Towards a multi-body dynamic model of the lumbar spine for estimation of segmental forces during daily activities.

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1. Background and motivation

75% of the workforces in industrial countries complain about low back pain (LBP). The exact cause of LBP is not known, however overloading of the spine and repetitive sub-maximal forces are known factors causing LBP. Therefore, quantification of these internal forces and moments are of high interest. Internal forces and moments of the spine may not be directly evaluated on humans as it is subject to availability of volunteers, technical limitations and ethical committee approval. Consequently, computer models of a complete human musculoskeletal system which incorporate active muscle elements are becoming an alternative tool to quantify segmental loads of the lumbar spine. This study describes the ongoing development of a detailed rigid-body model of the lumbar spine for integration in a complete human model. A multi-body model of the passive elements of the lumbar spine including facet joints is already constructed and those variables affecting validation of such a model are discussed. Our detailed passive model of the lumbar spine is being integrated into the complete model to have a better understanding of those active parameters (i.e. muscles and neural index) affecting the functional response of the lumbar spine. The intention of this study is to investigate and evaluate segmental forces of a lumbar functional spinal unit with both simple linear muscles and muscles with via points on every segment. A simple flexion/extension protocol is the motion input.

2. Materials and methods

A detailed multi-body dynamic model of the lumbar spine has been developed, incorporating 6-DOF non-linear elastic joints representing the intervertebral discs, non-linear contact at the facet joints and individual intersegmental ligaments. The model was validated against in vitro flexibility data. The neck is connected to the head and upper torso with simple hinge joints with high stiffness. The upper torso in turn is connected to L1 with linear and rotational springs. All parts are having mass and intertia based on anthropometric data. In the process of this study, the back muscles are divided into muscle fascia according to literature references. The simple trainable muscles are generated with physiological cross sectional area (pCSA) and maximum stress parameters. The muscles are considered as contractile elements producing tensile force. The effective muscle forces are produced in a forward kinematics simulation to replicate the desired motion (joint angles) of the body while constraining the maximum muscle force to its physiological limit. The assumption for such a modeling approach is if enough muscles are included, the calculated muscle forces will be very close to the physiological muscle forces values for the same activity. Neural input or activation is regulated by a simple step function.

3. Results and Conclusions

The passive model results are available for each level. The detailed multi-body model was able to reproduce the full three-dimensional flexibility response of the natural lumbar spine, including complex behaviour such as the low-stiffness “neutral zone” and coupled motion. The necessity to include a more complex representation of the disc, facets and ligaments was highlighted by the simulation results. Quantifying segmental spinal load is not only relevance to applied research (e.g. implant design) but also it is of high interest to clinician and those professional who work in rehabilitation and physiotherapy. Such a modeling provides insight into the actual therapeutic exercise on the lumbar spine. As it is possible to show that the back muscles are not simply work as an extensor, though each also generates compression and shear forces with certain magnitude and direction. A physiotherapist should consider those properties if intending to prescribe an exercise.