Seat Belt Webbing Under New Seating Positions: Injury Mechanisms and Textile Requirements for Automated Vehicles

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Abstract

The three-point seat belt is the most effective passive restraint in passenger cars, yet the same load transfer that keeps occupants in the seat also causes injuries, ranging from superficial seat belt signs and lacerations to rib and sternum fractures, lumbar flexion-distraction injuries and compression of abdominal organs. Mitigation is typically pursued from the vehicle side, whereas the textile itself, meaning webbing material, weave binding and selvedge, is rarely treated as a design variable. With automated driving enabling reclined, rotated and rearward-facing seating positions, belt routing over stable skeletal structures can no longer be assumed, and belt-induced loading is expected to gain rather than lose relevance.
This contribution bridges the gap between clinical injury description and textile specification. A systematic literature review following the PRISMA framework was conducted across biomedical and transport research databases (MEDLINE/PubMed, Scopus, Web of Science, TRID) to identify clinical case reports, cohort studies and accident research reporting injuries attributable to the seat belt. Included records were classified by body region and AIS severity. Each injury mechanism was subsequently attributed to the belt component triggering it, namely webbing, pretensioner or belt routing. The resulting attribution matrix was formalised through a system and function analysis derived from the FMEA method, decomposing the belt into webbing (material, weave binding, selvedge) and routing (shoulder and lap section).

Three dominant causes emerge: localised load transfer over a small contact area, incorrect positioning or slippage of the belt, and cutting of the skin by the tensioned selvedge. All three intensify under the seating positions expected in automated vehicles, where the lap belt is more likely to load the abdomen instead of the pelvis and the shoulder belt to leave the clavicle and rib cage. From these findings, a requirements catalogue for the textile component is derived, addressing load distribution and damping, selvedge compliance, material softness at constant tensile strength, and positional stability against submarining.
Design routes consistent with these requirements are outlined, including a widened shoulder section, tubular or channelled woven structures forming an air cushion, elastic or padded selvedges, and additional lap belt fixation. All remain bound by the strength and conditioning requirements of UN ECE R16, a regulation not written for automated vehicles and likely to require adaptation.

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