# A novel analytical tool to assess spine injury risk in impact biomechanics

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**Objective:** To determine the effect of natural lordosis of the cervical spine on contact-induced head-neck injuries under impact loading.

**Introduction:** Early clinical and descriptive studies postulated that the alignment of the spine affects injuries due to impact loading and injury mechanisms. Later field studies confirmed this postulate in sports-related activities. Biomechanical studies have applied loading to post mortem human surrogate (PMHS) head-neck complexes and reported failure loads and deformations. The risk of effect of the initial alignment on the type of injury, however, has not been quantified. In line with the aims of the symposium, the present study proposes an "analytical tool to assess injury risk." Competing risks analysis (CRA) to statistically quantify this curvature-based parameter in the production of head-neck trauma is presented in this study.

**Methodology:** Pre-flexed PMHS head-neck complex experiments conducted in our laboratory were analyzed. In addition, literature data from similar PMHS tests that maintained the natural lordosis were included in the analysis, leading to a total of 51 specimens. The effect of the absence or presence of lordosis on different types of injuries was analyzed using CRA: bone only, ligament only, and bone with ligament types. The effect was quantified by subdistribution hazard ratios from the CRA.

**Results and Conclusions:** A straightened spine had a 3.23 times higher risk of bony injuries than a spine with natural lordosis. A spine with natural lordosis had a 1.14 times higher risk of ligament injuries, and a 2.67 times higher risk for bone and ligament injuries than a spine without lordosis.

The absence of lordosis significantly increased the risk of bony injuries by three times than a spine with lordosis. The presence of lordosis increased the risk of injuries when ligaments were involved (regardless of the presence or absence of the bony fractures) compared to a straightened or preflexed spine, i.e., without lordosis. The CRA used is not novel in medical research, but its application to injury biomechanics is new. The CRA takes into account the information shared between the injury types and does not consider them as independent outcomes, as the presence of one type of injury precludes the ability to observe another (e.g., a bone only injury and a bone with ligament injury cannot happen simultaneously). This process did not treat the injuries as one homogeneous group, which also allowed for measuring the effect of lordosis on each separately. This statistical technique can be applied in military environments as the use of personal protective equipment is evolving, e.g., lighter vests to increase the lethality, which may change the torso posture that includes the thoraco-lumbar spine. As the seating posture in future highly automated vehicles will not be standardized like the current FMVSS postures, crashworthiness studies may need to include this type of analysis for advancing safety and evaluate the effectiveness of safety countermeasures.