Thatcham Research

Safer cars, fewer crashes

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WHIPLASH

CAUSATION AND COUNTERMEASURE

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WHIPLASH BACKGROUND

Soft tissue neck injuries, commonly known as whiplash, is a biomechanical injury resulting from a motor vehicle crash. Most frequently seen in front-into-rear crashes by the occupants of the struck vehicle, the mechanisms of injury have been the subject of intense research over the past two decades. Although the medical causation of neck pain is poorly understood the symptoms are well documented. Also well understood are the biomechanical loadings that car occupants are subjected to and how these can directly affect the severity and duration of injury and also the risk of having symptoms in the first place.

In essence, the occupants seated in a vehicle involved in a crash are subjected to typical forces well in excess of those in normal daily living. The transfer of energy through the neck is also not a loading path that the human has evolved to sustain leading to genuine pain even in relatively low speed events. The occupant's vehicle is typically hit from behind leading to the forces of the impact being transferred through the vehicle. Once any residual energy has been absorbed by deformable crash structures the occupants vehicle will be pushed forward. The seat, attached to the vehicle structure will also be pushed forward taking the occupants torso with it. Due to inertia the head, weighing 3-5kg will lag behind until the neck – a flexible element in the system catches up. The ensuing differential movement of head and torso creates distortion beyond normal biomechanical tolerances creating the so called "whiplash" movement, leading to the pain associated with the injury. 60% of whiplash injuries are from rear struck occupants in minor crashes where there is only superficial minor damage to either vehicle; typical repair costs per vehicle rarely exceed £2,000. Whiplash injuries are rarely identifiable from physical medical evidence and so most injuries are only reported symptoms. Insurers are poorly equipped to identify where injuries are likely to have occurred and so must attempt to settle claims in the easiest and most cost effective manner. Due to the current claims climate in which 'claims farmers' work to take advantage of the lack of resolution of the injury, most cases involve initial litigation and so many use an expert witness to attempt to explain the physics of the crash and shed light on the severity of the crash and the level of injury risk. However the majority of witness statements fail to consider the basic physical risk factors of whiplash injury and rarely consider the influence of the seat and vehicle structure on causation.

Biomechanical research from the German Insurance Association in the late 1990's established specific kinematics of the human spine structures in typical rear end crashes, leading to advances in seat and crash dummy design. It also introduced the concept of biomechanical tolerance – a typical limit that the average person could endure without long term consequences. Following this research the German Insurers introduced inclusion guidelines that would be accepted by the courts as legitimate. This lead to the, often-cited, 10 Km/h Delta V (change of speed) threshold. German insurers also include minimum cost of repair criteria to add to their inclusion criteria. The use of these thresholds is still current in the German legal system and has controlled whiplash claim rates although much of the data that it considers is now out of date.

In terms of classifying the severity of whiplash injury often many epidemiological studies cite the duration of symptoms as an indicator. Injuries are typically classed as initial – up to 1 week, short term – up to 1 month, long term – symptoms up to 1 year and permanent with symptoms lasting greater than 3 years (Kullgren 2010). In Sweden the majority of injuries are seen as initial only, 10 % are medically reported as long term and 1% permanent. (Kraftt 2002).

SEAT DESIGN

Since whiplash injuries are a direct result of a motor vehicle crash, key elements of the vehicle design directly affect the risk of sustaining an injury. Biomechanical research in the 1960's and 70's by Stapp and Patrick showed that the human frame can sustain very high forces in rear impacts where the head is supported with the body. In a motor vehicle it is the head restraint (typically called a head rest) that can protect the occupant from the distortion that creates the whiplash injury. But to protect the occupant the head restraint must be of adequate construction and be placed sufficiently close to the back of the head of the occupant to restrict this neck distortion. Research by Avery 1999 showed that 72% of head restraints were poorly placed or incapable of correct adjustment during a study of real world usage. Research by the Insurance Institute for Highway safety showed that head restraints with good geometry reduced real world neck injury rates by 25%. Since 2002 Thatcham and IIHS have measured and publically rated head restraint "geometry" to encourage vehicle manufacturers to improve the size of head restraints to protect the majority of the driving population. For a head restraint to offer protection it must be as tall as the centre of gravity of the head (ear height) and be within 60mm of the back of the head. Both height and backset are seen as influential in preventing whiplash injury.

Since whiplash injuries are the result of a dynamic event both organisations began to crash test seats using sophisticated rear end test dummies, recreating the forces in a typical 10 mph rear end crash. The test dummy – the BioRID was the result of international Swedish collaboration and enables very precise measurement of the forces seen in rear end crashes. From this research a number of biomechanical tolerance values were defined in order to rate seats and encourage best practice. Seats are rated from Poor to Good the later typically being a seat with specific anti-whiplash design attributes and a head restraint sufficiently tall to not require adjustment to protect the majority of occupants. Since testing began in 2006 over 1000 seats have been tested.

Good seat designs typically have anti-whiplash properties integral to their design, these include energy absorbing foams and structures and head restraints that automatically deploy to meet the back of the head of the occupant – negating the need for the occupant to adjust their restraint. These also offer protection in situations where the occupant maybe leant forward or looking sideways – referred to as "out of position".

In the first year of testing only 19% of new vehicles had seats rated as Good. 2012 data showed that 88% of new vehicle seats rate as Good – this would suggest a considerable reduction in the risk of real world whiplash injuries.

Good seats appear to significantly reduce the risk of sustaining a long term (symptoms over 1 month) whiplash injury. Research by Folksam Insurance showed a 40% reduction in long term symptoms with Good seats and IIHS show a 35% reduction in similar long term injuries reported to US insurer State Farm.

A Swedish study (Kullgren 2013) of cars manufactured between 1998 and 2012 and fitted with some form of whiplash prevention seats found that there is a 20% reduction in symptoms lasting more than 1 month and a 40% reduction in permanent medical impairment (pmi), symptoms still present after 3 years, for all occupants. A difference existed between gender for pmi based on seat types, males and females had a 47% and 52% reduction respectively for seats that have a controlled yielding seatback (Volvo and Toyota) but a marked difference exists for seats with reactive head restraints. Females had a 13% increase in pmi compared to a 70% reduction for males. It is hypothesized that the effectiveness of reactive head restraint designs is sensitive to occupant height, latest developments in assessment methods and tools is focussed on ensuring smaller statured occupants are as equally well protected.

Updated research from IIHS shows injury rates were 11.2% lower for vehicles with seats/head restraints rated good compared to vehicles with seats/head restraints rated poor. The percentage reduction for good- versus poor-rated seats was greater for females (12.7%) than males (8.9%). Comparing good- with poor-rated seats, driver ages 15–24 had the largest reduction at 19.8%, followed by 10.7% for driver ages 45–64 and 10.4% for driver ages 25–44. 95% of 2015 models are now rated as Good compared to only 9% in 2005.

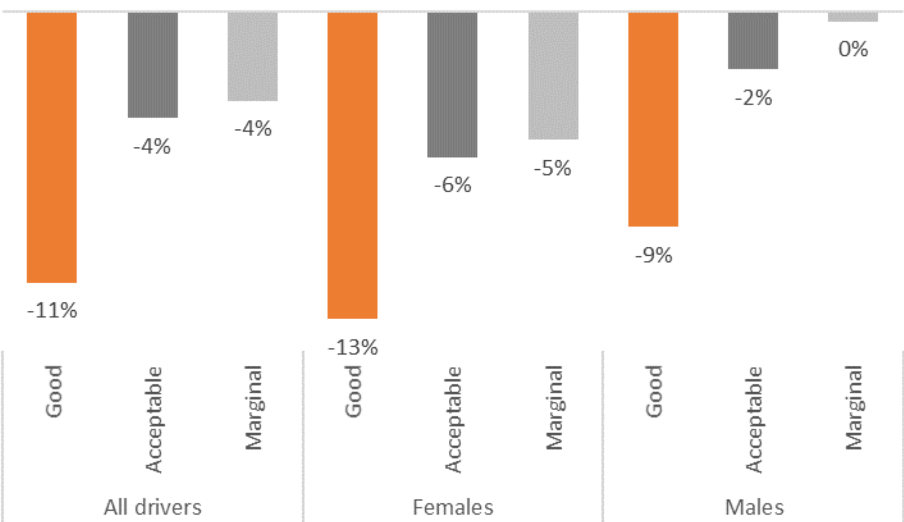

Figure 2. Estimated change in injury rate compared with poor head restraints, by rated driver gender (IIHS 2015)

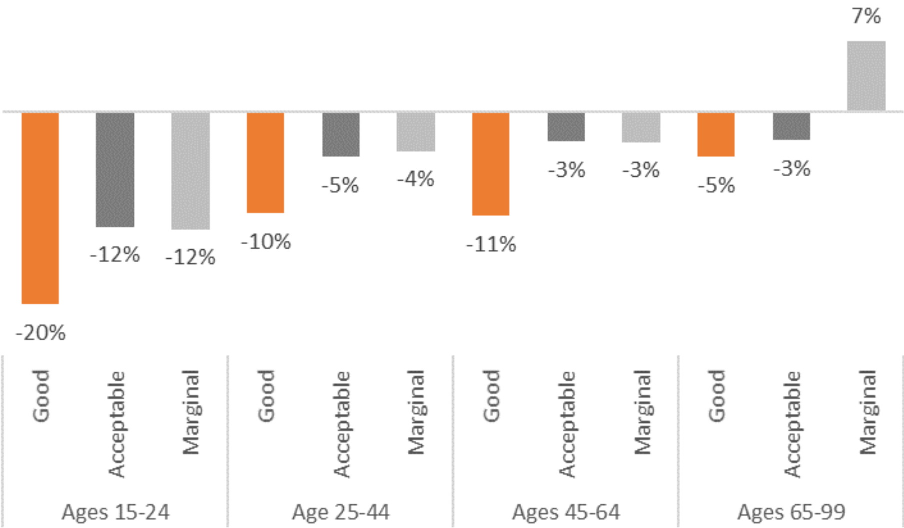

Figure 3. Estimated change in injury rate compared with poor head restraints, by rated driver age (IIHS 2015)

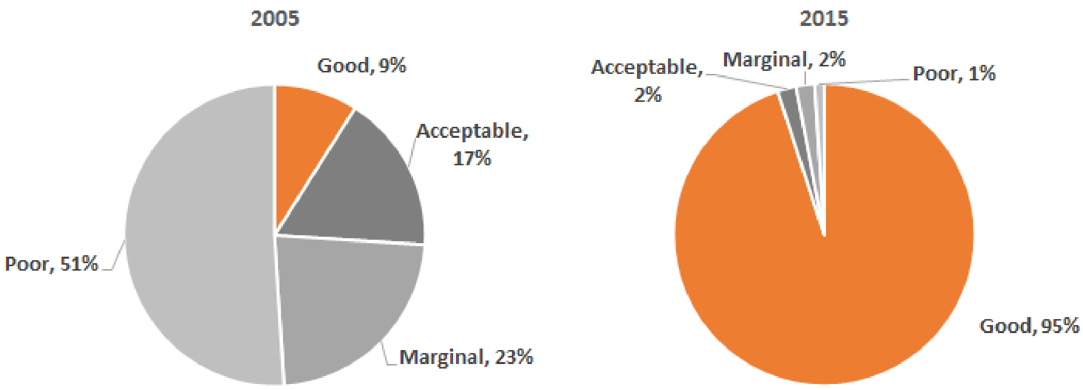

Figure 4. 10 year change in IIWPG ratings (IIHS 2015)

In 2009, based on the work of IIWPG and the Swedish Road Administration, a whiplash assessment was included into the Euro NCAP car safety rating protocol. In 2015 79% seats rated Good. To ensure that all occupants are adequately protected against whiplash injury a geometric only rating was introduced for the rear seat in 2014 aiming to encourage that head restraint are correctly positioned; in 2015 52% of rear seats rated as Good. Furthermore, given the success of consumer whiplash assessment programs and the associated test methodologies, a Global Technical Regulation (GTR) is being developed reflecting many of the RCAR and Euro NCAP requirements.

VEHICLE STRUCTURE

Vehicle interaction is the most significant factor in identifying injury risk with the mass and speed of the vehicles being the most important variables. Also influential is the stiffness of the vehicle and their structural properties. Vehicles have become significantly stiffer in the past 15 years to better protect their occupants from life threatening injuries. Consumer crash test programs from organisations such as Euro NCAP have strengthened vehicle structures, combined with better restraints in the form of airbags and seat belts, have led to a very significant reduction in the risk of being killed or seriously injured. In order to mitigate this stiffness vehicle seat design plays a significant role by absorbing the forces seen in a low speed crash.

Folksam Research from Sweden have fitted over half a million Event Data Recorders (EDR) to vehicles since 1996. This data has been invaluable in identifying real world injury risk factors such as crash speed and the influence of delta V, vehicle stiffness and seat design. Their data identified the influence of mean acceleration and identified injury risk curves for male and female occupants.

Real world data above illustrates that increased risk from vehicle stiffness is ameliorated by Good seat design. Good bumper design can also play a role in controlling energy transfer, Good bumpers being shown to work in conjunction with seats to reduce whiplash injury risk.

Whiplash injury risk is often related to transfer of energy (delta-v), but many other factors can influence injury risk including seat and bumper design, vehicle mass, and occupant morphology. Real world crash data reveals 35% of crashes exhibit unstable engagement where bumper beams underride.

Thatcham examined the effects of vehicle engagement on whiplash injury risk with 34 tests using identical Volkswagen Golfs, with impact delta-vs. ranging from 1 to 25km/h. In engagement condition each pair of vehicle bumpers overlapped. Each impact was duplicated to represent underride by raising/lowering the car suspension to represent brake dive. Data from a BioRID ATD in the struck vehicle was used to assess whiplash injury risk.

It was observed that the accelerations seen in a crash where bumper systems engage are typically higher than where the bumper systems are misaligned and underride. Underride creates an increase in repair costs and will make the vehicle less likely to be driveable after a low speed crash. However occupant accelerations of the struck car indicate an increase in whiplash injury risk where bumpers engage. Almost all neck performance metrics increase as impact speed increases, however these metrics are lower in the underride type crash than the engagement one. Upper neck injury criteria values remain low for all underride crashes in this seat and are well below any published tolerance limit. (Avery 2010)

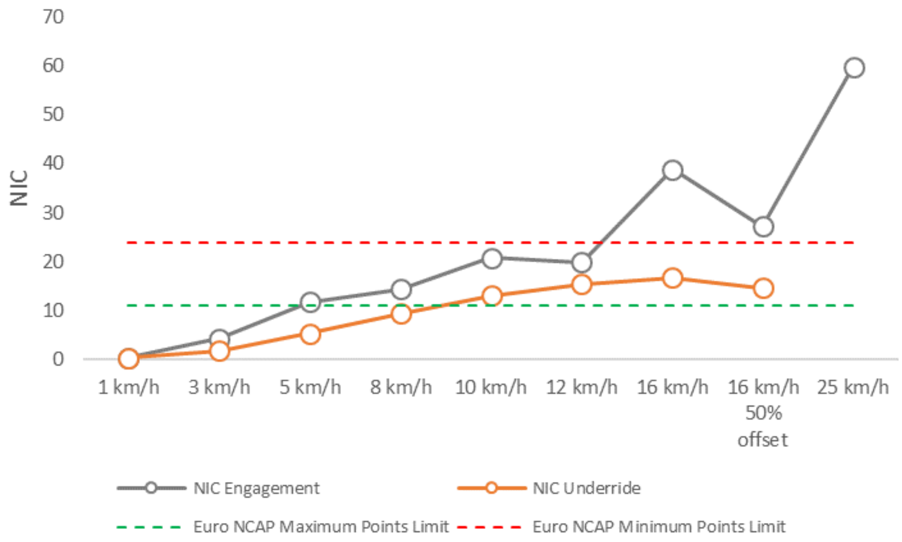

Figure 5: Neck Injury Criteria results for different delta V crashes for Engagement and Underride configurations

Figure 6: Vehicle damage – 16 km/h Engagement

Figure 7: Vehicle damage – 16 km/h Underride

WITKIT

Real world Whiplash injury risk is clearly linked in scientific data to characteristics of both the car and seat design. Where Good bumper and seat designs are employed whiplash risk can be up to 40% reduced. Any attempt to identify injury risk must adequately consider these properties.

Risk factors that affect whiplash injury risk are well researched. Most publications in the field have shown the influence of vehicle mass and the transfer of energy to be of prime importance (delta V). However other vehicle based risk factors have also been shown to have a key influence on injury risk and they include vehicle engagement paths and seat design. Key occupant risk factors include gender, age and occupant seated position.

The WITkit tool allows non-technical claims staff to input these basic descriptors of a vehicle crash using a web interface that is linked to a crash energy and injury risk engine. The system aims to be user-friendly and does not require scientific or engineering knowledge to calculate injury risk. Instead it employs basic crash principles to be simply input using a graphical on-screen system that has a large database of individual car types, specific mass and stiffness, and seat protection performance data; combined with generic crash information. The user can add generic occupant details including age and gender, vehicle load conditions and any other factors that are present from vehicle crash claim forms or engineers reports that can affect injury risk. Generic, but intelligent, crash configurators are also used to enable the engagement of the respective vehicles to be also considered and verified. The system will produce a risk factor (from a sliding scale) for the occupants of the struck vehicle. It also authors a basic, but auditable, report to record the risk calculation process.

WITkit calculates injury risk by combining published vehicle and occupant injury risk databases with established engineering principles. These databases are from peer-reviewed sources and represent the state-of-the-art in terms of whiplash injury risk knowledge. The system currently uses the RCAR-IIWPG seat tests to calculate relative seat performance; of which over 750 (2013) have been published since 2005. The performance in these tests has been related directly to injury risk in several studies.

Many series of low speed whiplash volunteer tests have been undertaken and this data is used to derive energy and gender risk profiles. To augment this a catalogue of real world impacts derived from Event Data Recorder (EDR) data is included uniquely relating injury risk to crash energy and will forms part of the modifier calculations.

A web-based engine calculates injury risk by the estimation of the relative transfer of energy for any specific crash with the system allowing the operator to add specific metrics such as occupant position, gender, vehicle load, etc.

Crash energy is calculated by the operator inputting responses to questions about the damage level of both the striking and struck vehicles. The responses to these damage questions produce an estimate of the crash energy. Logic paths are present that warn the operator of an incompatible crash; useful also as a fraud indicator.

The system is then able to compare input metrics with known rules and real world historical data to produce an estimate of the relative transfer of energy between the respective partners. Finally, reference to the specific seat performance data and occupant profile will enable the system to calculate a "whiplash injury risk". The risk of injury is shown for an average occupant in the struck car and is shown as a percentile of injury risk. The system cannot consider pre-existing medical conditions relating to the cervical spine and cannot be related to a specific occupant; nor can it prove or disprove the existence of a soft tissue neck injury.

An assumption is made that the operator has access to detailed information from the specific crash typical of the insurance claims process such as vehicle repair estimates, including visuals of both vehicles in their un-repaired state, and claimant profile data (such as gender, age and seated position). The system is capable of calculating injury risk with a more limited dataset but its fidelity will be impaired and it will produce an injury risk with less resolution. Input metrics can be altered at any stage and a re-calculation of injury risk established.

There is potential that this web-based claims tool could significantly benefit insurers and other stakeholders by the early identification of likely injured occupants in order to expedite rapid settlement and treatment without lengthy and costly court time. Since it can readily identify where injury risk is low it will also be of significant benefit in tackling the fraudulent or exaggerated claims that significantly burden the insurance and social system. It cannot be used to definitively identify or prove the existence or otherwise of the presence of an injury; nor can it be used as a medical assessment or rehabilitation tool. The system will only calculate injury risk based on sound scientific engineering principles.

AUTONOMOUS EMERGENCY BRAKING

New vehicle systems are available which automatically apply emergency braking to a vehicle at low speed if a crash is imminent, which will help to prevent and mitigate the severity of typical whiplash type crashes. Safety experts agree that Autonomous Emergency Braking (AEB) systems are fundamental to preventing crashes and saving lives; a report released by Euro NCAP in 2015 found that Autonomous Emergency Braking systems were responsible for a 38% reduction in rear-end crashes. Third party injury claims on the Golf Mk7 are 45% lower than an equivalent 'Small Family Car Control Group' according to a Thatcham Research study.

Thatcham has researched these AEB technologies and has developed a testing procedure for evaluating their effectiveness and was adopted within the Euro NCAP car safety rating scheme from 2014. In an unprecedented move, the UK insurers have incentivised the adoption of these systems into new cars by offering a significant reduction to the group rating of suitably equipped vehicles. These rating schemes are helping to influence AEB fitment, and eight of the UK's top ten best-selling cars now offer five-star crash protection alongside some availability of AEB technology. Three of the top 10 offer standard fit AEB on more than 70% of the model range, but just one, the Mercedes-Benz C-Class, has 100% availability. AEB is still not available at all on more than half of all new cars (52%) on sale in the UK and the best-selling models need to be setting an example to change this.