



# Comparison of risk factors for cervical spine, head, serious, and fatal injury in rollover crashes

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## ABSTRACT

Previous epidemiological studies of rollover crashes have focused primarily on serious and fatal injuries in general, while rollover crash testing has focused almost exclusively on cervical spine injury. The purpose of this study was to examine and compare the risk factors for cervical spine, head, serious, and fatal injury in real world rollover crashes. Rollover crashes from 1995–2008 in the National Automotive Sampling System-Crashworthiness Data System (NASS-CDS) were investigated. A large data set of 6015 raw cases (2.5 million weighted) was generated. Nonparametric univariate analyses, univariate logistic regression, and multivariate logistic regression were conducted. Complete or partial ejection, a lack of seatbelt use, a greater number of roof inversions, and older occupant age significantly increased the risk of all types of injuries studied ( $p < 0.05$ ). Far side seating position increased the risk of fatal, head, and cervical spine injury ( $p < 0.05$ ), but not serious injury in general. Higher BMI was associated with an increased risk of fatal, serious, and cervical spine injury ( $p < 0.05$ ), but not head injury. Greater roof crush was associated with a higher rate of fatal and cervical spine injury ( $p < 0.05$ ). Vehicle type, occupant height, and occupant gender had inconsistent and generally non-significant effects on injury. This study demonstrates both common and unique risk factors for different types of injuries in rollover crashes.

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## 1. Introduction

Rollover crashes are responsible for a disproportionate number of serious injuries and fatalities compared to other crash modes (NHTSA, 2010). Injuries caused by rollover crashes have been studied extensively using both field data and crash testing. Due to the potentially catastrophic consequences of cervical spine injury, biomechanical studies have focused principally on neck loading measured by instrumented dummies in rollover crash tests (Orlowski et al., 1985; Bahling et al., 1995; Moffatt et al., 2003; Croteau et al., 2010). Epidemiological studies, on the other hand, have typically investigated rollover-induced injuries in much broader terms, focusing on serious or fatal injuries in general (Moffatt and Padmanaban, 1995; Digges and Eigen, 2003).

Previous studies have identified several risk factors for serious (AIS 3+) injury given involvement in a rollover crash. These factors included occupant ejection (Parenteau and Shah, 2000), a lack of seatbelt use (Digges and Eigen, 2003; Moore et al., 2005; Padmanaban et al., 2005; Gloeckner et al., 2006; Viano et al., 2007), number of quarter turns (Digges and Eigen, 2003; Moore et al., 2005; Gloeckner et al., 2006; Viano et al., 2007; Parker et al., 2007),

far side seating position (Gloeckner et al., 2006; Viano et al., 2007), roof crush (Conroy et al., 2006), vehicle type (Digges and Eigen, 2003; Padmanaban et al., 2005; O'Connor and Brown, 2006), and occupant age, gender, and alcohol consumption (Padmanaban et al., 2005). Some of these risk factors have also been associated with fatal injury in rollovers, including occupant ejection (Malliaris and Digges, 1987), a lack of seatbelt use (Viano et al., 2007), roof crush (Mandell et al., 2010), and far side seating position (Jehle et al., 2007; Viano et al., 2007).

Risk factors specific to neck injuries in rollover crashes have received less detailed attention in the epidemiological literature. Several previous studies have grouped head, face, and neck (HFN) injuries together in their analyses (Rains and Kianianthra, 1995; Friedman and Friedman, 1998; Parker et al., 2007; Hu et al., 2007). This practice may not identify risk factors specific to neck injury, because head and neck injuries usually occur independently of one another and typically have different mechanisms (Friedman and Friedman, 1998; Atkinson et al., 2004; Hu et al., 2007). Other studies have considered all types of car crashes, rather than just rollovers, and found that ejection greatly increased the odds of neck injury (Huelke et al., 1981; O'Connor and Brown, 2006). Neck injury risk in rollover crashes has been shown to increase with a greater number of quarter turns (Atkinson et al., 2004; Moore et al., 2005; Hu et al., 2007), a lack of seatbelt use (Viano and Parenteau, 2004; Moore et al., 2005), greater roof crush (Hu et al., 2007; Burns et al., 2010; Mandell et al., 2010), older age (Hu et al., 2007), and higher

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