Development Of An In-Vivo Imaging Protocol To Quantify The Kinematics Of The Lumbar Spine

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INTRODUCTION: Spinal disorders such as low back pain incur a substantial societal and economic burden, with an estimated 619 million affected by back pain globally in 2020[1]. Currently, there is a lack of understanding about these disorders and their treatments and this is further impeded by the challenge of measuring in-vivo spine biomechanics. Biplane Video X-ray is an imaging technique that allows direct measurement of the individual vertebra during dynamic activities. To use this technique to evaluate the in-vivo biomechanics of spine disorders it is first necessary to characterise the lumbar spine kinematics in a healthy population. The objective of this study is to develop an in-vivo imaging protocol to quantify the kinematics of the lumbar spine during different activities of daily living.

METHODS: Ethical approval for this study was obtained from the London Bridge Research Ethics Committee. For the development of the protocol one healthy volunteer was recruited and written informed consent was received. The participant underwent Magnetic Resonance (MR) imaging (Magnetom 3T Prisma, Siemens) which were manually segmented into 3D vertebra models (Simpleware Scan IP, Synopsis). Anatomical coordinate systems were applied[2] to each individual vertebra. Biplane Video X-ray (10Hz, 3.33ms, 85kVp and 320ma) and simultaneous marker-based motion capture (Qualisys) was carried out during different range of motion activities and other activities of daily living. Bone position and orientation for the five lumbar vertebrae were calculated by manual matching of 3D bone models to X-ray images (DSX Suite, C-motion, Inc.). Intervertebral kinematics were calculated in MATLAB (MathWorks, Inc.) based upon the recommended International Society of Biomechanics standards[3]. A 10kg stoop lift activity was chosen to develop the in-vivo protocol.

RESULTS SECTION: Figure 1 shows the developed in-vivo imaging protocol to enable quantification of in-vivo lumbar spine kinematics. Figure 2a shows the intervertebral flexion-extension angles between each vertebra and the overall lumbar flexion angle (black, between L1-L5) throughout the 10kg stoop lift activity and Figure 2b shows the intervertebral anterior posterior translations.

DISCUSSION: An in-vivo imaging pipeline combining Biplane Video X-ray and MR imaging was successfully developed. The initial results show the individual vertebra contribution during the stoop lift task. L1-L2 showed the largest range of motion for both flexion-extension and anterior-posterior translation. Future work will focus on applying this protocol on up to 15 healthy volunteers and to analyse different activities including twisting, lateral lift, and backward bending. In addition, analysis looking at the coupling of in-vivo kinematics will be investigated to understand the relative vertebra and how they may change due to injury or disease.

SIGNIFICANCE/CLINICAL RELEVANCE: (1-2 sentences): Quantifying in-vivo lumbar spine kinematics can provide better insights into spinal disorders and the interventions used to treat them. The protocol developed and the data collected as part of this study will be used to understand different spinal disorders in the future.

REFERENCES: 1. Ferreira, M. L. et al. *Lancet Rheumatol.* **5**, e316–e329 (2023). 2. Anderst, W. J. et al. *Spine J.* **14**, 1221–1227 (2014). 3. Wu, G. et al. *J. Biomech.* **35**, 543–548 (2002).

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IMAGES AND TABLES: Figure 1: Overview of in-vivo protocol and processing pipeline for calculating kinematics of the lumbar spine.

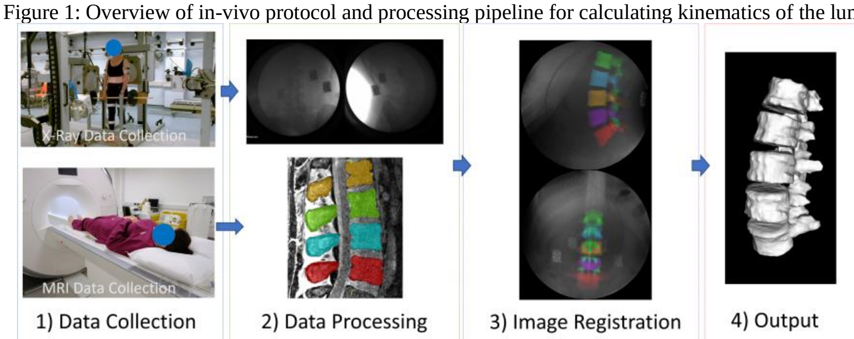

Figure 2: a) Intervertebral flexion-extension angles and b) Anterior-Posterior translations during stoop lift activity.