Author's response to reviews

Title: Are cervical multifidus muscles active during whiplash and startle? An initial experimental study.

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Response to Reviewer’s Comments

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We thank Drs. Ivancic and Dickey for accepting the prior revisions to the manuscript. Below are our responses to Dr. Ivancic’s new comments.

1) We elected to use the seat from a 1991 model year vehicle because this seat was used for all of our previous human subject tests. We wanted the ability at some future date to compare data across multiple studies.

There are no studies that have directly tested how seat properties affect the muscle response. Data exist showing delayed muscle responses in a moulded plastic chair (Kumar et al., Accident Analysis & Prevention, 2000, 32:233-241). We presume this plastic chair to be less stiff than an automobile seat, but the stiffness of the plastic chair’s seatback was not reported. Some modern seats, particularly those with integrated seat belts, have considerably stiffer seatbacks than seats of the vintage tested here, but these stiffer seats are installed in only a small proportion of the current fleet. A stiffer seat back will likely yield an earlier and larger acceleration of the torso, which we expect to generate an earlier and larger neck muscle response. Alternatively, some modern anti-whiplash seats may attenuate the speed change experienced by the occupants and thus potentially delay and attenuate the neck muscle response.

We have added a paragraph addressing the use of a single older seat to the limitations section of the Discussion (page 14, lines 5-14).

2) A more detailed description of the sled and pulse have been added to the Methods section of the manuscript (page 6, lines 10-14 and lines 20-21). Panel B of Figure 2 has also been replaced with a photograph of a subject on the sled.

3) The brief negative acceleration at the terminal end of the pulse is part of a small mechanical oscillation as the feedback control system arrests the acceleration. The controller is attempting to match a pre-programmed profile and the specific proportional and differential control constants used for this experiment generated an acceleration oscillation at the end of the pulse. Friction and the seatback extension torque play no role in this artifact since it is also present when the subject and seat are not mounted on the sled. The same oscillation is present in every trial for all subjects, and it is not coincidence that it is present in all three overlayed pulses in Figure 2c.

A similar oscillation exists on the leading edge of the pulse, but in this case it replicates an oscillation also present in the vehicle response.

No changes to the text have been made in response to this comment.

4) The capsular elongation rate from reference 35 was estimated from Figure 5 of that reference. This has been clarified on page 8, line 10.

In response to Dr. Ivancic’s comments, we have modified the Discussion (page 11, lines 8-23) to address the issue of higher severity crashes. We have also provided more detail regarding the conditions used to estimate the 50 mm/s strain rate and have expanded our calculations to consider elongation rates up to 100 mm/s.
5) The times to the peak kinematic responses have been added to Table 1 as requested (page 23). A reference to these data was added to the end of the Results (page 8, lines 14-16).

Dr. Ivancic correctly points out that the data depicted in the lower panel of Figure 2a shows multifidus onset after peak retraction for the sled perturbation. In this subject’s response to the acoustic tone, however, onset occurs at a time that would precede peak retraction if a startle was presented coincident with the sled acceleration. Thus in an unexpected rear-end impact, the multifidus may be active before peak retraction because it’s onset was mediated by a startle reflex rather than a postural response.

The bigger picture Dr. Ivancic raises here is that multifidus activation may not affect capsule strain in individuals whose multifidus muscle does not activate before or during the period of peak capsule strain. To address this bigger issue, we have altered the Discussion to clarify this issue (page 9, lines 13-25).