Title

Combined musculoskeletal and structural finite element modelling of the lumbar spine

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Introduction

Lower back pain (LBP) is a common debilitating condition related to spinal biomechanics and often associated with altered lower limb stability strategies [1]. To investigate this condition, a simulation workflow combining musculoskeletal (MSK) and structural finite element (SFE) modelling techniques is being developed. The study presented here is focused on lifting activities.

Methods

Six healthy male volunteers with no history of back pain were recruited for a high-resolution full-body MRI scan. Motion capture and electromyography (EMG) signals of a complete range of everyday life activities were also recorded for each subject.

A full body MSK model composed of 566 muscle actuators for the lower limbs and lumbar spine was developed (Figure 1a). The spine is composed of five articulated lumbar vertebrae and a three-segment thoracic and cervical spine. The complete bone geometry, muscle insertions and moment arms are adapted from the MRI scan. Muscle and joint reaction forces for the recorded activities are obtained from MSK simulations and used as loading conditions with the SFE model.

This second model is based on the same bone geometry. At first, cortical bone is modelled with standardised shell elements and trabecular bone with a random network of beam elements (Figure 1b). The structure is then optimised to resist the loading conditions using an adaptation algorithm [2].

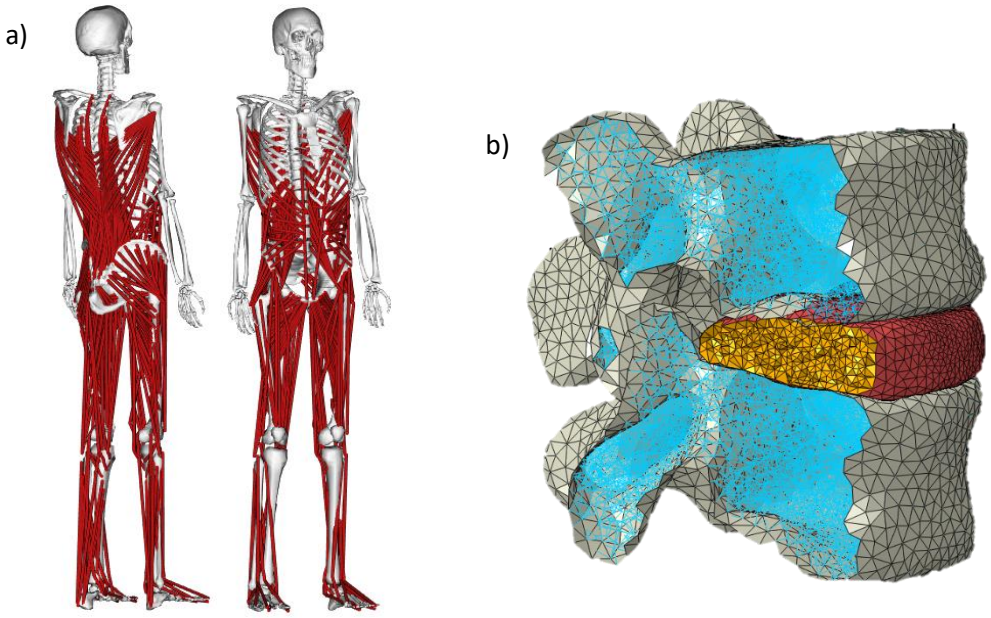


Figure 1: a) Musculoskeletal model. b) Structural finite element model.

Results

The MSK model has been evaluated for quasi-static movements against in-vivo measurements [3,4,5]. The dynamic assessment using EMG recordings suggests the model is suitable for modelling the lifting tasks. The SFE adaptation method used with a broad range of everyday life activities gives a structural bone architecture in agreement with clinical observations.

MSK simulations are now run for lifting tasks including spine twisting and flexion. These results will quantify the load applied on the spine and describe the muscle recruitment patterns for these activities. Applied to the previously optimised vertebrae, the computational workflow will give an estimation of the spine structures' deformations for such tasks. The SFE adaptation method is also used here on its own to study how each lifting task can influence trabecular bone architecture.

Discussion

This study will give a first understanding on how different lifting techniques applied in various scenarios can trigger LBP. Future studies will investigate LBP mechanisms by modifying the models in the simulation workflow. Muscle weakness and structural deficiencies will be introduced to simulate altered biomechanics and understand how it can lead to pain. Other activities such as balance recovery following a perturbation will also be investigated.

References

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