Putting the 5mph injury threshold to the test

Brian Henderson reveals the results of his extensive research into the impact of low-speed-change collisions

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Much has been promulgated about soft-tissue neck injury in recent years, and it is often cited that below a certain speed change injury will not occur. Many studies have been made, primarily in the US, following collision testing of one sort or another.

The common argument is that the threshold is 5mph, but before a sweeping statement such as that can be considered, one needs to be aware of what is actually being talked about.

Physics facts

Collisions between motor vehicles are subject to Newton's Laws of Motion, as are the contents of those motor vehicles – including the occupants.

In a collision, momentum (mass x velocity) is conserved. This means that the total momentum before the collision is equal to the momentum after the collision. In simple terms, where one vehicle is stationary, all the momentum before the collision is with the striking vehicle and after the collision it is shared between the striking vehicle and the struck vehicle.

The amount of momentum given to the struck vehicle will determine its velocity immediately after the collision, in other words, its change in velocity or D_v (delta v).

The greatest change in velocity for the struck vehicle occurs when the centres of mass of the vehicles are aligned. Again, in simple terms, a square-on, rear-end shunt.

Where there is a large misalignment or the collision is a glancing blow, very little momentum is transferred to the struck vehicle.

For the purposes of this article I will deal only with the effects on the occupants of the struck vehicle in a squarely aligned, rear-end collision.

Assessing the likelihood of injury

Historically, the argument about injury or likelihood of injury has been the domain of the medical expert, albeit without any true scientific evidence on which to base an opinion.

My colleagues and I have been involved in crash testing and other research for a number of years. As a consequence of our research we are now better placed to consider a likely threshold for injury.

That does not mean that we can say whether a person can be injured or not, but it does mean that we are able to say that a given collision will likely result in acceleration of given magnitude to the vehicle's occupants. Further, we are also able to suggest what physically happens to occupants of a vehicle as a consequence of applied accelerations.

What actually happens in a crash?

In a rear-end collision as described earlier, the occupant of a vehicle is at the greatest risk of whiplash-type injury. The following is a step-by-step account of the events of a crash:

- When the two vehicles come together, at first contact there will be no damage at all to the vehicles.
- The striking vehicle continues forwards and its movement is resisted by the struck vehicle.
- Damage (if any) is now caused up to the point of maximum engagement. Once this point is reached, no further damage will occur.

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- The struck vehicle, including the fixed internal features, will now be moving.
- The seat therefore begins to move forward. The body, because of its inertia, initially resists that movement and sinks into the seat padding.
- It is effectively scooped up and it too moves forward. The head, however, does not.
- As with the body, the head initially resists movement but then it too is accelerated.
- In the same order, the vehicle and then the body begin to slow down.
- The head is still accelerating.
- The situation therefore is that the head was initially lagging behind but then it is accelerated forwards ahead of the chest.

It is this movement that is the trigger for whiplash, if the initial acceleration at the chest is large enough, together with even greater acceleration applied at the head. In other words, there needs to be a large difference in the acceleration applied at the head in comparison to the chest, but it too must be exposed to considerable acceleration.

Crash testing

For example, I have written a paper dealing with a crash test undertaken in June 2005. It can be found at www.gbbuk.com/technical.asp and its title is CT2/2005/1.

In the test, we attempted to crash two vehicles so that the resultant change in velocity was around 5mph. The crash resulted in an actual change in velocity for the struck vehicle of 5.97mph.

The maximum positive acceleration at the chest was 4.7g and at the head it was 8.3g. The difference was 3.6g. The time difference was 0.07 seconds. This is the delay between chest movement and head movement as described above.

It is interesting to note that the acceleration applied to the struck vehicle was 2.43g.

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Injury did occur in the test – symptoms of strains and headache lasting up to five days, all of which are recorded within the research paper.

This would tend to support a general threshold of 5mph, given that relatively mild symptoms lasted for a number of days when the speed change was around 1mph over the argued threshold.

However, this threshold could only be considered as a general threshold, as not all vehicle occupants react in the same manner. Perhaps it could be seen as a starting point for healthy, correctly seated occupants.

My ongoing research aims to refine a threshold, based on greater knowledge.

Lower speed changes

In crash tests at lower speeds (or indeed offset collisions at greater speeds) the same level of acceleration of the occupants did not occur.

With that in mind, having constructed a simulator, a series of tests were undertaken with velocity changes of between 1.8 and 3.1mph. Again, all occupants were fitted with accelerometers at the head and the chest.

The acceleration recorded on the test rig (vehicle) was between 0.87g and 2.06g. The average maximum acceleration applied at the chest and the head was 2.93g and 3.46g respectively.

This is a difference of 0.53g. (See the graph below.)

Results

What this research shows so far is that with a velocity change up to 3mph, the acceleration applied at the chest and the head were fairly close together in terms of magnitude. That is, 0.53g as opposed to 3.6g in a collision resulting in a near 6mph change in velocity (delta v). This has also been mirrored in actual collision testing.

The other interesting point is that the accelerations at the head and chest do not rise linearly with an increase in velocity beyond 3mph, but rather each rises more rapidly, with the head more than the chest.

It is my opinion that beyond a speed change of 5mph, the risk of neck injury is high. The risk between 3mph and 5mph is a grey area that would need further exploration, and injury cannot be ruled out. The risk below 3mph is minimal. It may be that as the research continues it can be further refined or redefined.

The research, which was self-funded and completely independent, can be utilised by either claimant or defendant in these types of cases.

Summary

Previous received wisdom has included the following:

- Historical American research suggests a whiplash threshold of 5mph.
- Whiplash symptoms were evident in a UK study for collision testing with a speed change of 6mph.
- Whiplash symptoms were not evident in collision testing with speed changes below 6mph, or simulation testing with speed changes below 3mph.

Conclusions

Based on our research, we can now confidently suggest that:

- speed changes above 5mph indicate a high risk of injury;
- speed changes between 3-5mph are a grey area where injury cannot be ruled out; and
- speed changes below 3mph indicate minimal risk of injury. ■

Graph of acceleration