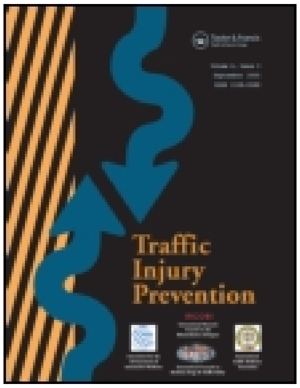

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Bull Bars and Vulnerable Road Users

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Bull Bars and Vulnerable Road Users

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Objectives: *Pedestrian injuries are a leading cause of the global death and injury burden, accounting for 65 percent of the 1.2 million annual road deaths. The purpose of this brief literature review is to examine whether bull bars, a rigid aftermarket accessory fitted to the front end of passenger vehicles, increase the risk of severe and fatal injuries to vulnerable road users in the event of a collision.*

Methods: *Applicable peer-reviewed research, review papers, and grey literature were identified from a search of MEDLINE; the Transportation Research Board (TRB) database composed of Transportation Research Information Services (TRIS) and International Transport Research Documentation (TRID) databases; the Cochrane Database of Systematic Reviews; and Google Scholar. The following search terms were used: "bull bars" OR "nudge bars" OR "sahara bars" AND "pedestrians" OR "vulnerable road users" for 1948 to March 1, 2011. A secondary set of search terms was also included "bull bars" OR "nudge bars" OR "sahara bars" OR "vehicle frontal protective systems" AND "pedestrians" OR "vulnerable road users" for 1948 to March 1, 2011.*

Results: *Neither the MEDLINE search nor the Cochrane Review search returned any relevant literature. The TRID search returned 19 research articles, 9 of which were included. Searches using Google Scholar returned 110 items, of which 21 were included in the present review after excluding patents and citations. Seven of the articles from TRID were also found in the Google Scholar search, resulting in 23 unique articles being included in this review. The studies used included 12 real-world studies, 3 computer modeling studies, and 8 laboratory testing studies. Very few studies examined the road safety of pedal-cyclists and motorcyclists; therefore, we focused solely on studies examining pedestrian safety.*

Conclusions: *The literature reviewed in this study indicates that vehicles fitted with bull bars, particularly those without deformable padding, concentrate crash forces over a smaller area of vulnerable road users during collisions compared to vehicles not fitted with a bull bar. Rigid bull bars, such as those made from steel or aluminum, stiffen the front end of vehicles and interfere with the vital shock absorption systems designed in vehicle fronts. These devices therefore significantly alter the collision dynamics of vehicles, resulting in an increased risk of pedestrian injury and mortality in crashes. This literature review shows that bull bars do indeed increase the severity of injuries to vulnerable road users in the event of a collision and highlights the need for current traffic safety policies to reflect the safety concerns surrounding the use of bull bars.*

Keywords Vehicle design; Pedestrian injury; Vehicle fronts; Rigid bull bars

INTRODUCTION

Pedestrian injuries are a leading cause of global death and injury burden, accounting for 65 percent of the 1.2 million annual road deaths (Peden et al. 2004). Efforts have been made to reduce the incidence of traffic fatalities caused by motor vehicle collisions. Improvements to vehicle design, for example, have been shown to reduce the severity of injuries to pedestrians and cyclists in the event of a collision (Peden et al. 2004). Although road safety researchers have had a basic understanding of the relationship between vehicle design and pedestrian injuries since the 1960s (Kratzke 1995), the safety of *vulnerable road users*, defined by the World Health Organization (Peden et al. 2004) as pedestrians, cyclists, and motorcyclists, did not become a serious concern in the field of vehicle design safety research until the early 1990s. This delay may have been partially due to the belief that little could be done to protect pedestrians in the event of a vehicle crash (Kahane 2004; Kratzke 1995).

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Furthermore, manufacturers may have been reluctant to develop and invest in an area not considered to provide sufficient added value to the vehicle from a market share perspective. Therefore, safety research for vulnerable road users has been relatively slow and poorly funded, in comparison to safety considerations for vehicle occupants. Moreover, scientific consensus on the requirements of vehicle design for pedestrian protection has still not been fully achieved (Crandall et al. 2002).

Studies have been conducted examining how the shape, stiffness, and speed of motor vehicles can influence injury type and severity to pedestrians and cyclists. Early work by Ashton and McKay (1979) related specific vehicle impact speeds to risk of death. In the 1990s, the term *aggressivity* was introduced to describe the vehicle properties of geometry, mass, and stiffness, defined by Fildes et al. (1993) as the extent to which a vehicle transfers collision energy to the struck object in comparison to the amount of collision energy that it absorbs itself. The design of vehicles, particularly frontal structures, determines aggressivity and contributes largely to the severity of injuries sustained in pedestrian–vehicle and cyclist–vehicle crashes. Semi-trailer trucks and large 4-wheel-drive vehicles, vans, and sports utility vehicles (SUVs) have particularly harmful effects on vulnerable road users (Oxley et al. 2004).

The subject of this review, bull bars, are predominantly rigid metal bars fixed to the front end of an SUV, originally designed to prevent damage to the vehicle upon contact with animals in rural areas (Higgins 1994). Fitting of rigid, aggressive bull bars for protection against wildlife or simply for aesthetic reasons has been publicized as a cause for concern in many countries (Higgins 1994; Peden et al. 2004). It has been argued that bull bars are essential safety features that protect occupants in the event of such a collision; however, there has been much debate about their use in densely populated urban areas where pedestrians are often the only casualties they come into contact with (Attewell and Glase 2004). Figure 1 (top) presents a photograph of a pickup truck fixed with a metal bull bar. Figure 1 (bottom) presents a photograph of a pickup truck fixed with a metal nudge bar.

Determining the impact of bull bars on vulnerable road users is necessary for informed traffic safety and car manufacturer policy making, especially to support the Global Technical Regulation (GTR) on pedestrian protection (United Nations Economic Commission for Europe [UNECE] 2009). The purpose of this brief review, therefore, is to examine whether bull bars increase the severity of injuries to vulnerable road users in the event of a collision and to shed light on the reasons motorists choose to fit these devices to their vehicles. Though the goal of this study was to research the influence of bull bars on collision outcomes with all vulnerable road users, very few studies identified in this review elaborated on the impact of these devices on the road safety of pedal-cyclists and motorcyclists. Thus, our study focused solely on pedestrian safety.

Figure 1 Pickup trucks fitted with a metal bull bar (top) and a nudge bar (bottom) (color figure available online).

METHODS

Sources

Applicable peer-reviewed research, review papers, and grey literature were identified from a search of MEDLINE; the Transportation Research Board (TRB) database composed of Transportation Research Information Services (TRIS) and the International Transport Research Documentation (TRID) databases; the Cochrane Database of Systematic Reviews; and Google Scholar.

Study Selection

The following search terms were used: "bull bars" OR "nudge bars" OR "sahara bars" AND "pedestrians" OR "vulnerable road users" for 1948 to March 1, 2011. A secondary set of search terms was also used: "bull bars" OR "nudge bars" OR "sahara bars" OR "vehicle frontal protective systems" AND "pedestrians" OR "vulnerable road users" for 1948 to March 1, 2011. Medical Subject Heading (MeSH) terms were not available for any of the search terms. Abstracts were evaluated against criteria as follows.

Inclusion criteria.

- English language;

  Real-world studies or computer modeling or laboratory testing results from:
- Research on bull bars and impact on safety of vulnerable road users published as independent studies; or
- Research from traffic safety conference proceedings; or
- Research within traffic safety reports; or
- Research supporting reviews of current regulations.

Exclusion criteria.

- Textbooks
- Non-research papers

- Patents
- Citations

Full articles were retrieved for included abstracts, and articles were examined to confirm satisfaction of inclusion standards. All literature searches were supplemented with manual screening of bibliographies in publications accepted for inclusion into the evidence base. The selection and results flowchart is presented in the Appendix.

RESULTS

As seen in the Appendix, neither the MEDLINE nor Cochrane database of systematic review search returned any entries on bull bars and pedestrian crashes.

The TRID search returned 19 research articles, 9 of which were included. Google Scholar provided 110 articles, which, after excluding patents and citations, yielded 21 articles. Seven of the articles from TRID were also found in the Google Scholar search, resulting in 23 unique articles being included in this review.

Studies on bull bars were categorized into real-world studies, computer modeling studies, and laboratory testing, as described in the following subsections.

Real-World Studies

Real-world studies represented the largest category of literature. These 12 papers were mainly from Australia (10 papers). There was also one paper from Ireland and one from The Netherlands.

Computer Modeling

Three studies using computer modeling were included in this review, all from Australia.

Laboratory Testing

Eight of the included studies utilized laboratory testing to study the effects of bull bars and vulnerable road users. Four papers were from work done in Australia, 2 from Britain, 1 from Belgium, and 1 from Japan.

DISCUSSION

Real-World Studies

In 2006, 11.5 percent of pedestrians struck by large SUVs in the United States were killed, compared to 4.5 percent of pedestrians struck by passenger cars. Simms and Wood (2006) attributed the high bumpers and bonnets (hoods) present on these vehicles as the cause of the observed increase in pedestrian mortality during collisions, using real-world data and simulation models. Bull bars are an additional hazard contributing to an already high injury rate because they reduce the average impact speed for fatal collisions and thus severe injuries and death rates are higher (Bowd 1995).

The Federal Office of Road Safety in Australia (1996) estimated that 12 percent of pedestrian deaths in Australia in 1992 involved vehicles fitted with bull bars. Subsequent work has suggested that this value may in fact be an underestimate, due to a large proportion of missing data, raising the possibility that vehicles fitted with bull bars may have been involved in up to 20 percent of collisions resulting in road deaths (Bowd 1997; Federal Office of Road Safety 1996). Due to the incompleteness of bull bar status of vehicles in the Australian national fatality database, it is difficult to draw firm conclusions about the effect of bull bars on pedestrian fatalities in this jurisdiction (Anderson et al. 2008). Upon examination of the South Australian Coroner's records of pedestrian fatalities between 1991 and 1997, researchers found that bull bars were fitted to 8.8 percent of vehicles involved in fatal pedestrian collisions (Kloeden et al. 2000).

The prevalence of bull bar use in urban areas is significantly high. A recent survey of vehicles in areas where pedestrian crashes have occurred showed that 8.6 percent of vehicles in the region of Adelaide, Australia, were equipped with bull bars. However, a higher proportion of vehicles in the outer metropolitan region were equipped with bull bars compared to those in the central business district and the inner metropolitan region (Anderson et al. 2008). A follow-up study determined proportions of vehicle types equipped with bull bars by using video footage of survey sites. It showed that 45.4 percent of 4-wheel-drive vehicles (4WDs)/SUVs, 49.8 percent of work utility vehicles, 15.6 percent of vans, 1.5 percent of passenger cars and derivatives, 28 percent of trucks, and 23.3 percent of buses were equipped with a bull bar, with alloy bull bars being the most common (Doecke et al. 2008).

The Transport Research Laboratory (TRL 1996) in Britain examined crashes involving vehicles equipped with bull bars and found that there were 2 to 3 additional fatalities and approximately 40 additional serious injury casualties as a result of vehicles being fitted with bull bars.

An analysis of Dutch national road statistics showed that SUVs are significantly more aggressive toward vulnerable road users compared to other vehicles (Margaritis et al. 2005). One factor found to have an influence on accident severity was frontal stiffness, which is increased by bull bars. The large difference between the stiffness of the bull bar and impact partner increases the deformation of the partner. The authors noted that bull bars are of no use in road traffic and recommended more restricted regulations on the use of bull bars (Hoogvelt et al. 2004; Margaritis et al. 2005). If used, bull bars should conform to the geometry of the vehicle, and sharp edges from additions such as a fishing rod carrier must be removed because they are also hazards to pedestrians and are noncompliant with bylaws in some areas (Staysafe Committee 2006).

Older road users are especially vulnerable to the effects of bull bars, accounting for up to 45 percent of pedestrian fatalities and up to 70 percent of cyclist fatalities. Increased frailty in older pedestrians and cyclists often results in increased severity of injuries when compared to younger road users, even in moderate crashes (Oxley et al. 2004). The trend toward aggressive and large vehicles with rigid bull bars is thus of large consequence to this population in particular.

Though a majority of motorists chose to fit these devices to protect their vehicle and passengers from damage during a collision, some chose to use bull bars for purposes other than protection. A survey by Page et al. (1984) indicated that the 3 major reasons given for fitting bull bars to sedans were to protect against parking collisions, to make the vehicle more visually attractive, and to allow for more aggressive driving in peak hours. Bull bars provide motorists with a convenient location to mount additional accessories to their vehicles, such as spotlights and recovery winches. Further, though drivers have the option of fitting "pedestrian-friendly" bull bars in place of metal varieties for this purpose, a study by Anderson et al. (2008) demonstrated that the majority of motorists still prefer steel or alloy models over plastic, even in densely populated urban areas. The prevalence of these devices in urban areas, in conjunction with the increased risk of severe injury and death they pose to vulnerable motorists, raises the question of why bull bars, particularly those made of rigid metal materials, continue to remain permitted in urban zones where they serve no safety benefit.

Computer Modeling Studies

Recent computer simulation tests conducted by the University of Adelaide found that in a test simulating a pedestrian's head striking the front of an SUV with a steel bull bar, the head decelerations produced were typically 5 times greater than those from a vehicle with no bull bars (Anderson et al. 2009).

Modeling studies have also indicated that bull bars might have other effects in pedestrian crashes because they alter the front geometry of the vehicle and therefore alter the kinematics of the struck pedestrian, either onto the upper surface of the vehicle or onto the road. The simulation results further showed that the addition of a bull bar to the front of a vehicle increases the speed of the head impact with the bonnet (Anderson et al. 2009). The MADYMO simulation showed that a bull bar alters the trajectory of the head of struck pedestrians and consequently increases the danger of fatal head injuries (Anderson et al. 2009).

Laboratory Testing Studies

From laboratory testing conducted as early as the 1970s, it was recognized that bull bars altered the profile of a vehicle front end, making it potentially more aggressive in pedestrian collisions. A number of crash simulation studies have been conducted using pedestrian dummies and vehicles equipped with and without bull bars in order to investigate the altered injury mechanisms and kinematics involved.

Chiam and Tomas (1980) examined the effect of bull bars on vehicle–pedestrian collision dynamics. The experiments reproduced collisions between an adult male dummy and cars with and without bull bars and at impact speeds of 20 km/h. The results showed that impacts with bull bars result in a higher incidence of knee or ankle fractures and higher severity head injury in both adults and children. It was concluded that this is due to higher and more concentrated impact points in the case of bull bars (Chiam and Tomas 1980).

Zellmer and Otte (1995) reported on crash tests conducted in Germany at the Federal Highway Research Institute (BASt). They concluded that bull bars strongly increase the risk of injury and injury severity in vehicle crash with pedestrians or cyclists (Zellmer and Otte 1995). The study further stated that injury risk for a child in an impact with a vehicle fitted with a bull bar at 20 km/h is similar to an impact with an off-road vehicle traveling at 30 km/h and a regular passenger car traveling at 40 km/h. It was also concluded that hip and lower limb fracture risk for an adult impacting a bull bar at 25 km/h is similar to impacting a car bonnet at 40 km/h (Zellmer and Otte 1995).

Mizuno et al. (2001) conducted child pedestrian headform impact tests and found that the head injury criteria are higher when struck by an SUV fitted with steel bull bars. The study went on to state that the geometrical incompatibility (e.g., the steel bull bars, the higher bonnet height) of SUVs is the major cause of a higher mortality rate (Mizuno et al. 2001).

Testing using impact test procedures developed to assess the safety of cars in impacts with pedestrians has shown that, in general, vehicles equipped with bull bars are more likely to cause injuries to pedestrians, especially child pedestrians, than vehicles not fitted with bull bars (Shield 1999; Zellmer and Otte 1995). Full-scale crash testing has proven that impact kinematics are significantly changed by the addition of a bull bar (Reilly-Jones and Griffiths 1996).

Anderson et al. (2006a) examined the performance of various bull bars in pedestrian impact tests and found that steel and aluminum bull bars can produce extremely high impact loads which, in the case of pedestrian contact, can cause high levels of morbidity and mortality. Their research on the impact of bull bar material showed that steel poses the most significant risks to pedestrians in the event of a collision. Bull bars constructed of lighter metals (e.g., aluminum or alloy) performed better but were still a dangerous addition to the vehicle. Polymer bull bars were suggested to be an acceptable way to protect the front of the vehicle without causing increased risk of injury to pedestrians (Anderson et al. 2006b). In a later observational study of bull bars at pedestrian crash sites, it was found that metallic bull bars were the most common of all bull bar types (Anderson et al. 2008). It was suggested that more rigorous testing protocols and a bull bar rating system should be implemented for regulators (Anderson et al. 2006b; McLean 2005).

Current Regulations and Recommendations

European, Japanese, and Korean carmakers committed in 2001 to stop installing "rigid" bull bars on new cars beginning in 2002 (European Union Committee 2007). The vehicle safety regulations introduced in Europe and Japan in 2005 required all new vehicle models to comply with pedestrian safety standards (McLean 2005). These regulations are expected to lead to safer bull bars that are designed with more pedestrian-friendly materials. More recently, the Working Group on Passive Safety under the UNECE drafted a Global Technical Regulation (GTR) on pedestrian protection (UNECE 2009).

A Regulation Impact Statement (RIS) for pedestrian safety in Australia reviewed the evidence for an intervention to improve the pedestrian safety performance of new Australian vehicles. It was recommended that a mandatory standard, known as an Australian Design Rule (ADR), be adopted based on the GTR on pedestrian protection (Vehicle Safety Standards Branch, Department of Infrastructure and Transport 2011). Currently there are no ADRs in Australia related to the protection of vulnerable road users in the event of a collision with a motor vehicle. It was acknowledged that the fitting of extra equipment, including bull bars and/or vehicle frontal protection systems (VFPS), is almost exclusively an aftermarket activity. It was also acknowledged that VFPS manufacturers could be affected by the adoption of an ADR relating to pedestrian safety, so VFPS were considered as part of the RIS analysis. ADR 42/04 specifies design and construction requirements such that "any additional objects or fittings must be technically essential" (Vehicle Safety Standards Branch, Department of Infrastructure and Transport 2011, p. 3). Whether VFPS are technically essential depends primarily on where the vehicle is being used. However, the ADR can only mandate requirements to apply to all vehicles in Australia. To address this issue, it was proposed that the fitting of a VFPS could be considered in terms of the primary use of the base vehicle. For instance, adjustments for VFPS could be limited to vehicles designed for off-road use (Vehicle Safety Standards Branch, Department of Infrastructure and Transport 2011). Despite the RIS recommendations, a recent statement released by the Australian government indicates that a ban on bull bars is not a consideration (Noller 2011).

Study Limitations

The most obvious limitation of this review is the lack of scientifically sound peer-reviewed literature on the impact of bull bars on vulnerable road users, fatal injuries, injury patterns, and injury mechanisms. This greatly limits the understanding of actual traffic safety problems and solutions concerning bull bars, both among the traffic safety research community and policy makers. In general, clinical understanding of bull bar impact injuries is poor due to lack of scientifically sound real-world studies. Similarly, there are no scientifically sound real-world studies examining the benefit of bull bars for preventing animal-related crashes. Further, there is a lack of research examining the impact of bull bars on pedal-cyclist and motorcyclist road safety. Though there is little doubt that bull bars represent a hazard to cyclist and motorcyclist safety, the underrepresentation of these vulnerable road users in the literature makes it difficult to assess the influence these devices have on collision outcomes. This population of road users represents an important component of many traffic systems, and the dangers that bull bars pose to these vulnerable road users is a topic that needs to be addressed in future studies.

CONCLUSIONS

Although the evidence base is limited to a relatively small number of studies, the data conclusively point to the contribution of bull bars to unnecessary levels of human trauma and fatalities.

Presently, there is active discouragement toward the manufacture of rigid and aggressive bull bars. Recently, the European Council Working Group and European Parliamentary Committee reached consensus on a proposal that will effectively outlaw aggressive metal bull bars while permitting the use of compliant (non-rigid) systems that offer broadly equivalent levels of protection to the vehicle to which they are fitted (European Union Committee 2007). As noted above (Anderson et al. 2006b), redesigning bull bars with softer materials such as plastic would make them more pedestrian friendly.

The United Nations Economic Commission for Europe Working Party on the Protection of Pedestrians recommended that the use of bull bars on roads be banned, notably by encouraging both car manufacturers and component manufacturers to stop selling them as vehicle accessories (UNECE 2002). GTR No. 9 introduced performance criteria to improve the construction of certain parts of the front of vehicles and thereby reduce the levels of injury sustained by pedestrians involved in frontal impacts with motor vehicles. The GTR outlines requirements such as the height and lateral limits of the frontal structures of a vehicle, including any attachments to the structure (UNECE 2008). Furthermore, the European Commission recently introduced a consolidated regulation on the construction and function of motor vehicles and frontal protection systems in an effort to reduce pedestrian injuries (European Parliament Council 2009).

This review shows that rigid bull bars, particularly those made of metal, increase the severity of injuries to vulnerable road users. Our findings highlight the urgent need for current traffic safety policies to reflect the safety concerns surrounding the use of such bull bars.

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APPENDIX—LITERATURE SEARCH FLOWCHART

Note: overlaps occurred during literature searches.

Primary screening Cochrane Review (0), MEDLINE (0), TRID (19), Google Scholar (110)

Secondary screening Included (23), Excluded (106)

Real world (12), Computer modelling (3), Laboratory testing (8)