A MULTISTEP MODELLING APPROACH OF A SLED TEST TO DETERMINE IN SITU STRESS IN THE LUMBAR SPINE

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Introduction

Epidemiologic studies indicate that the vast majority of car crashes results in mild to moderate injury while acute spine trauma (i.e. whiplash) is encountered predominantly in rear collision rather than head on impact [Jakobson, 2000]. Collisions with partial frontal overlapping represents however a severe crash scenario evoking hyper-physiological loading throughout the human body. The pathogenesis of collision induced injury to the lumbar spine remains elusive, as the manifestation of intervertebral disk or ligamentous tissue trauma, is in most cases fostered by chronic post traumatic degeneration due to prolonged exposure to dynamic loading (occurring during diurnal activities such as running).

Methods

The occupant kinematics of a frontal crash scenario were modelled by a sled test manned with a Hybrid III dummy (175cm in height, weighting 77kg) with integrated virtual markers, representing a simplified version of the Plug In Gait protocol [Schwartz, 2008] for motion analysis. This represented simulation of the IIHS offset barrier test with a delta-v of 65km/h.

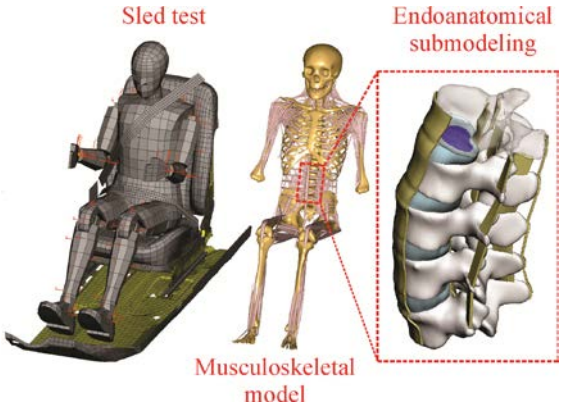

Figure 1: FE model of the sled test including dummy, inverse dynamics muskeloskeletal model and FE sub-model of the lumbar spine.

The kinematic analysis of the sled test was employed to monitor the embedded markers. The trajectories of the virtual markers were adopted as input to an inverse dynamic analysis in AnyBody to account for active musculature. In a final step, the calculated endo-anatomical loads and inertia phenomena due to acceleration were considered as input to a non-linear model of a lumbar spine, yielding the in situ stress development during the sled test.

Results

The simulation focused on the developing stress within the lumbar spine, a region which is considered as well protected by existing seats belt systems. This resulted in moderate muscle activation in the trunk region [Östh, 2012] and the developing stress can be attributed predominantly to the compressive response of the spine and inertial loads. Although these loads do not exceed the absorption capacity of the intervertebral discs [Ishihara, 1996], the accumulated stress distributions may disturb the discs matrix's balance and foster chronic pain rendering the disc susceptible to future injury. Critical stress values were also observed in ligamentous tissue and facets, which is consistent to similar findings in other spine segments [Panjabi, 2004] and is considered as an indicator of local degeneration.

Discussion

According to the WHO, vehicle accidents account for approximately 400 billion € annually allocated to treatment and indirect costs. Even though the effect of active musculature on acute trauma during nonfatal collision is improbable, the weight of the developing endo-anatomical loads should not be neglected as they may lead to chronic patients and post-traumatic complications yielding a significant socioeconomic impact. Chronic spine patients are exemplary to this, as their estimated life-long treatment cost may lie within millions [Chabok, 2010].

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