Time and temperature sensitivity of the Hybrid III lumbar spine

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Background

The standard Hybrid III (HIII) dummy was designed primarily to assess frontal impacts for seated vehicle occupants. However, the HIII has been used in a variety of environments and conditions, some of which expose the ATD to multiple impacts in a relatively short time frame or in which test temperature is not easily controlled. When accelerations and forces are applied from beneath the dummy, as is often the case aboard vehicles, the reaction of the lumbar spine dictates the forces and motion transmitted to the rest of the upper body. Both variations in temperature and the time interval between tests affect the biofidelity and repeatability of the lumbar spine response, highlighting the importance of characterizing how these variations affect the compressive behavior of the HIII lumbar.

Objective

The two aims of this study are to determine the influence of the duration of the rest interval between tests on the compression performance of the HIII lumbar; and to quantify the effect of temperature on the lumbar's compressive stiffness in temperatures relevant to indoor and outdoor testing.

Methods

To characterize the effects of different test conditions, a series of high-rate axial compressive tests were run on a 50th percentile male HIII lumbar component in a materials testing machine. Between-test recovery intervals were varied from 2 hours to 1 minute, and temperature conditions of 12.5°, 25°, and 37.5°C were tested.

Results

During repeated compressive loading the force levels, characterized by F3mm, decreased consistently across long and short rest intervals. Even after 2 hours of rest between tests, full viscoelastic recovery was not observed (Figure 1).

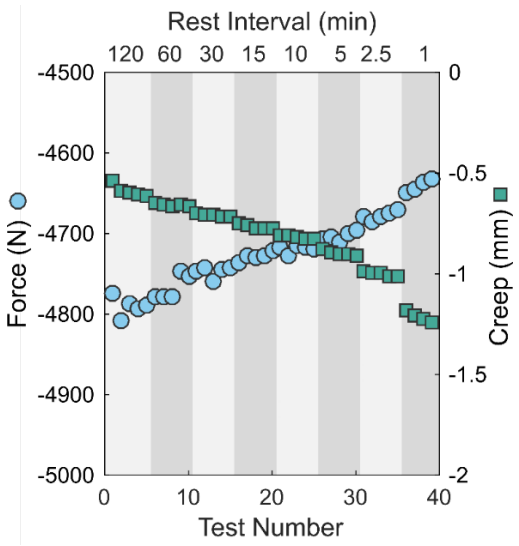

Figure 1. F3mm and creep values from the duration tests. Tests are presented left to right in the order they were run, with bands separating the rest interval levels

Temperature effects were pronounced, resulting in compressive force differences of 261% over the range of 12.5° to 37.5°C. Compared to the stiffness of the lumbar at 25°C, the stiffness at 37.5°C fell by 40%; at 12.5°C, the stiffness more than doubled, increasing by 115% (Figure 2).

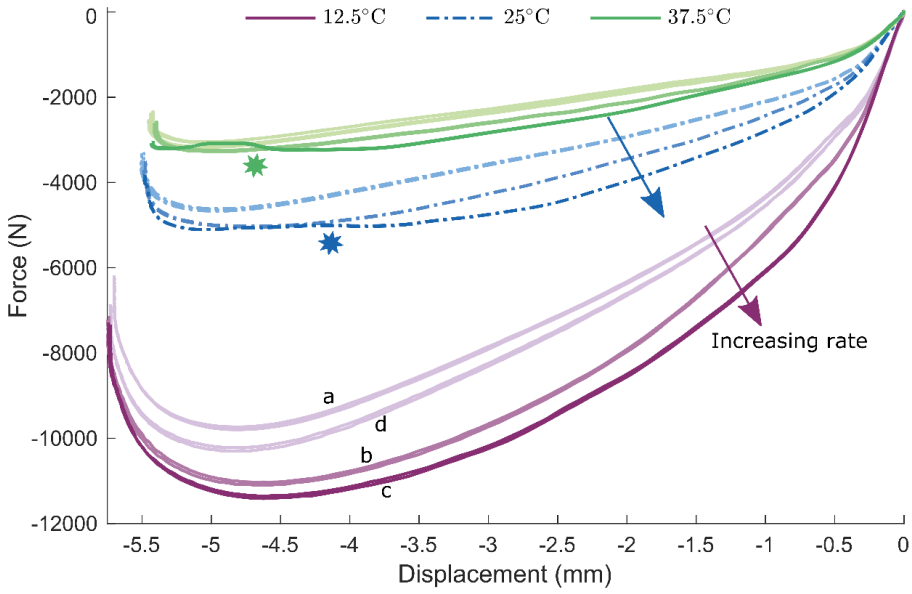

Figure 2. Force-displacement curves for each of the three rates at all three temperatures. Each distinguishable trace includes all repetitions of that test. Colder temperatures and higher rates were associated with increased stiffness. The 12.5°C traces were not repeatable; each letter indicates a pair of tests, applied in the order aa – bb – cc – dd, where a and d represent identical Rate 1 inputs. Star symbols indicate Rate 3 trace regions with marked changes in behavior.

Conclusions

While the duration of the recovery interval for the Hybrid III lumbar spine had a small influence on recorded force, a modest decrease in temperature can be sufficient to dramatically change the response and repeatability of the lumbar HIII component in compressive loading. The large magnitude of the

temperature effect has severe implications in its ability to overwhelm the contributions of targeted test variables. These findings highlight the importance of controlling, monitoring and reporting temperature conditions during HIII testing, even in indoor laboratory environments.