creating model geometry.

Tissue properties

We have identified MRI sequences that provide information on the disc tissues. These include relaxation times (T1, T1rho, T2, T2*), magnetisation transfer ratio, and diffusivity parameters.

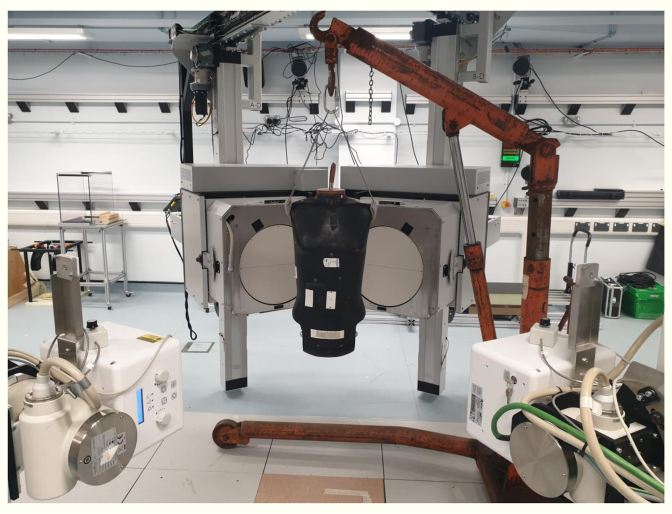
Our next step is to learn how to use the data to predict subject-specific tissue properties. We will achieve this by combining finite element modelling, machine learning, and six-axis mechanical testing on human, porcine and bovine specimens.

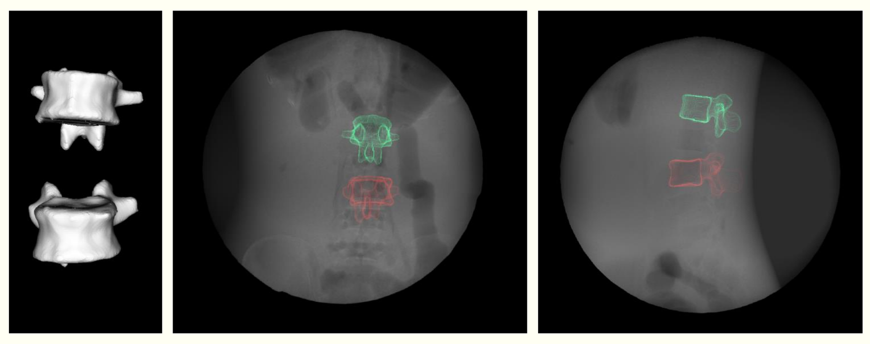
Project progress

Motion

We have designed protocols to capture full motion analysis, EEG muscle activity, and video X-ray using our biplane X-ray system. This will allow the three-dimensional location and orientation of the vertebrae to be tracked during motion.

We have also received ethical approval to recruit 15 healthy volunteers and collect data on how their spine moves during everyday movements and when lifting weights up to 10 kg.



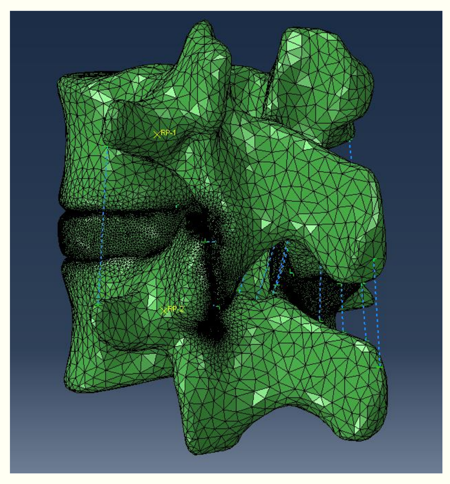


Biplane X-ray system with phantom torso (left) and video X-ray data of vertebrae (above).

Modelling

We have developed our modelling pipelines and identified potential methods for learning how to predict disc tissue properties from MRI data.

We have also demonstrated that ligament stiffnesses do not need to be subject-specific.



Finite-element model of a spine segment.

Conclusions

Our project will deliver novel image-driven subject-specific spine modelling methods for determining forces in the spine in vivo. It will also deliver new data and tools for measuring spine movement and quantifying the properties of the spinal tissues.

Our methods have applications in understanding how the healthy spine functions, determining the effects of injury and disease, and improving current and future treatments for those suffering from spinal disorders.

- Data, methods & tools
- Application to research
- Potential clinical use

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