Implementation of physiological functional spinal units in a rigid-body model of the thoracolumbar spine

Created on: 06-03-2020 - Last modified on: 19-03-2020

SCOPE OF THE METHOD

The Method relates to	Human health
The Method is situated in	Basic Research
Type of method	In silico
This method makes use of	Animal derived cells / tissues / organs

DESCRIPTION

Method keywords

Rigid-body modelling

Functional spinal unit

Nonlinear stiffness

Spinal kinematics

Follower compressive loadRigid-body modelling

Follower compressive load

Scientific area keywords

biomechanics

Method description

Most of the current rigid-body models of the complete thoracolumbar spine do not properly model the intervertebral joint as the highly nonlinear stiffness is not incorporated comprehensively and the effects of compressive load on stiffness are commonly being neglected. Based on published *in vitro* data of individual intervertebral joint flexibility, multi-level six degree-of-freedom nonlinear stiffness of functional spinal units was modelled and incorporated in a rigid-body model of the thoracolumbar spine. To estimate physiological *in vivo* conditions of the entire spine, stiffening effects caused by directly applied compressive loads, and contributions to mono-segmental stiffness from the rib cage as well as multi-segmental interactions in the thoracic spine were analysed and implemented. Forward dynamic simulations were performed to simulate *in vitro* tests that measured the load-displacement response of the spine under various loading conditions. The predicted kinematic responses of the model were in agreement with *in vitro* measurements, with correlations between simulated and measured segmental displacements varying between 0.66 to 0.97 ($p<0.05$) and average deviations below 1.6°. Coupling relationships were found between lateral bending and axial rotation. Under compressive loads, the model behaved stiffer and showed a decreased range of motion: The flexion/extension response of the full thoracolumbar spine under compressive loads up to 800N was found to strongly correlate with the literature ($r=0.99$, $p<0.0001$). The implementation of physiological functional spinal units with nonlinear stiffness properties into rigid-body models can enhance accuracy of biomechanical simulations, and enable detailed analysis of spinal kinematics under complex loading conditions seen *in vivo*.

Lab equipment

Method status

Published in peer reviewed journal

PROS, CONS & FUTURE POTENTIAL

Advantages

We presented a novel model of non-linear FSU stiffness and integrated this model in an existing rigid-body model of the thoracolumbar spine. The stiffness formulations are comprehensive enough to capture the physiological response of spinal kinematics under various loading conditions, and are also simple and generic enough to be used for various spine modelling studies.

Modifications

We presented a generic model of spine stiffness that does not account for geometrical factors like disc height and area or pathological conditions.

Future & Other applications

In future work, combining the proposed generic stiffness formulation with stiffness calibration methods (e.g., optimization technique) will be developed to better describe subject-specific FSU mechanical behavior in pathological conditions.

REFERENCES, ASSOCIATED DOCUMENTS AND OTHER INFORMATION

Associated documents

Links

Implementation of physiological functional spinal units in a rigid-body model o...

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