OCCUPANT INJURY SYMPTOM DURATION RESULTING FROM LOW SPEED COLLISIONS

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ABSTRACT

Published data from human volunteer testing and real world collision studies were assessed with a survival analysis to predict injury symptom duration based on collision parameters. This metanalysis considered the effect of age, occupant position, sex, impact direction, type of impact (real world versus staged) and change in velocity (ΔV) as predictor variables. A log-logistic model survivor function was defined with ΔV as the only predictor variable. All other parameters were found not to be significant in predicting injury symptom duration.

Keywords: low velocity; injury probability; whiplash; occupants

CURRENT TECHNOLOGY is limited in its ability to detect soft tissue injuries and, as a consequence, medical practitioners are restricted to basing their diagnosis of the injuries to the symptoms reported by those affected. Often, the distinction between soft tissue symptoms and soft tissue injury is not considered. This is particularly true with WAD (Whiplash Associated Disorder) grade I and II symptoms as the specific injury mechanism is unclear. For the purposes of this paper, no specific injury is assessed and the reporting of the presence or absence of symptoms was the only criteria.

In a previous paper, Moss et al. (2005), the authors published a statistical analysis of the incidence of WAD I and WAD II symptoms from staged and real world rear-end collisions as they relate to change in velocity (ΔV). This paper expands on the previous analysis by evaluating the duration of symptoms from front and rear-end collisions. This comprehensive meta-analysis of the duration of reported symptoms was conducted based upon published results of staged and real world collisions.

LITERATURE REVIEW

A review of literature of real world and staged motor vehicle collisions was completed and sled tests involving occupants in low speed impacts were performed. Only tests where individuals were exposed to a single impact per person were considered as multiple impacts are a confounding variable.

The data set for single impact events for both front and rear collisions included 264 instances, drawn from 15 papers. The soft tissue symptoms reported ranged in severity and were not all classified in the same manner. Some reported the symptoms as a function of the Quebec task force classification (Spitzer et al., 1995) of WAD I to WAD II whereas other sources reported the symptoms based upon the Abbreviated Injury Scale (AIS), with all reporting as AIS 1 (i.e. acute strain with no fractures or dislocation). The remaining sources reported a variety of specific symptoms; however, these tended to be more descriptive variants of WAD I, WAD II and AIS 1. The focus of this study was on soft tissue injury symptoms; therefore, persons with WAD III symptoms were not included in the data set.

As previously shown in Moss et al. (2005), ΔV is useful in measuring the relative severity of these types of collisions and predicting the presence of injury symptoms after the collision. ΔV represents the change in the velocity a vehicle undergoes during the collision (comparing the speed before and after the collision). Although mean acceleration has been suggested as a better predictor of the injury symptom characteristics (e.g. Krafft et al., 2002; Siegmund et al., 2005), this form of measurement is not available for real world collisions as a duration of the impact would have to be assumed. As a consequence, mean acceleration was considered a less practical approach to assessing the likelihood of symptoms or their duration from real world collisions.

METHODS

Statistical risk functions are used in order to define the relationships between known or measurable predictors. These statistical techniques provide a prediction of the probabilities of an individual incurring a particular injury or, in this case, a symptom. Typically, the data consists of precise data or data that are considered censored (left or right). Censored data refers to recorded parameters that are above or below the specific threshold they are intended to measure.

The symptoms reported in the data set were simply evaluated according to their presence or absence and treated as a binary condition. The duration of symptoms resulting from rear and front impacts was analyzed using the SAS LIFEREG procedure. This procedure estimates a parametric regression model with censored survival data using the maximum likelihood approach. This class of regression models is known as accelerated failure time models. The data set contained uncensored data as well as both right and left censored observations. A wide range of distributions were considered including exponential, Weibull, normal, lognormal, logistic, log-logistic, and gamma in order to find the best fit. Predictor variables considered included collision direction (front versus rear), collision type (real world, sled, or staged vehicle-to-vehicle), sex (female or male), position in the vehicle or sled (driver or passenger), age of person (in years), and ΔV (in km/h). The presence or absence of symptoms after the collision was used as an indicator variable.

RESULTS

A total of 39 studies were reviewed for possible sources of data from rear and front impacts. The initial data set was reduced from 965 data points from 39 papers to 264 data points across 15 papers. Several data points had to be eliminated due to insufficient information on symptom duration. Many of the papers would report how many of the occupants experienced symptoms but did not follow-up on their duration. In addition, human volunteers that had been in multiple impacts during testing were also eliminated as it could not be determined which impact the symptoms were associated with or if the symptom duration was affected by multiple exposures. The data set analyzed included human volunteer tests (Bailey et al., 1995; Braun et al., 2001; CATAIR, 2004; Castro et al., 1997; Davidsson et al., 1998; Geigl et al., 1994; Kaneoka, et al., 2002; McConnell et al., 1995; Nielson et al., 1996; Szabo et al., 1994; van der Kroonenberg et al., 1998) and real world collisions (Jakobsson and Norin, 2003; Krafft et al., 1998; Krafft et al., 2002; Kullgren et al., 1999).

There were 114 frontal and 150 rear impacts in the data. The sex breakdown of individuals was 71 females, 99 males and the remainder not specified. The occupants' ages ranged from 5 to 68. The symptom durations were reported as exact values, or with upper or lower bounds (e.g., < 2 weeks, > 6 months). The majority of the symptoms resolved themselves relatively quickly but the recorded duration values ranged from less than one hour (0.04 days) to greater than one year (365 days).

The data set was heavily censored. Out of the 264 data points, 69 were left censored and 21 were right censored. The log-logistic distribution was selected for the accelerated failure time model based on its log-likelihood (-318.64). The log-normal and Weibull distributions were second and third, respectively, in terms of the model fit based on the log-likelihood. The final model only contained ΔV ($p<0.0001$) as a predictor variable. All other prediction variables were found to be excluded from the model due to non-significance (all $p>0.05$). The log-logistic model survivor function was defined as follows (Eq.1):

$$S(t) = \frac{1}{1 + (\exp\{-[-9.7015 + 0.0482 * DeltaV + 11.3149 * Symptoms]\} * t)^{1/0.538}} \quad (1)$$

where *DeltaV* (km/h) is the change in velocity, *Symptoms* equals 1 if symptoms were reported and 0 if they were not, and *S(t)* is the probability of symptom duration greater than time *t* (days).

Figure 1 shows the predicted probabilities of the duration of symptoms lasting longer than 7 days (1 week), 14 days (2 weeks), and 30 days (~1 month) as a function of ΔV based on the fitted model for

occupants who experienced symptoms after the collision. These durations were arbitrarily chosen based upon reasonable demarcations in time.

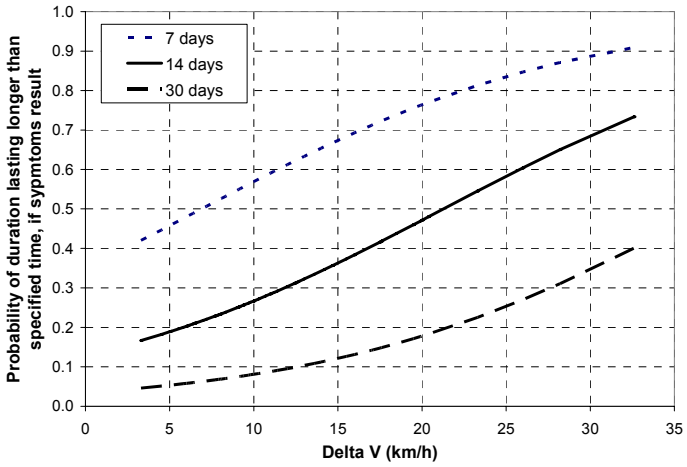

Figure 1 - Predicted probabilities of symptoms lasting beyond 7, 14, and 30 days as a function of delta V (km/h) for occupants who experienced soft tissue injury symptoms after a collision.

DISCUSSION

Age, occupant position within the vehicle, sex, collision type and orientation of the collision were found not to be statistically significant in predicting symptom duration. There were 94 data points that did not specify the sex of the occupant and this lack of reported information may have affected its significance as a predictor in the data set. The same applies to age as a predictor, as only 70 of the data points reported age of the occupant. Since the orientation of the impact should affect the injury mechanism that produces these symptoms, it was expected that there would be a correlation with symptom duration. Although, in general, occupants in frontal collisions may begin showing symptoms at higher changes in velocity (e.g. Otte and Rether, 1985), this analysis suggested that when symptoms appeared their duration was similar to that of rear impacts.

Figure 1 shows that there was substantial difference between the probabilities of symptoms lasting longer than 7, 14 and 30 days. For example, when symptoms were experienced at a change in velocity 8 km/h, the probability of injury symptoms lasting longer than 7 days was 52%, longer than 14 days was 23%, and longer than 30 days was 7%. For the velocity range where symptoms were experienced (3.3 to 32.6 km/h), the probability of the symptoms lasting longer than 30 days was less than 50%.

The data set included real world collisions and likely included some occupants with previous medical conditions (e.g. degenerative changes in the spine), which may have affected their rate of recovery. However, previous medical conditions were not reported in the data and as a result could not be evaluated as a predictor. Therefore, readers wishing to compare an occupant's injury symptom duration outcome to the results presented in this paper, specific medical history and collision circumstances (e.g. occupants that are out of position or have their head turned) must also be considered.

CONCLUSIONS

Based upon the results from the analysis of the data, the following conclusions were drawn:

1. Several different statistical models were evaluated to predict the duration of WAD I, WAD II and AIS 1 injury symptoms. The most statistically significant was a log-logistic model using an accelerated failure time model.
2. A log-logistic model survivor function was defined with ΔV as the only predictor variable.

3. In front and rear end collisions that result in symptoms, sex, age, occupant position within the vehicle, collision type and collision direction were found not to be predictor variables for symptom duration.

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