Epidemiological Study of the Impact of Whiplash on Subsequent Driver Safety

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EXECUTIVE SUMMARY

This research project involved two studies aimed to determine whether drivers who have experienced a traffic crash resulting in a Whiplash Associated Disorder (WAD) are at an elevated risk of a subsequent traffic crash.

Using data and records held by the Queensland Motor Accident Insurance Commission (MAIC) and Queensland Transport Crash Database (QTCD) the first study examined the crash involvement of two samples of drivers subsequent to a crash in which a compensable injury was incurred. One sample was of persons who had suffered a WAD, the second of persons with a soft tissue injury of equivalent severity. Since differentially altered driving exposure following the relevant injury in the two groups could be a potential confound, in the second study such exposure was estimated using survey data obtained from a sample of similarly injured drivers. These studies were supplemented by a brief analysis of qualitative data drawn from open-ended questions in the survey. In addition a comprehensive review of the literature on impaired driving due to similar medical conditions was undertaken and is reported.

RESULTS

In the first study there were 4280 cases and 1116 controls aged at least 17 years. Time in study from claim date ranged from 2.5 to 3.4 years. Females formed over 60% of the WAD group, but under half in the control group. Almost three-quarters of cases were drivers, whereas this type of road user comprised well under half of controls. Age distributions differed comparatively little between cases and controls at the time of collision.

Analytic results

All analyses made use of failure-time models; the outcome variable was the number of months between the date of the index crash and the date of the first subsequent crash, if any, or to the end of follow-up if none. The persons with WAD had somewhat higher subsequent crash rates than persons with other soft-tissue injuries, particularly among females, although not significantly so. Hazard ratios for WAD claimants versus claimants with other soft tissue injuries ranged from 1.11 for female drivers and for all males as a group (driver or otherwise), to 1.36 for male drivers. For the entire sample, the hazard ratio adjusted for all other potentially influential factors was 1.14, with 95% confidence interval 0.87 – 1.48, and hence not significantly different from parity.

The second study was undertaken to establish whether there were differential changes in exposure or the amount of driving done by cases and controls before the index crash compared to the amount driven thereafter. It aimed to place these results in context by determining whether drivers in these groups modified their subsequent driving to the same extent. A survey was undertaken to capture the essential information on driving both prior and subsequent to the crash where the participant was injured. Items included: gender; current age; year and month of index crash; part(s) of the body injured; the nature of these injuries; the effect of the injury or injuries on daily activities; the number of kilometres driven per year before injury; and the relative change in the amount driven at one, three and six months after injury. Respondents were also invited to give reasons for these changes in their own words. The major source of respondents was the RACQ through an electronic newsletter.

Eligible respondents included 113 in the WAD group and 53 in the non-WAD group (control series). For participants for whom gender was recorded, the proportion of females was 69.2% and 60.0% for WAD and non-WAD groups respectively. There were no significant differences in the average distances driven before and after the index crash by the two groups. We tentatively conclude that, on average, for drivers injured in a traffic crash, driving exposure is similar irrespective of whether the injury is WAD or another soft-tissue injury.

Reasons for changes in driving exposure were also examined. The strongest and most consistent theme was anxiety or fear, nominated in almost 70% of interpretable cases. One participant simply stated, "It hurt and I was scared it might happen again." Restricted movement and pain were also common themes. It is of interest that two participants increased their driving, as they felt anxious being a passenger. Whilst the question did not specifically address difficult driving tasks, the most commonly nominated task was shoulder checking when merging. A representative quote was "restricted movement due to the injury prevented me from being able to turn and see traffic on the road around me." Several participants also nominated driving for long periods as difficult.

Overall

Results indicated that there is little or no difference in crash risk between WAD and non-WAD groups. Note that the effective sample size is in reality modest. There were only 375 individuals with a subsequent crash, 307 in the WAD group and 68 in the Other group. This is reflected in the widths of the confidence intervals round the point estimates of relative risk, and implies that although no significant differences between WAD affected drivers and those with other soft tissue injuries were found, a definitive answer to the question of the relative safety of drivers with whiplash cannot be given.

Crash risk and exposure of drivers subsequent to a crash in which they sustained a soft-tissue injury was investigated. Drivers with WAD were compared to those with other soft-tissue injuries. Results also indicated that both these groups reduce their driving to a similar degree on average. Here too the modest size of the sample means that the 95% confidence intervals for the differences in percentage change in kilometres driven are correspondingly wide.

Qualitative data provided by participants clearly indicate anxiety associated with post injury driving and confirmed driving difficulties previously reported in the literature [9, 10]. Specific difficulties noted by participants were shoulder checking, merging, and driving for long periods. Inexpensive vehicle modifications, such as additional mirrors, should be considered

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SECTION 1 – INTRODUCTION

1.1 Project Background

This study was undertaken to establish whether drivers who have experienced a traffic crash resulting in a Whiplash Associated Disorder (WAD) are at elevated risk of a subsequent traffic crash.

1.2 Project Objectives

The objectives of this injury prevention project were to:

- Assess subsequent crash and injury risks of drivers with WAD compared to crash records of matched non-WAD drivers.

- Characterise circumstances and crash type of drivers with WAD.

- Assess the driving patterns and on-road exposure of drivers with WAD.

1.3 Factors influencing progress of proposed research

The completion of this project was delayed due to difficulties obtaining relevant and adequately sized samples for both phases of the project.

At the time of initial grant submission, communications among stakeholders indicated that data regarding insured drivers would be available from IAG/NRMA Insurance. The data sought related to persons who had experienced a traffic crash in 2000 resulting in a WAD condition, either as the injury, or as the most serious injury, and a control group from the same insurance cohort who had no injury or a minor injury. After extensive time lapse and negotiations it became evident that the data was unavailable for research and we were advised to seek the information required for the first phase of the research from the Queensland third party insurer, Motor Accident Insurance Commission, and additionally the Queensland Transport Department. The Trust were advised and approved of this change, but there was considerable additional delay related to obtaining the relevant ethics clearances from QUT and the involved institutions. The modifications also meant that Professor Rakotonirainy who had expected to take responsibility for the direction and management of the extraction and data linking involved in the NSW data approach became less closely involved in the project. In the new arrangements these tasks were undertaken by the data analysts at MAIC and Queensland Transport. Professor Siskind assumed principal responsibility for the conduct of the study.

In the second phase of the research, collection of survey information required for the measurement of post injury driving exposure was also delayed. The first source through which respondents were sought was physiotherapy clinics linked as research associates with the University of Queensland Physiotherapy Department. This source lead to very few responses, hence a variety of alternative sampling techniques were attempted. Following substantial effort in this regard, a reasonable sample was recruited with the assistance of the RACQ.

1.4 STRUCTURE OF THE REPORT

This report is in four sections. The first includes an extensive literature review related to whiplash associated disorders and potential driving safety risk factors. The second section reports on Phase 1 of the research, concerned with crash rate among vehicle controllers subsequent to whiplash or other soft tissue injury. The third section is concerned with investigating driver exposure of vehicle controllers subsequent to a whiplash of other soft tissue injury, and self-reported reasons for change. The fourth section summarizes the findings and gives recommendations for future research.

1.5 WHIPLASH AND DRIVER SAFETY

Concern has been raised in recent years about the potential for adverse effects on vehicle controllers of conditions other than impairment by alcohol or illicit drugs. One such condition is whiplash, formally whiplash associated disorder (WAD), the most common soft tissue injury incurred in motor vehicle crashes by vehicle occupants. While a few studies, described below, have investigated the relative road safety impacts of various medical and musculoskeletal conditions, little is known specifically about the role of WAD. The current study aims to determine whether drivers who suffered a WAD as a result of a road crash are at increased risk of further crash involvement because of the impact of the WAD on their driving skills.

Phase 1 of the study investigated crash involvement subsequent to a crash in which a compensable injury was incurred. Using data and records held by the Queensland Motor Accident Insurance Commission (MAIC) and Queensland Transport Crash Database (QTCD), two samples of drivers were compared: (1) persons who had suffered a WAD; (2) persons with a soft tissue injury of equivalent severity. Alterations to driving exposure following these injuries could be a potential confound. Phase 2, therefore, compared changes in driving exposure in the two groups using survey data obtained from a second sample of injured drivers.

1.6 BACKGROUND

There is a growing international research literature concerning the effects of medical conditions on driving and traffic safety. Several reviews of this literature have been conducted [1, 2, 3, 5]. Musculoskeletal conditions are a class of medical condition considered in most such reviews. To date, however, these do not appear specifically to include Whiplash Associated Disorder (WAD). This is surprising as litigation and insurance data consistently indicate that WAD is prevalent, being the most common injury outcome of motor vehicle collision by a substantial margin [12, 13, 19, 32, 38, 53]. The incidence of WAD is likely to be at least 300 per 100 000 in many Western countries and shows a consistent rising trend [15, 16, 32].

Whiplash is the characteristic mechanism of hyperflexion-hyperextension of the cervical spine typically induced by a rear impact motor vehicle collision. Acceleration of the head can exceed 8G at speeds as low as 8 km per hour [14]. The resulting injuries to soft-tissue associated with the cervical spine together with a range of related sequelae are termed Whiplash Associated Disorder (WAD) [17]. Symptoms of WAD can include pain, restriction of movement, poor balance and coordination, reduced concentration, and visual disturbance [18, 22, 25, 27, 30, 38]. For about half of those suffering a whiplash injury, symptoms will resolve within the first three months. For the remainder, however, the course is likely to be chronic, with little if any symptom improvement for a number of years or indefinitely [6, 21, 23, 24, 28, 30, 32, 33].

The Australian manual for assessing fitness to drive specifies that "persons with severe neck pain and **very reduced** mobility including that arising from wearing soft collars or braces should be advised not to drive for the duration of their treatment" (4 pg. 68.) though no supporting research studies are cited [4]. There are a number of studies examining the effectiveness of varying physical therapies and/or psychological interventions that aim to reduce the negative impacts and duration of impairment as an outcome of the condition [6, 7, 8]. Little primary research, however, has investigated the impact of WAD on driving skills [for exceptions see 9, 10, 11] and to our knowledge no reported research has directly investigated crash risk. In order to devise methods aimed at reducing the frequency of crashes involving drivers with previous WAD, the extent of the problem, if any, needs to be ascertained.

In 1995 a Canadian provincial government insurer commissioned the Quebec Task Force on Whiplash-Associated Disorders, a multidisciplinary expert panel, to provide a synthesis of extant literature regarding whiplash injuries. They established the classification system for WAD severity, shown in Table 1 [17]. Hartling and Colleagues have suggested that the grade II category be subdivided into those who initially present with point tenderness only, and those who also present with a decreased range of movement [39]. They contend that this distinction has substantial prognostic value regarding progression to chronicity. Grades 0 and IV are now normally excluded from consideration as the former is signified by the lack of symptoms whilst the latter goes beyond soft-tissue injury [21, 33, 35].

Table1

The Québec Classification of WAD severity [17]

Grade	Symptoms
0	No complaint about the neck; no physical signs.
I	Neck complaint–pain, stiffness, or tenderness only.
II	Neck complaint AND musculoskeletal signs. Musculoskeletal signs include decreased range of motion and point tenderness.
III	Neck complaint AND neurological signs. Neurologic signs include decreased or absent deep tendon reflexes, weakness, and sensory deficits.

IV	Neck complaint AND fracture or dislocation.

1.7 Symptoms

1.7.1 Symptoms - Pain

As implied by the Quebec grading system, neck pain or stiffness is almost always associated with WAD [19, 21, 34]. The severity of pain on initial presentation has consistently been found to be the most reliable indicator of prognosis, with more pain being associated with greater number, duration and severity of symptoms [23, 26, 28, 29, 36]. In many cases, pain is also experienced at sites other than the neck, the most frequent being head, shoulders and arms [18, 37]. Temporomandibular joint pain is also sometime experienced [27]. Pain hinders movement and hence impacts upon both daily living tasks and physical rehabilitation activities such as exercise and manual therapies [22]. Chronic pain also impacts substantially on well-being and quality of life in general [22, 31].

1.7.2 Symptoms – Movement, Perception and Coordination

Symptoms of chronic WAD can also include somatosensory and coordination disturbance [40, 25], neck movement deficits [22], and cognitive deficits [18]. Somatosensory symptoms include poor static and dynamic balance with increased trunk sway [33, 41, 42, 43, 44], dizziness [40], poor coordination of eye and hand movements [25], and sensory disturbances such as blurred vision, tinnitus, and paraesthesia [40, 14, 27, 45, 30]. Neck control and movement symptoms include reduced range of movement, reduced acceleration and speed of movement, and weakness [41, 46, 47].

1.7.3 Symptoms – Psychological Distress

Studies concur that symptoms of depression, anxiety and PTSD as well as fear, fatigue and irritability are associated with WAD. Such negative affective conditions are also prognostic of chronic and poorer outcomes with respect to both pain and disability [19, 31, 36, 37, 51, 52]. Regarding cognitive symptoms, reduced concentration and memory are often reported, however studies employing objective neuropsychological tests rather than self-report data have found this not to be the case [49, 50]. Guez et al. concluded that “the subjective complaints and poor performance in patients with chronic neck pain may be associated with somatisation and inadequate coping, especially in chronic whiplash patients” [50, pg 151]. Similarly Robinson et al. concluded that “reports of memory or concentration problems appear to be indicators of heightened somatic vigilance rather than indicators of actual neuropsychologic deficits” [49, pg.774]. In summary, typical psychological sequelae of WAD are better characterised as psychological distress, rather than decreases in cognitive abilities per se.

1.8 Causes

1.8.1 Causes - Physiological Mechanisms

There has been substantial conjecture regarding the aetiology of WAD, largely stemming from the fact that, until recently, physical lesions seemed elusive [23, 24]. Advances in imaging technologies, however, have facilitated the identification of morphological changes at a finer level [23, 58, 59, 60, 61]. These include damage to the facet joint capsule [63], inflammation of deep cervical musculature [58], and the presence of fatty infiltrates [23, 61]. At the macro level, changes to the alignment of neck, head and shoulders have been demonstrated [25, 40, 64]. Further, damage to the facet (zygapophysial) joints and surrounding tissue is consistent with bio-mechanical studies [63, 69]. Some characteristics predispose individuals to developing a chronic WAD condition following a crash. McLean et al. have identified genetic variations associated with a greater pain, dizziness, psychological symptoms and recovery time in acute WAD. This genotype is known to be associated with greater pain sensitivity, vulnerability to chronic pain and greater activation of both the sympathetic nervous system and endocrine stress response [70].

1.8.2 Causes - Biopsychosocial Models

Whilst, biomechanical and physiological mechanisms are becoming more apparent, it is clear that there is a complex interaction between physiological, psychological and social processes, such as that depicted in models presented by McLean, Clauw, Abelson and Liberzon [67], and Buitenhuis and de Jong [68]. In these models WAD is initiated by a motor vehicle crash. The course may then take one of two paths, moderated to some extent by the nature of the individual's stress response: recovery within the first few months; or a chronic course with little resolution of symptoms in the short or medium term. A maladaptive stress reaction in response to the initial MVC and associated pain makes the transition to chronicity more likely, as the response becomes self-perpetuating rather than self-limiting. Such a response is characterised by psychological distress such as fear and anxiety [79, 80, 81]. Factors likely to give rise to such a response include pre-existing negative affectivity [36], illness beliefs that are threatening [18, 68, 51], catastrophizing [82, 83], an external locus of control [84], and genetic influences [70]. The resulting anxiety gives rise to kinesiophobia, avoidance of usual activities and hypervigilance [26, 68, 85]. This it turn causes muscle tension and central sensitization, thus exacerbating the pain experience. WAD, therefore, may be maintained by positive feedback involving interrelated neurological, psychological and physiological systems. This biopsychosocial description is congruent with the conceptualisation of chronic WAD as a central sensitisation syndrome as described in the following section [37].

Nijs et al. reported that several personality traits were associated with worse outcomes on a range of mental health and well-being measures. Importantly, however, no dimension of personality correlated significantly with total Neck Disability index (NDI) scores [37]. Similarly mixed or ambiguous results have been reported in other studies regarding personality and chronic WAD. As is the case with depression, a challenge is that psychological factors (in this case personality dimensions) are typically measured subsequent to the development of WAD. A notable exception reported by Mykletun et al. [36] evaluated data from the Norwegian Nord-Trøndelag Health Study (HUNT). In this longitudinal cohort study anxiety-depression symptoms were measured at two time points: initially in the period 1984-1986 (HUNT-1), and subsequently 11 years later (HUNT-2). Baseline caseness, defined as a HUNT-1 anxiety-depression score above the 80th percentile, was associated with an increased risk of WAD *subsequent* WAD, that is, incident WAD in the intervening 11 year period (OR = 1.60) [36].

1.8.3 Causes – Central Sensitization

The theory that central sensitization contributes to the maintenance of chronic WAD now has substantial support [18]. Other conditions thought to be central sensitization syndromes include chronic lower back pain, chronic fatigue syndrome, fibromyalgia and temporomandibular joint disorders [72]. In such conditions, responses of the central nervous system to initial physical injury or other noxious stimuli give rise to long lasting hypersensitivity to pain [80, 48]. Increased pain perception can include greater pain associated with normally painful stimuli (hyperalgesia) [29, 35, 48, 69, 80] and experience of pain at sites other than that of the original injury [18, 30, 86]. Such hypersensitivity is due to plastic changes in nociceptive pathways of the central nervous system, including increase in synaptic transmission and the recruitment of other afferent pathways to nociception [87]. Changes in brain activity can also be observed [88]. Two common types of hypersensitivity are pressure hyperalgesia and cold hyperalgesia. In a study conducted by Jull, Sterling, Kenardy and Beller 72.5% of participants with chronic grade II WAD exhibited either mechanical or cold hyperalgesia or both, indicating pathologic alterations to sensory processing [71]. Other recent studies have reported similar findings, for example, in one recent study a cold pain threshold of 13°C or more, vastly increased the probability of a chronic and severe trajectory (OR = 26.3) [29].

1.9 Driving Difficulties

Chronic WAD is associated with particular difficulties when driving. Two recent studies, one employing a semi-structured interview and the other employing a range of well known measures, have found that checking blind spots, reversing/reverse parking and prolonged driving were particularly troublesome [9, 10]. Following these, changing/merging lanes and driving in heavy traffic were also often nominated. Perceived driving difficulty was strongly related to pain and psychological distress but not objective measures of neck function. These studies also reported that drivers with WAD did not reduce their driving exposure, in spite of being more anxious and cautious whilst driving. Due to these findings it was suggested vehicle modifications such as “additional mirrors, automatic transmission, or power steering” be considered [9].

1.10 Comparison Groups

1.10.1 Comparison Groups – Older drivers

Other populations also have difficulties with some driving tasks. One comparison group of interest, often incorrectly assumed to have a higher than average crash risk, is older drivers. A range of sensorimotor functions are known to decline with age, including visual acuity, visual processing speed, balance, proprioception, coordination and strength [75]. Ostensibly, therefore, there are similarities between older drivers and those with chronic WAD. It has been found that older drivers often perform poorly in traffic and whilst merging due to inadequate shoulder checks and poor gap selection [74, 75].

At the time of Vaa's review and meta-analysis, the risk of crash per kilometre driven for those aged 75 and above was believed to be of the order of four times greater than those in the 45-54 age group [2]. Langford and colleagues, however, demonstrated that this apparent increased risk could be entirely accounted for by the low mileage bias [76]. Irrespective of age, drivers who drove less than 3000km/year had a crash risk of the order of 6 times greater than those who drove at least 14 000 km/year [76, 77]. Similarly, Alvarez and Fierro [77] investigated the crash risk of a cohort of 4316 drivers presenting at Medical Driving Test Centres in Spain. From results of this study it can be calculated that the drivers in the ≤ 75 age group had a lower than average risk of being involved in a crash (RR = 0.83), and at most a marginally higher risk compared to the safest age group of 31-64 (RR = 1.05). The example of older drivers, therefore, strongly demonstrates the need to interpret crash rate data for specific groups in the light of exposure data. Mendez and Izauirerdo comment that "the lack of appropriate data on exposure is one of the greatest problems that road safety analyses have faced so far" [78].

1.10.2 Comparison Groups – Psychological Distress

Depression [2, 55], anxiety [55] and the general psychological distress associated with musculoskeletal disorders [54] have all been found to be associated with a higher crash risk in other populations, although this evidence is not consistent [73]. A study involving 4448 crash involved drivers with a wide age range determined the odds of being at-fault associated with a range of medical conditions [55]. Anxiety and depression were both substantially associated with a greater relative risk compared to the not-at-fault drivers being 1.30 and 1.84 respectively. When adjusted for age and driving distance, these ratios increased to 3.15 and 2.43 respectively. In contrast, for arthritis and a range of other musculoskeletal conditions there was no significant increase in relative risk. Similarly Vaa calculated the relative risk of crash involvement for a range of conditions compared to those without the condition [2]. This analysis yielded an odds ratio of 1.67 for depression/depressive symptoms, compared to a modest 1.17 for arthritis/locomotor disability. In another well powered study (n = 4935), Mann et al. reported that the odds of crash involvement increased by 5% for every point on an 18 point depression-anxiety scale derived by factor analysis of the GHQ-12 [56]. Finally, a recent study of older drivers in New Zealand (54) found that the level of distress related to medical conditions such as arthritis, was significantly associated with crash risk, whereas the medical conditions themselves were not [54]. Existing studies, however, typically employ retrospective designs with affective symptoms measured in the present used to predict previous crashes. Results should, therefore, be interpreted with caution as there is no doubt that crashes give rise to psychological distress [56, 57]. In summary, whilst it appears that psychological distress is associated with increased crash risk, further prospective research is required to determine causal direction.

1.10.3 Comparison Groups – Musculoskeletal conditions

Musculoskeletal conditions are germane to the present study. In Vaa's 2003 review, the relative risk of crash for people with arthritis or locomotor disability was reported as 1.17, not much above the average crash risk for the population [2]. Vernon et al. [62] reported a relative crash risk of 1.33 for drivers with an unrestricted licence and reporting only one medical condition in comparison to drivers matched on a range of variables with no medical condition. This research also found a relative crash risk of 1.11 for "functional motor impairment" defined as "history of impaired functional motor ability including difficulties with muscular strength, coordination, range and motion, spinal movement and stability, amputations or the absence of body parts and/or abnormalities affecting motor control." The relative risk of at fault crash, however, was higher (RR = 1.71). Henrikson [65] investigated crash risk for 793 people who drove a car adapted for a disability. Three quarters of these drivers used a wheelchair for mobility when not driving, with 7% also driving from the wheelchair. Despite this being a well-powered study, there was no significant difference between crash risk for these drivers with a disability and the general population. Taken together, extant research suggests the possibility of a modest increase in crash risk for drivers with chronic WAD.

SECTION 2 – CRASH RATE

Phase 1 investigated crash rate among vehicle controllers subsequent to a whiplash or other soft tissue injury.

2.1 METHODS

We requested and received a file generated by the Motor Accident Insurance Commission (MAIC) with additional data from the Queensland Transport Crash Database (QTCD). These files contained records of persons who had made claims to MAIC in 2003 for a whiplash associated disorder (WAD) or another level 1 soft tissue injury incurred in a traffic crash (the "index" crash) as driver, motorcyclist, pedal cyclist, passenger or pedestrian. Each record consisted of the month and year, but, for confidentiality reasons, not the day, of the crash for which a claim was made; the nature of the injury (whiplash, other); gender and age of claimant; road user type (driver, passenger , etc) of claimant in the incident resulting in the injury; and information, supplied by the QTCD, on crashes within the 5 years prior to the index crash, the index crash where identified and all crashes subsequent to the index crash which had been reported to the QTCD. This information included month, year and nature and severity of crash. Claimants with WAD are referred to as "cases", those with other soft tissue injuries as "controls".

Since driving licences were not available to persons under 17 years of age in Queensland, the analyses have been confined to persons who were aged at least 17 years at the date of the index crash. There were 4280 cases and 1116 controls in the data set meeting this criterion.

Initial discussions indicated that similar files would be available from the corresponding bodies in New South Wales, however the researchers were not able to obtain this data.

2.1.1 Data Editing

Not all persons in the file with index crash dates supplied by MAIC had their index crashes identified by the QTCD, particularly for road users who were not motor vehicle controllers (i.e. drivers or motorcyclists). Where the index crash could not be identified in the QTCD data, it could erroneously be taken to be a prior or subsequent crash in the analysis, leading to misclassification error. Among claimants with no index crash identified in QTCD data, 46 (0.9%), almost all vehicle controllers, had a non-index crash in the same month and year as the claim crash. Of these 40 had no index crash identified in the QTCD, and 6 had both an index and non-index crash in the same month. On the basis of the proportion of claimants with index crashes identified in the QTCD among all claimants, 33 of the 46 would be expected to have an index crash identified, whereas, as mentioned above, there were only 6 such.

The Queensland Transport Crash Database kindly re-examined the records of the 40 claimants described above and noted that 27 had an apparently non-index crash date within two days of the claim crash. Since it is our experience that discrepancies of a few days between two or more routine files in the dates of the same event are common, we have accepted these crashes as an index crash and created a second, revised, file on this basis. Main results will be presented using the revised file, but similar analyses will also be carried out on the original file; any noteworthy discrepancies will be reported.

For brevity, motor vehicle controllers will be termed in what follows as drivers, unless motorcycling is specifically considered.

2.1.2 Data analysis

All analyses made use of failure-time models; the outcome variable was the number of months between the date of the index crash and the date of the first subsequent crash, if any, or to the end of follow-up if none. Univariate analyses used Kaplan-Meier curves to estimate three-year crash incidences and log-rank chi square statistics to test difference in incidence between study factors. Multivariate analyses used conventional Cox proportional hazards modelling. Analytic models included WAD status and factors found to have a significant univariate association with time to first subsequent crash, which is a proxy for likelihood of having a subsequent reported crash within the observation period. When the analysis is confined to claimants who were motor vehicle controllers at index crash, motorcycle riding is included since it is strongly associated with WAD status at claim: 16.2% of control drivers were motorcyclists compared to only 1.6% of case drivers. The outcome measure for this analysis is the hazard ratio (HR) which is an estimate of the rate ratio, the ratio of the crash rate among the WAD sufferers to that among claimants with other soft tissue injuries.

All models included the variables, WAD status, the reference category being other soft tissue injury at claim; prior crashes within the past 5 years (coded as none, the reference category, one, more than one); and age (< 35 years, the reference category, 35 – 54 years, ʀ 55 years). Six models were examined:

(1) Males and (2) female drivers separately; the variable, motorcycle use, was included in these models.

(3) All males and (4) all females separately; the variable, driver, which encompassed also motorcyclist, was included.

(5) All drivers; here the additional variables were motorcycle use and gender, the reference categories being car or truck drivers and males respectively.

(6) Entire sample; the additional variables here were driver and gender.

2.2 RESULTS

2.2.1 Sample characteristics

There were 4495 cases and 1307 controls of whom 4280 cases (95%) and 1116 (85%) were at least 17 years of age at the date of their index crash. Only the persons aged at least 17 years are considered in subsequent analyses. Time in study from claim date on, ranged from 2.5 to 3.4 years, mean 3.0 years.

Females formed over 60% of the WAD group, but under half in the control group (Table 2). Among cases almost three quarters were drivers, whereas this type of road user comprised well under half of controls. The next largest type in both groups was passengers, somewhat under one quarter in cases, somewhat over in controls. Pedestrians, cyclists and other miscellaneous types of road users formed together 21% of the control group, but only 2.3% of cases (Table 2).

Table 2

Gender and road user type distributions by WAD status

Factor		Cases		Controls	
		N	%	N	%
Gender:	Males	1653	38.6	590	52.9
	Females	2624	61.3	526	47.1
	Not stated	3	0.1	0	0.0
Road user type:	Car/truck drivers	3803	72.0	477	42.7
	Motorcyclists	50	1.2	92	8.2
	Passengers	1050	24.5	313	28.1
	Pedestrians	43	1.0	134	12.0
	Cyclists	25	0.6	52	4.7
	Others	29	0.7	48	4.3
Total		4280	100.0	1116	100.0

Among drivers, index crashes were identified for 75.4% of cases, 74.0% of controls in the original file. In the revised file the percentages rise to 76.1% and 74.5% respectively. Among other road users only about 1% in both groups and in both files had identified index crashes.

Age was taken to be that stated at claim. In the sample as a whole the age distributions differed comparatively little between cases and controls (Table 3). The same was true for drivers, but among non-drivers the cases were approximately three years younger on average than controls (data not shown).

Summary statistics relating to crashes prior and subsequent to claim date are given for the entire sample in Table 4, from the revised file. The analogous figures from the original file are only trivially different. Cases had on average slightly more crashes recorded than controls both prior and subsequent to the crash leading to their MAIC claim.

Table 3

Age distributions by WAD status and gender

Age (yrs)	Cases (%)			Controls (%)		
	Males	Females	Total	Males	Females	Total
17 - 24	392 (23.7)	654 (24.9)	1046 (24.5)	138 (23.4)	131 (24.9)	269 (24.1)
25 – 34	437 (26.4)	727 (27.7)	1164 (27.2)	162 (27.5)	132 (25.1)	294 (26.3)
35 – 44	366 (22.1)	580 (22.1)	946 (22.1)	109 (18.5)	82 (15.6)	191 (17.1)
45 – 54	240 (14.5)	393 (15.0)	633 (14.8)	94 (15.9)	74 (14.1)	168 (15.1)
55 – 64	146 (8.8)	188 (7.2)	334 (7.8)	46 (7.8)	56 (10.6)	102 (9.1)
ʀ 65	72 (4.4)	82 (3.1)	154 (3.6)	41 (6.9)	51 (9.7)	92 (8.2)
Mean	36.9	35.8	36.2	37.7	38.8	38.2
Median	34.0	33.0	34.0	34.0	34.5	34.0

Table 4

Average numbers of crashes prior and subsequent to claim date (i.e., non-index crashes)

		Total	Average	Prior	Average	Subsequent	Average	ʀ 1 crash (%)
All Road Users:	Cases	758	0.18	421	0.10	337	0.08	638 (14.9)
	Controls	170	0.16	94	0.09	76	0.07	140 (12.5)
Drivers only:	Cases	602	0.19	326	0.10	276	0.90	502 (16.0)
	Controls	100	0.18	54	0.09	46	0.80	85 (14.9)

2.2.2 Analytic results

Results of the univariate failure-time analysis by individual factors, with p-values derived from the log-rank test for differences between levels of the factor are presented in Table 5, together with an estimated subsequent crash incidence rate within 3 years for each level of the factor. On this basis it appears that the persons with WAD had somewhat higher subsequent crash rates than persons with other soft-tissue injuries, particularly among females, although not significantly so. As expected, males had a significantly greater propensity to crash than females. Drivers at index crash have higher rates than non-drivers, as do those with a prior crash compared to those without. Overall age is significantly associated with subsequent crash rates, the highest rates being among those under 35 years of age in both case and control groups. However among cases there is little difference between those under 35 years and those between 35 and 54 years of age, whereas among controls those aged 35 years and over have noticeably lower rates.

Whether or not an individual had a claim crash identified in Queensland Transport records was also associated with time to subsequent crash, but since those who did were overwhelmingly drivers (> 99%), this factor had no independent effect.

Table 5

Results of the univariate failure-time analysis by individual factors

(a) Three year crash incidence by injury group.

	3 year crash incidence (%) (s.e.)		*N*	χ^2	*d.f.*	*p*
	Cases	Controls				
All	7.3 (0.4)	6.3 (0.8)	5396	1.30	1	0.26
Males	9.2 (0.7)	7.7 (1.2)	2243	0.55	1	0.46
Females	6.1 (0.5)	4.7 (1.0)	3150	2.58	1	0.11

(b) Three year crash incidence by gender.

	3 year crash incidence (%) (s.e.)		*N*	χ^2	*d.f.*	*p*
	Males	Females				
All	8.8 (0.6)	5.9 (0.4)	5393	17.35	1	< 0.001
Cases	9.2 (0.7)	6.0 (0.5)	4277	12.79	1	< 0.001
Controls	7.7 (1.2)	4.7 (1.0)	1116	6.42	1	0.011

(c) Three year crash incidence by road user type.

	3 year crash incidence (%) (s.e.)		*N*	χ^2	*d.f.*	*p*
	Drivers	Other				
All	8.0 (0.5)	5.3 (0.6)	5396	14.09	1	< 0.001
Cases	8.0 (0.5)	5.4 (0.7)	4280	10.13	1	0.002
Controls	7.6 (1.2)	4.8 (1.0)	1116	3.08	1	0.08

(d) Three year crash incidence by prior crash.

	3 year crash incidence (%) (s.e.)		*N*	χ^2	*d.f.*	*p*
	None	≥ 1				
All	6.6 (0.4)	13.0 (1.6)	5396	24.83	1	< 0.001
Cases	6.7 (0.4)	13.4 (1.8)	4280	20.77	1	< 0.001
Controls	6.1 (0.8)	11.3 (4.0)	1116	3.77	1	0.052

(e) Three year crash incidence by age group.

	3 year crash incidence (%) (s.e.)			*N*	χ^2	*d.f.*	*p*
	17 - 34	35 - 54	≥ 55				
All	7.8 (0.5)	7.0 (0.6)	4.9 (0.9)	5396	7.56	2	0.023

Cases	7.8 (0.6)	7.5 (0.7)	5.0 (1.0)	4280	5.53	2	0.063
Controls	8.0 (1.2)	4.8 (1.3)	5.5 (2.1)	1116	3.40	2	0.182

2.2.3 Multivariate analysis

As reported above, this used conventional Cox proportional hazards modelling, the included variables being WAD status – of primary interest – plus prior crash history, gender, age and road user type or motorcycle use, as appropriate, at claim.

Hazard ratios for WAD claimants versus claimants with other soft tissue injuries derived from the six models are set out in Table 6. These ratios ranged from 1.11 in all males and in female drivers to 1.36 in male drivers. For the entire sample, the hazard ratio adjusted for all other factors was 1.14, with 95% confidence interval 0.87 – 1.48, and hence not significantly different from parity.

Table 6

Hazard ratios with 95% confidence intervals (95% CI) for WAD status derived from Cox proportional hazard models.

Model composition	Hazard Ratio	95% CI
Male drivers	1.36	0.86 – 2.13
Female drivers	1.11	0.64 – 1.92
All Males	1.11	0.79 – 1.55
All Females	1.18	0.76 – 1.84
All Drivers	1.25	0.88 – 1.78
Entire Sample	1.14	0.87 – 1.48

2.3 Discussion

Despite the apparently large numbers of persons in our sample, the effective sample size is in reality modest, since there were only 375 individuals with a subsequent crash, 307 in the WAD group and 68 in the Other group. This is reflected in the widths of the confidence intervals round the point estimates of relative risk, and implies that although no significant differences between WAD affected drivers and those with other soft tissue injuries were found, a definitive answer to the question of the relative safety of drivers with whiplash cannot be given. That lack of certainty is inherent in all observational research such as this. However large differences in relative safety are unlikely. It is to be hoped that other researchers with larger samples will undertake the further studies needed.

There is also an implicit assumption that the Other Injury drivers group is an adequate proxy for uninjured drivers in terms of driving safety. This issue has been discussed in earlier sections of this report.

As a consequence of the limited sample size, we were unable to classify the subsequent crashes by severity. Restricting the crashes to those in which an injury occurred would have reduced statistical power too much. However overall there was little difference between the comparison groups in distribution of injury severity.

This result needs to be set in the context of the possible changes in exposure, that is, the amount of driving done by cases and control before the index crash compared to the amount driven thereafter. To establish this we have conducted a survey of injured drivers using a questionnaire and distribution methods to be described in the following section.

SECTION 3 - EXPOSURE

Phase 2 investigated driving *exposure* of vehicle controllers *subsequent to a whiplash or other soft tissue injury.*

The first phase of the study examined driving experiences of drivers with WAD, subsequent to the crash in which the initial injury was incurred. These drivers were compared to those involved in an initial crash where they sustained non-WAD soft tissue injuries of comparable severity as judged by the MAIC. After adjustment for other crash predictors, there was little difference in crash rates between the WAD and non-WAD groups. The second phase of the study aimed to place these results in context by determining whether drivers in these groups modified their subsequent driving intensity to the same extent, that is, to see whether their exposure to traffic after injury differed.

3.1 METHODS

A questionnaire was designed to capture the essential information on driving both prior and subsequent to the crash where the participant was injured. Before launch, it was thoroughly piloted and revised. Items addressed: gender; current age; year and month of index crash; part(s) of the body injured; the nature of these injuries; the effect of the injury or injuries on daily activities; the number of kilometres driven per year before injury; and the relative change in the amount driven at one, three and six months after injury. Respondents were also invited to give reasons for these changes in their own words. To encourage participation, the questionnaire was designed to require no more that 7 minutes to complete. Also, no restrictions were placed on injury type, as ineligible respondents could be identified during editing. The gender item was inadvertently omitted on some questionnaires. A copy of the questionnaire is appended.

Initially, paper questionnaires were distributed to 26 physiotherapy clinics recruited via the School of Physiotherapy at the University of Queensland. These were displayed to clients at the reception desk. A payment of $5 per returned questionnaire was offered to clinics to cover administrative costs associated with collection and return. Initial response was disappointing, with 31 questionnaires being returned. To recruit additional participants an on-line version of the survey was implemented. An invitation to participate and link to the questionnaire was published in the electronic newsletter of the Royal Automobile Club of Queensland (RACQ) on two occasions. This elicited a larger response.

3.2 RESULTS

Usable questionnaires were identified from 229 participants. Of these, 63 had fractures or dislocations, and hence were not included in analyses. The remaining 166 participants consisted of 113 in the WAD group and 53 in the non-WAD group. The non-WAD group forms the control series to which the WAD group will be compared. Information on gender was missing for 66 individuals (39.8%). For participants for whom gender was recorded, the proportion of females was 69.2% and 60.0% for WAD and non-WAD groups respectively.

Mean and median ages, self-reported distances driven before the index crash and reported percentage changes in amount driven after the index crash are given in Table 7. Control drivers are on average older than drivers with WAD, but average differences driven are very similar in the two groups. At one, three and six months post crash, mean percentage changes are also similar, and no differences approach significance after analysis by the Wilcoxon non-parametric two-sample test. Age in these samples is unrelated to the other variables so we conclude that it did not affect comparisons. Adjustment by linear regression for age, gender or prior distance driven made very little difference to these results.

Table 7

Age, prior distance travelled and changes to driving exposure after index crash in cases and controls

	WAD			Other soft tissue injuries			Wilcoxon	p
	N	Mean	Median	N	Mean	Median	$\chi2$ (1 df)	
Age	112	39.8	38.5	51	46.5	47	7.08	0.008
Prior kilometres driven	113	17898	12500	53	17405	12500	0.25	0.61
% age change at 1 month	111	-35.7	-30	52	-33.3	-15	0.37	0.54
% age change at 3 months	102	-18.0	0	46	-14.6	0	0.56	0.45
% age change at 6 months	92	-11.2	0	44	-10.5	0	0.51	0.47

The samples are, however, relatively small, and the 95% confidence intervals for the differences in percentage change in kilometres driven are correspondingly wide, being -17.7 to 13.0, -18.1 to 11.1 and -14.5 to 13.0 at one, three and six months, respectively. In each instance 0 km (corresponding to no difference between groups) is close to the centre of these ranges, hence there was no significant difference in the extent to which case and control groups curtailed their driving. We tentatively conclude that, on average, for drivers injured in a traffic crash, driving exposure is similar irrespective of whether the injury is WAD or another soft-tissue injury.

Reasons for changes in driving exposure were also examined. Of the 110 participants who responded to the open-ended question "if you changed the amount you drove, why," 79 were in the WAD group. In 14 cases, however, the response concerned damage to their vehicle or changes to personal circumstances (e.g., employment status), or did not nominate specific reasons, leaving 65 interpretable responses. The strongest and most consistent theme was anxiety or fear, nominated in approximately 70% of interpretable cases. Associated with this, some participants also specifically noted decreased confidence when driving. One participant simply stated "It hurt and I was scared it might happen again." Restricted movement and pain were also common themes, although nominated to a substantially lesser extent than anxiety. It is of interest that two participants increased their driving, as they felt anxious being a passenger. Several participants noted that, due to the exigencies of daily life, it was not feasible to change their exposure.

Whilst the question did not specifically address difficult driving tasks, the most commonly nominated difficult task was shoulder checking when merging. This was often explicitly linked to restricted movement, especially restricted neck movement. In this regard, shoulder checking was more of a concern than other tasks affected by restricted movement (e.g. reversing) due to the potential for serious traffic crash. A representative quote was "restricted movement due to the injury prevented me from being able to turn and see traffic on the road around me." Several participants also nominated driving for long periods as difficult. Another theme that emerged in spite of not being specifically sought was that of increased caution and vigilance for potential hazards. One participant commented that they were "much more careful of other vehicles on the road, increasing distance between vehicles, slightly anxious, especially on the motorway."

There were 20 relevant and interpretable responses among the control group. In this group, anxiety, pain and increased caution were nominated to a similar extent to the WAD group. In contrast, restricted movement, shoulder checking and driving for long periods were not nominated, supporting the suggestion that these tasks are particularly troublesome for people with WAD.

SECTION 4 – GENERAL DISCUSSION

This is the first study specifically to address the crash risk associated with pre-existing whiplash injury. Crash risk and exposure of drivers subsequent to a crash in which they sustained a soft-tissue injury was investigated. Drivers with WAD were compared to those with other soft-tissue injuries. Results indicated that there is little or no difference in crash risk between WAD and non-WAD groups. Results also indicated that, on average, these groups reduce their driving to a similar degree.

4.1 Crash Risk

This study adds to the literature regarding crash risk and medical conditions, indicating that the crash risk associated with a range of musculoskeletal conditions is not substantially elevated [2, 3, 5]. Hoggarth et al. recently found that whilst musculoskeletal conditions were not associated with a significant increase in crash risk, the psychological distress associated with the conditions was [54]. Henrikson investigated crash risk for 793 people who drive a car adapted for a disability [65]. Three quarters of these drivers used a wheelchair for mobility when not driving, with 7% also driving from the wheelchair. Despite this being a well-powered study, there was no significant difference between crash risk for these drivers with a disability and the general population. The Henrikson study is of particular interest as physical musculoskeletal disabilities could be studied without substantial confounding by multiple medical conditions, sensory deficits and cognitive deficits which may occur in studies of older drivers or degenerative conditions.

4.2 Exposure

Drivers who drive lower distances tend to have higher crash involvement on a per kilometre basis (low mileage bias) hence data should be considered in the context of exposure data [66]. Whist drivers in this study reduced their distance driven by one third (WAD 35.7%, non-WAD 33.3%) at one month following injury in a crash, this had reduced to approximately one tenth by the sixth month (WAD 11.2%, non-WAD 10.5%). The recent study by Takasaki et al. also indicated that drivers with WAD do not substantially curtail their driving, although an interesting finding was that those who did not believe their driving ability had diminished drove less than those who did. Nevertheless the average distance driven per year for the entire sample was 14 164 km which is very similar to the national average [89]. This supports the finding of the present study that, as a group, drivers with chronic WAD do not substantially reduce their exposure in the longer term. A corollary is that data pertaining to this group are unlikely to be substantially affected by the low mileage bias.

4.3 Psychological Distress

The issue of psychological distress associated with WAD presents an enigma. Previous studies have indicated that psychological distress is associated with increased crash risk. Many of these studies, however, were retrospective, measuring the risk of previous crash in relation to present psychological distress. In contrast, a prospective study of a large cohort of young Australian drivers found a reduced crash risk for those with moderate distress [20]. It was suggested that moderate anxiety may give rise to increased vigilance and concern regarding traffic safety. Qualitative data provided by participants in phase 2 of the present study, clearly indicate such anxiety. This is understandable as people injured in a traffic crash have reason to fear further crashes. More broadly, the need for prospective cohort studies is underscored.

4.4 Recommendations

Results such as those reported here support the view that WAD and potentially similar musculoskeletal conditions do not preclude driving and confirm the experience of particular driving difficulties [9, 10]. Participants reported problems with shoulder checking, merging, and driving for long periods. Increased safety awareness and self regulation may serve to mitigate these negative impacts of WAD and similar conditions upon driving safety. For example, there are inexpensive and practical ways to ameliorate these difficulties such as the addition of reversing cameras and extra mirrors to vehicles. Such modifications should be suggested to people with WAD. In the context of the apparent increased vigilance of people with WAD such measures are likely to be accepted. As vehicle technologies continue to evolve, the amelioration of onerous driving tasks for these groups should continue to become more feasible and readily available. Finally, continuing research regarding the aetiology, prevention, and treatment of WAD, especially the prevention of a chronic course, is clearly needed.

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