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Fragility and crash over-representation among older drivers in Western Australia

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Abstract

This study assessed age-related and gender differences in the relative contribution of fragility and crash over-representation to serious injuries per crash-involved driver in Western Australia. Police-reported crashes for the period 1998–2003 were extracted from the Western Australian Road Injury Database. For each passenger vehicle driver age and gender group, serious injuries per crash-involved driver and driver involvements in crashes per 100 million vehicle-kilometre travelled (VKT) were calculated as the respective measure of fragility and crash over-representation.

Results from the decomposition method of analysis showed that older drivers over the age of 70 sustained serious injury rates more than twice as high as those of the 30–59-year-old drivers. Fragility increased with age, contributing between 47% and 95% for drivers above 65 years, but crash over-representation was the dominant factor for male drivers above 80 years. In contrast, fragility contributed little to the excess injury risk of younger drivers under the age of 30.

The importance of fragility as a contributing factor to the inflated serious injury risk per vehicle-kilometre travelled for older drivers suggested that road safety initiatives should be directed towards the protection of vehicle occupants as well as screening for their driving ability.

Keywords: Decomposition method; Excess injury risk; Fragility; Older drivers; Over-representation

1. Introduction

Older drivers comprise the fastest growing segment of the Australian driving population and represent a larger percentage of the driving public than ever before (Australian Bureau of Statistics, 2003). The proportion of Australians over 65 years will be doubled from 12.5% in 2000 to 25% in 2021 (Australian Institute of Health and Welfare, 2001), leading to more old drivers on the road. This growth will be more pronounced in the 85 years and above age group, with the proportion of people in this age group expected to increase four-fold (Australian Bureau of Statistics, 2003).

The exposure measure to quantify the crash risk is a controversial issue. Rates of crashes per licensed driver are found to be highest amongst young drivers, with a steady decline in age. But when these results are presented in terms of crashes per kilometre traveled, a U-shaped curve is evident, with an increase in rates after the age of 55 (McGwin and Brown, 1999; Holland, 2002). For older drivers, physiological changes associated with increasing age such as decline in vision and reaction time are perceived to increase the risk of a crash (McGwin and Brown, 1999; Lyman et al., 2001; Janke, 2001). In addition, age-related decline in physical health also increases the likelihood of poor outcomes among older drivers involved in a crash. Their risk of being killed or suffering serious injury as a result of a road crash is between two and five times greater than that of a younger person because of their increased fragility (Holland, 2002). Even a minor crash could have more serious implications for an older person than a younger person suffering the same injuries (Burkhardt and McGavock, 1999; Li et al., 2003).

In view of the rising number of older drivers and associated mortality and morbidity, issues related to their safety while ensuring their mobility needs are met must be addressed. Very few studies have examined the role of fragility and over-representation of older drivers in crashes. Li et al. (2003) examined the roles of fragility versus excessive crash involvement

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and their contribution to the high fatality rate among older drivers in the United States. Using multiple national data systems, they found that fragility steadily increased from age 60–64 and accounted for 60–95% of the excess death rate per vehicle mile travelled in older drivers. Quantifying the respective contributions of such risks to the rates of serious injury per vehicle-kilometre of travel is important to understand the nature of the problem and to suggest possible counter measures. Therefore, this study aims to examine age-related and gender differences in the relative contribution of fragility and crash over-representation to serious injury among drivers in the State of Western Australia using the decomposition method of Li and Baker (1996), which have not been reported previously in the literature.

2. Methods

Older drivers (aged 60–64, 65–69, 70–74, 75–79, 80–84 and 85+) and younger drivers (aged 15–19 and 20–29) were compared to drivers aged 30–59, the age group with the lowest death rate per vehicle-kilometre travelled (VKT) (Ryan et al., 1998).

2.1. The Western Australian road injury database

Police-reported crash data from 1st January 1998 to 31st December 2003 were retrieved from the Western Australian Road Injury Database which is maintained by the Injury Research Centre at The University of Western Australia. This database contains detailed information on all crashes reported to the police, hospital discharge records of persons admitted to hospital as the result of a road crash injury (extracted from the Hospital Morbidity Data System maintained by the Department of Health, Western Australia), and the Registrar General's death records.

For the purpose of this study, the definition of a crash is "any apparently unpremeditated collision reported to the police which resulted from the movement of at least one road vehicle on a road open to and used by the public and involving death or injury to any person, or property damages" (Legge et al., 2001). It is mandatory in Western Australia to report a crash to the police if a person is injured or if property damage exceeds $1000. Crashes that occur on public roads are also required to be reported to the police (Legge et al., 2001). Serious injury refers to an injury where the driver was recorded as being admitted to the hospital or death within 30 days of the crash. The analysis undertaken was restricted to driver whose crashes (both single and multi-vehicle) occurred within the Perth metropolitan area, involving cars, sedans, station wagons, utilities, pick-up and multi-seater vans. The restriction was imposed to coincide with the available driving exposure data.

2.2. Perth and regions travel survey

Estimates of exposure to driving were obtained from the Perth and Regions Travel Survey 2003 (Department of Planning and Infrastructure, 2004). This survey of day-to-day travel included the collection of vehicle-kilometre travelled by age and gender for a representative sample of households across the Perth metropolitan region. Travel patterns were assumed to be stable throughout the 6-year study period.

2.3. Analysis by the decomposition method

Li and Baker (1996) and Li et al. (2003) used the decomposition method to investigate the relative contributions of different component rates to cause-specific injury morbidity rates for various populations. In this study, three measures of driving safety are considered: serious driver injuries per million vehicle-kilometre travelled, serious driver injuries (I) per driver involved in police-reported crashes, and driver involvement (C) in police-reported crashes per 100 million VKT. The relationship between these measures is given by:

$$\frac{I}{\mathrm{VKT}} = \frac{I}{C} \times \frac{C}{\mathrm{VKT}}.$$

The outcome measure 'serious driver injuries per million VKT' is a morbidity rate per unit of exposure to quantify driver injury risk. It is decomposed into two contributing rates. The number of serious driver injuries per driver involved in all police-reported crashes reflects the risk of serious injury or death to a driver when involved in a crash. As such, this measure is considered to be a marker of fragility. The definition relies on the assumption that vehicle and crash characteristics are constant. The number of drivers involved in police-reported crashes per million VKT represents the tendency for drivers to be involved in crashes and may be considered as a marker of crash over-representation. This measure assumes that travel exposure characteristics are constant across age groups.

According to Li et al. (2003), the differences in serious driver injury rates per unit of travel between two age groups can be expressed as a ratio of rates for the two age groups as:

$$\begin{aligned}\text{Injury rate ratio} &= \frac{(I/\mathrm{VKT})_1}{(I/\mathrm{VKT})_2} = \frac{(I/C)_1}{(I/C)_2} \times \frac{(C/\mathrm{VKT})_1}{(C/\mathrm{VKT})_2} \\ &= \mathrm{Ratio}_a \times \mathrm{Ratio}_b,\end{aligned}$$

where Ratio_a = fragility rate ratio, and Ratio_b = over-involvement rate ratio. It can then be determined quantitatively how much more likely older drivers are seriously injured in a crash, given their exposure, when compared to the 30–59 reference age group. Similarly, excess fragility and over-representation can be determined using Ratio_a and Ratio_b for comparison between age groups.

The relative contribution of each element (fragility and crash over-representation) to the overall excess injury risk per unit of travel for a particular age group over a reference group is given by:

$$\mathrm{RC}_i = \frac{|\ln(\mathrm{Ratio}_i)|}{\sum_{i=a}^{b} |\ln(\mathrm{Ratio}_i)|} \times 100\%$$

where $i = a$ (fragility) or b (over-representation), assuming no other factors are involved.

Caution must be taken when interpreting these measures (Li et al., 2003). A high relative contribution does not necessarily

imply that drivers in a particular age group are more fragile or more susceptible to crash involvement. Rather, it suggests that the overall morbidity rate is more heavily influenced by one of these factors. Therefore, the relative contributions should be interpreted in conjunction with the corresponding rate ratios. For example, if fragility has a relative contribution exceeding 50% and a rate ratio greater than 1.0, this implies that drivers in the target age group are not only more likely to be seriously injured as a result of a crash but this excess rate explains a large portion of the differences in injury rates per unit of exposure between the target and reference age groups. On the other hand, if the relative contribution of fragility exceeds 50% while the rate ratio is less than 1.0, it may be concluded that the target age group is less fragile than the reference group and fragility contributes substantially to the injury rate ratio.

3. Results

A total of 5020 passenger vehicle drivers were seriously injured or killed as a result of involvement in one of the 270,194 crashes reported to police from 1998 to 2003 in the Perth metropolitan area. Males represented 58% of drivers involved in a crash. Of those reporting a serious injury 52% were males. It was estimated that registered drivers drove 47,099 million kilometres over the study period, with males contributing 26,858 million kilometres (57%).

3.1. Injury rates

Serious driver injury rates per unit of travel for both genders were higher amongst the youngest and oldest age groups. As expected, the 30–59-year-age group incurred the smallest number of serious injuries per 100 million VKT for both male and female drivers, with their respective rates being 5.93 and 8.15; see Table 1. It can be seen from Table 2 that female drivers aged 80–84 were most at risk of serious injury per 100 million VKT with a rate ratio of 4.74 relative to the 30–59 reference group, but the risk declined for the 85+ group though it was still more than twice the rate of the reference group. Male drivers, on the other hand, exhibited an increasing trend of serious injury as a function of age after 60 years. In particular, the rate ratio for the 85+ group was extremely high at 37.64, in contrast to the corresponding ratio of 2.13 for the females.

3.2. Crash over-representation

Female drivers were involved in fewer crashes than their male counterparts across age groups (Table 1). They also drove less distance, on average, except the 80–84 and 85+ age categories. Consequently, the crash rates for males and females were quite different especially among the older drivers. Crash over-representation was measured by driver involvements in crashes per 100 million VKT. Not surprisingly, the young drivers (15–19 age group) demonstrated considerably high crash involvement with rate ratios of 3.24 for female and 4.31 for male drivers (Table 2). Male drivers above 85 years reported the highest rate ratio of 6.5 whereas their female counterparts were least likely to be involved in a crash (rate ratio = 0.73).

3.3. Fragility

Driver fragility was measured by serious injuries per 1000 drivers involved in police-reported crashes. In general, the rates increased with age beyond 60 years for both genders. Drivers 85+ were much more likely to be seriously injured when involved in a crash, as evident from their rate ratios of 2.92 for

Table 1
Passenger vehicle serious driver injuries from police-reported crashes in Western Australia, 1998–2003

Age group	Serious driver injuries	Drivers in crashes	VKT (million)	Serious driver injuries per 100 million VKT	Serious driver injuries per 1000 drivers involved in crashes	Drivers in crashes per 100 million VKT
Female						
15–19	317	14952	1087	29.17	21.20	1375.73
20–29	704	32760	4057	17.35	21.49	807.55
30–59	1089	56685	13370	8.15	19.21	423.98
60–64	76	3137	639	11.90	24.23	491.22
65–69	56	2014	452	12.39	27.81	445.61
70–74	57	1586	235	24.24	35.94	674.51
75–79	48	1112	252	19.04	43.17	441.12
80–84	31	598	80	38.61	51.84	744.77
85+	12	214	69	17.35	56.07	309.43
Male						
15–19	426	21609	1155	36.87	19.71	1870.50
20–29	797	44219	5148	15.48	18.02	858.99
30–59	1022	74774	17240	5.93	13.67	433.72
60–64	79	5729	1241	6.37	13.79	461.65
65–69	68	3845	988	6.88	17.69	389.13
70–74	70	3112	617	11.34	22.49	504.04
75–79	85	2242	371	22.89	37.91	603.65
80–84	41	1075	79	52.11	38.14	1366.31
85+	42	531	19	223.12	79.10	2820.92

Table 2
Serious driver injury rate ratios and relative contributions (RC) of fragility[a] and crash over-representation[b] in Western Australia, 1998–2003

Age group	Serious driver injuries per VKT rate ratio	Serious driver injuries per 1000 drivers involved in crashes		Drivers in crashes per 100 million VKT	
		Rate ratio	RC (%)	Rate ratio	RC (%)
Female					
15–19	3.58	1.10	7.73	3.24	92.27
20–29	2.13	1.12	14.82	1.90	85.18
30–59[c]	1.00	1.00	–	1.00	–
60–64	1.46	1.26	61.17	1.16	38.83
65–69	1.52	1.45	88.14	1.05	11.86
70–74	2.98	1.87	57.43	1.59	42.57
75–79	2.34	2.25	95.33	1.04	4.67
80–84	4.74	2.70	63.79	1.76	36.21
85+	2.13	2.92	77.28	0.73	22.72
Male					
15–19	6.22	1.44	20.04	4.31	79.96
20–29	2.61	1.32	28.82	1.98	71.18
30–59[c]	1.00	1.00	–	1.00	–
60–64	1.07	1.01	12.43	1.06	87.57
65–69	1.16	1.29	70.37	0.90	29.63
70–74	1.91	1.65	76.83	1.16	23.17
75–79	3.86	2.77	75.53	1.39	24.47
80–84	8.79	2.79	47.21	3.15	52.79
85+	37.64	5.79	48.39	6.50	51.61

[a] Fragility measured by serious driver injuries per 1000 drivers involved in police-reported crashes.
[b] Crash over-representation measured by driver involvements in crashes per 100 million VKT.
[c] Reference group.

females and 5.79 for males. Overall, male drivers appeared to be less fragile than female drivers for the older age categories.

3.4. Relative contributions of fragility and crash over-representation

Although the younger drivers had high fragility rates and crash over-representation, their excess injury risk was attributable to crash over-involvement, with relative contribution ranging from 71% to 92%. On the other hand, increased fragility explained at least 50% of the excessive injury risk incurred by older female drivers (range 57–95%). The pattern for male drivers was less obvious. For the 60–64 year old males, their slightly inflated injury rates were largely (87.6%) due to over-representation. But for those within 65 and 79 years, the increased injury risk was reflected by their excess fragility which varied between 70% and 77%. The relative contributions of fragility and crash over-representation were about equal when the male drivers reached 80 years of age and their injury rate attained the highest ratio among all age groups.

4. Discussion

The decomposition method was used to investigate age and gender discrepancies in the relative contribution of fragility and crash over-representation to serious injury per million VKT. Serious injury rates were found to be substantially higher for older drivers. Fragility, as a measure of vulnerability, appeared to explain the excessive injury risk for both male and female older drivers. Although crash over-representation slightly overtook fragility as the dominant component for males over the age of 80, fragility still contributed about half the excess injury risk, noting that these older drivers sustained an injury rate 8–37 times that of the 30–59-year-old drivers. Our results are consistent with those of Li et al. (2003), which showed that fragility accounted for 60–90% of the excess risk of dying among drivers aged 60+. Even among drivers over the age of 75, for whom inflated rates of crash over-involvement were observed, fragility still accounted for 60–70% of their excess risk of dying.

Male drivers over the age of 85 demonstrated the highest crash involvement rate across gender and age groups, followed by young drivers at the 15–19 year category. Although similar results were reported by Ryan et al. (1998), it must be cautioned that the extreme age group involved relatively small number of drivers and low VKT as a result of the manipulations undertaken with the driving exposure data from the Perth and Regions Travel Survey. Older female drivers also tended to have higher crash involvement relative to the reference middle-age group despite their apparent variation in rates. Females had fewer crashes than males but had less exposure in term of kilometres driven (except for the 80–84 age group) according to the travel survey. The differences in crash involvement between age groups may be due to a combination of exposure and changes in ability to cope with driving situations. Research has shown that older drivers have difficulty with complex situations such as intersections, reversing out of parked places and night-time driving (Hakamies-Blomqvist, 1993; Ryan et al., 1998; Holland, 2002).

Some limitations should be considered when interpreting the findings. Because older drivers are more likely to be injured

severely from crashes, they may be over-represented in the data, leading to over-estimation in rates. The analysis was also restricted to metropolitan crashes, which would introduce bias as older drivers tend to reduce their driving in urban areas (though not necessarily considered as lower-risk exposure), yet a large part of the road network in Western Australia is located in rural areas. The assumptions and manipulations performed to obtain driving exposure data in a useable form might have reduced the accuracy of the results. For example, female drivers in the 85+ group were more at risk (rate ratio = 2.13) than the 30–59 group but less at risk (rate ratio = 0.45) than the 80–84 group. This result appeared to be inconsistent with the general theory, which might be partly due to the overestimation of VKT for the oldest age group. This study did not examine fragility and over-representation by the type of crash. The types of crash involving older drivers are not the same as those involving younger drivers, which may have influenced the results. It would be worthwhile to explore these differences in subsequent research. Lastly, the assumption concerning driving exposure is also likely to affect the accuracy of the results. The markers adopted for fragility and crash over-representation in this study assume constant crash, vehicle and driving exposure characteristics, which are difficult to justify in practice. For example, it is known that older drivers generally self-regulate with respect to the conditions they drive in, effectively restricting themselves to lower-risk exposure (Benekohal et al., 1994).

Results of this study have implications for the implementation of older driver safety countermeasures. The high relative contribution of fragility to the excess risk of serious injury per million VKT for older drivers suggests that safety initiatives should concentrate on improving vehicle occupant protection. Possible strategies include improved safety harnesses, changes to airbag design and measures to enhance protection in side-impact crashes. Although older drivers are slightly over-involved in crashes relative to 30–59 year olds, the problem becomes more dramatic for male drivers over the age of 80. Therefore, policies aimed at reducing older drivers' involvement in crashes, such as screening of driving ability, may curtail their serious injury rates per VKT (Stutts and Wilkins, 2003). Countermeasures aimed at reducing the frequency and severity of crashes involving older drivers are needed. These include improvements to the road environment such as the design and operation of intersections, which remain a problematic area for older drivers (Cooper, 1990; Hakamies-Blomqvist, 1993). Improvements to licensing procedures can also play an important role in appropriately identifying those drivers at increased risk of crash involvement due to health conditions and/or functional deficits and therefore improve the safety of older drivers (Lee et al., 2003).

In conclusion, the importance of fragility as a contributing factor to the inflated serious injury risk per vehicle-kilometre travelled for older drivers suggests that road safety initiatives should be directed towards the protection of vehicle occupants as well as screening for their driving ability.

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