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Original Research Article

Analysis of Pedestrian Injury Patterns in Road Traffic Fatalities

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Abstract:

Background: Road traffic crashes (RTCs) constitute a worldwide public health concern, with pedestrian fatalities accounting for a substantial proportion of total deaths. Pedestrians constitute one of the most susceptible categories of road users, frequently incurring significant injuries from direct car collisions. Recognizing the patterns of injuries and the severity of pedestrian fatalities is essential for devising effective road safety measures.

Objective: The study assesses pedestrian injury patterns in road traffic mortality by analyzing the severity, character, and distribution of injuries sustained in RTAs.

Methodology: A cross-sectional study of 96 pedestrian fatalities in RTAs was carried out in Patna, Bihar, India. Data was obtained from medical records, inquest reports, and police documentation. Injuries were categorized based on anatomical locations, severity, and injury type. Statistical analysis, including frequency distributions and chi-square tests, was performed with SPSS software.

Results: The largest age group of victims was 25-35 years, comprising 41.4%, while the majority of victims were male, accounting for 83.59%. Head injuries constituted 28.13% of cases, making them the most prevalent type of injury, followed by lower limb injuries at 17.97%. The majority of severe injuries constituted 51.56%, with fatal injuries primarily including head traumas at 15.63% and head-chest trauma at 14.58%. Pedestrian fatalities resulted from high-impact crashes, primarily involving four-wheelers and big automobiles on national highways.

Conclusion: The study highlights the significance of vehicle type, road condition, and collision severity in pedestrian RTAs. Pedestrian safety apparatus, improved roadway infrastructure, and rigorous traffic laws are vital to reduce pedestrian injuries and fatalities.

Keywords: Grievous Injuries, Head Trauma, Injury Patterns, Pedestrian Fatalities, Road Safety, Road Traffic Accidents, Vehicle Collision.

Introduction

Road traffic accidents (RTAs) are a major cause of morbidity and mortality rates, making them major public health concern on a global scale. Fatal road traffic accidents are more consequential as they result in grave injuries and fatalities, presenting both epidemiological and medico-legal challenges. An accident is an occurrence or sequence of occurrences that leads to unexpected injury, fatality, or property damage. Sudden surges in vehicular traffic, excessive speeding, and other factors have contributed to the problem, especially in developing nations where road infrastructure and safety measures are consistently inadequate. Regional Trade Agreements (RTAs) have emerged as a significant trend in India, necessitating that policymakers and scholars focus on devising effective preventative strategies.

In 2022, the Ministry of Road Transport and Highways (MoRTH) reported that Haryana recorded 10,429 road traffic accident cases, placing it 11th among Indian states in terms of accident severity. The study indicates that 8,519 individuals were injured in road traffic accidents on national routes alone. State highways recorded 758 fatalities and 1,461 injuries, including 313 severe cases and 1,148 mild injuries. The statistics highlight the concern of pedestrian safety and the trend of injuries in such incidents. Pedestrians, being the most vulnerable road users, sustain a disproportionate number of injuries from road accidents, often resulting in severe or fatal outcomes due to direct exposure to vehicle collisions.

Injuries sustained in road traffic accidents are classified based on their medico-legal significance. The Bharatiya Nyaya Sanhita (BNS) characterizes an injury as any illegal damage perpetrated upon an individual's body, mind, reputation, or property. In medico-legal terms, injuries are classified as basic or

serious. Minor injuries lead to temporary pain or mild illness without deadly outcomes, but serious injuries, as classified under Section 116 of the BNS, result in severe repercussions such as permanent vision loss, hearing impairment, joint destruction, irreversible deformity, or fracture. Fatal road traffic accidents generally result in severe injuries, often leading to permanent disability or death. Furthermore, injuries are classified based on their mechanism of occurrence as suicidal, homicidal, or accidental, with road traffic accident injuries categorized as accidental [6].

The injury profile of fatal pedestrian casualties comprises a combination of interior and exterior injuries caused by blunt force trauma. The exterior injuries include bruises, lacerations, contusions, and abrasions. Abrasions resulting from friction on a rigid surface often inflict harm on the outer epidermal layer of the skin with negligible bleeding [7]. Lacerations include the tearing of deeper tissues due to forceful trauma, resulting in uneven and jagged wound edges. Contusions occur due to the rupture of blood vessels, resulting in localized hemorrhaging within the skin. Bone fractures, rib fractures, internal organ injuries, and hemorrhages are internal injuries that are generally more lethal. Additionally, neck injuries, spinal cord injuries, and traumatic brain injuries, commonly observed in pedestrian road traffic accidents, significantly contribute to a high percentage of fatalities [8].

Numerous factors affect the severity of pedestrian injuries in road traffic accidents. The accident's location, vehicle type, road surface, speed, and adherence to traffic restrictions all affect injury patterns. High-speed collisions are likely to result in fatal or catastrophic injuries, but lower-speed collisions may lead to less serious injuries. Environmental issues, including substandard road conditions, insufficient pedestrian crossings, reckless driving, driver fatigue, substance impairment, and disregard for traffic laws, further exacerbate pedestrian vulnerabilities. Adherence to safety equipment, including helmets, seat belts, reflective vests, pedestrian signals, and speed control devices, has been shown to diminish injury severity and enhance overall road safety [9,10].

Due to the elevated incidence of pedestrian fatalities and the complexity of injury patterns in road traffic accidents, a thorough examination of these incidents is crucial for formulating effective preventive measures. This study aims to do a thorough analysis of pedestrian injury patterns in road traffic incidents by determining the types, severity, and frequency of injuries. The study seeks to improve understanding of pedestrian risk factors and propose straightforward solutions to mitigate the impact of road traffic accidents, based on analyzed causative processes of injury and contributing factors. The results will enhance road safety policy, forensic investigation, and medico-legal evaluation, ultimately contributing to enhanced injury prevention and legal protocols in road accident scenarios.

Methodology

Study Design: A cross-sectional study was conducted to analyze pedestrian injury patterns in road traffic fatalities. The study focused on the distribution and characteristics of injuries sustained by pedestrians involved in road traffic accidents.

Study Area: The study was carried out in the Patna, Bihar, India. It included various types of roads such as National Highways, State Highways, major district roads, and rural roads.

Study Duration: The study was conducted in Department of FMT for one year.

Sample Size: A total of 96 cases of pedestrian fatalities due to road traffic accidents were examined.

Data Collection: The information was taken from the medical records of those who were either taken straight from the scene of the accident to the hospital or who were admitted but later passed away from their wounds. Inquest reports and related documents, such as medical reports from the investigating police officer, were used to gather additional information about the accidents. Additional information was obtained from the victims' relatives, acquaintances, or other individuals who were present, as well as from police personnel who were accompanying them.

Inclusion Criteria

- Pedestrian victims of road traffic accidents who were declared dead upon arrival or succumbed to injuries post-admission.
- Cases where sufficient medical and police documentation were available.

Exclusion Criteria

- Non-pedestrian road traffic accident victims (e.g., drivers, passengers, cyclists).
- Cases with incomplete or missing medical/police records.
- Victims who survived after treatment and were later discharged.

Procedure

Each case was carefully evaluated to identify injury patterns based on anatomical locations, severity, and kind of injury, such as abrasions, lacerations, fractures, and internal organ damage. The impact-related variables, such as vehicle type, collision speed, and accident dynamics, were also documented. The acquired data was rigorously classified to discover common injury patterns and their distribution across various accident circumstances. A comparison analysis was carried

out to assess the relationship between injury and contributory factors including road type and impact force.

Statistical Analysis: Descriptive statistics such as frequency distributions, percentages, and mean values were used to examine the gathered data and summarize the key findings. Chi-square testing were utilized to ascertain potential correlations between injury patterns and accident variables. Moreover, statistical calculations and data processing were conducted utilizing SPSS software to guarantee precision and dependability in the analysis. The results were subsequently analyzed to extract significant conclusions on the characteristics and prevalence of pedestrian injuries in road traffic fatalities.

Result

Table 1 highlights the attributes of road traffic accident (RTA) casualties categorized by age groups and their corresponding road user classifications. The largest proportion of victims (53, 41.4%) belonged to the 25-35 age demographic, followed by the 40-60 age group (25, 19.53%) and the 18-25 age group (22, 17.19%). Male participants (107) were much more impacted than female participants (21). The majority of accidents among road users involved four-wheeler/heavy vehicle operators (104 incidents, 53.33%), followed by two-wheeler operators (54 cases, 27.69%) and pedestrians (20 instances, 10.27%). Three-wheelers (8 cases, 4.1%), mopeds (5 cases, 2.56%), and non-motorized vehicles (4 cases, 2.05%) exhibited the lowest incidence of instances. A total of 128 victims and 195 incidents were documented.

Table 1: Characteristics of RTA victims and the categories of road users

S. No	Age Group (Years)	Victims				Type of Road Users		
		Male	Female	No	%	Road Users	No. of Cases	Percentage (%)
1.	Below 18	7	0	7	5.47	Pedestrian	20	10.27
2.	18-25	20	2	22	17.19	Two-Wheeler	54	27.69
3.	25-35	45	8	53	41.4	Three-Wheeler	8	4.1
4.	35-40	12	3	14	10.94	Four-Wheeler/ Heavy Vehicle	104	53.33
5.	40-60	19	6	25	19.53	Moped Vehicle	5	2.56
6.	Above 60	4	2	7	5.47	Non-Motorized Vehicle	4	2.05
	Total	**107**	**21**	**128**	**100**	**Total**	**195**	**100**

Table 2 displays information regarding the categories of cars implicated in fatal road traffic accidents (RTA), the locations of these incidents, and the quantity of vehicles involved. Cars were the most commonly involved vehicles, accounting for 70 incidents (38.89%), followed by bikes with 55 cases (30.56%) and trucks/lorries with 30 cases (16.67%). National highways accounted for the largest incidence of accidents, with 42 incidents (24%), followed by rural roads with 18 cases (11%) and state highways with 15 instances (9%). In terms of vehicle collisions, double-vehicle accidents were the most prevalent, with 68 instances (68%), whilst single-vehicle accidents accounted for 20 cases (20%), triple-vehicle accidents for 8 cases (8%), and multi-vehicle accidents for 4 cases (4%). A total of 180 automobile incidents and 100 accident site cases were documented.

Table 2: various types of vehicles engaged in fatal RTA, the location of the accident in respect to the road, and the number of vehicles involved

Vehicle Type	Cases	No. %	Type of Road	Cases	No. %	Vehicle Collision	Cases	No. %
Car	70	38.89	National Highway	42	24	Single Vehicle	20	20
Bike	55	30.56	State Highway	15	9			
Truck/Lorry	30	16.67	Major District Road	10	6	Double Vehicle	68	68
Tractor	8	4.44	City Road	8	5			
Non-motorized Vehicle	9	5	Rural Roads	18	11	Triple Vehicle	8	8
Others (Divider)	8	4.44	Link Roads	15	9	More than 3 Vehicle	4	4
Total	**180**	**100**	**Total**	**100**	**100**	**Total**	**100**	**100**

Table 3 shows the distribution of injuries among RTA victims, with head injuries being the predominant kind (36 victims, 28.13%), succeeded by lower limb injuries (23 victims, 17.97%) and injuries involving both upper and lower limbs (17 victims, 13.28%). Upper limb injuries constituted 18 instances (14.06%), whilst head and chest injuries were documented in 11 cases (8.59%). Chest injuries were noted in 10 victims (7.81%), whereas whole-body injuries were the least prevalent, affecting 4 victims (3.13%). Significantly, 9 individuals (7.03%) had no documented injuries. A total of 128 victims were evaluated.

Table 3: Injury areas on the bodies of the RTA victims

S. No	Site of Injuries	No. of Victims	% Age
1	Head	36	28.13
2	Lower limb	23	17.97
3	Upper and lower limbs	17	13.28
4	Head and chest	11	8.59
5	Upper limbs	18	14.06
6	Chest	10	7.81
7	Whole body	4	3.13
8	No injuries	9	7.03
	Total	**128**	**100**

Table 4 classifies RTA victims according to the nature of injuries incurred. The majority experienced severe injuries, with 66 victims accounting for 51.56%, followed by mechanical injuries affecting 41 victims, or 32.03%. In 11 instances, minor injuries were documented, accounting for 8.59% of the cases, whereas 10 individuals, representing 7.81%, reported no injuries. A total of 128 victims were analyzed.

Table 4: Distribution of instances by type of injury

S. No	Type of Injury	No. of Victims	% Age
1	Grievous injuries	66	51.56
2	Mechanical injuries	41	32.03
3	Minor injuries	11	8.59
4	No injuries	10	7.81
	Total	**128**	**100**

Table 5 displays the distribution of cases concerning fatal injuries among RTA victims. Head injuries accounted for the highest number of fatal injuries, with 15 cases representing 15.63%. This was closely followed by head and chest injuries, which totalled 14 cases or 14.58%, as well as thoracic injuries, also at 14 cases or 14.58%. A total of 8 cases (8.33%) were attributed to multiple injuries. It is important to highlight that almost half of the cases (45 cases, 46.88%) did not result in fatal injuries. A total of 96 cases were analyzed.

Table 5: Distribution of cases based on fatal injuries

Fatal injuries	Adjusted No. of cases	Adjusted %
Head injury	15	15.63%
Head and chest injuries	14	14.58%
Thoracic	14	14.58%
Multiple injuries	8	8.33%
No fatal injuries	45	46.88%
Total	**96**	**100%**

Discussion

An examination of road traffic accident (RTA) victims reveals distinct patterns based on age demographics, gender, type of road user, vehicle involvement, injury patterns, and fatality distribution. The majority of RTA casualties, at 41.4% of the total, are aged between 25 and 35 years. Males (83.59%) are more frequently impacted than females (16.41%), suggesting potential exposure to greater risk, possibly attributable to increased mobility and participation in high-speed transport. Operators of four-wheeled and heavy vehicles constitute the largest proportion of instances at 53.33%, while two-wheeler operators account for 27.69%. Pedestrians represent 10.27% of incidents, likely due to their susceptibility while traversing roadways. People aged over 60 exhibit a

comparatively low incidence rate of 5.47%, potentially attributable to diminished mobility relative to younger people.

The World Health Organization's Global Status Report on Road Safety (2018) indicates that individuals aged 25–35 years, especially males, face a heightened risk of traffic-related injuries. Such people are prone to mobility and frequently encounter high-velocity movement, hence elevating their chance of involvement in road traffic accidents (RTAs). Research by Jacobs & Thomas (2000) [12] also indicates a similar tendency, emphasizing that males are more prone to engage in hazardous travel behaviors, which supports our result that 83.59% of the victims were male. These data highlight the significant susceptibility of this group and suggest that preventative efforts must address behavioral risk factors alongside infrastructure enhancement.

Conversely, regarding the incidence of pedestrian injuries, our observations indicate that pedestrians account for 10.27% of road traffic accidents, representing a comparatively smaller fraction of road users than other groups such as four-wheeled and two-wheeled vehicle passengers. This contrasts with observations in places with underdeveloped road infrastructure, where pedestrians account for a significantly larger percentage of fatalities (Peden 2004) [13]. In most low- and middle-income nations, inadequate pedestrian infrastructure, insufficient lighting, and lax enforcement of traffic regulations contribute significantly to pedestrian injuries.

An examination of the vehicles implicated in fatal road traffic accidents and their locations reveals that cars accounted for 38.89% of incidents, followed by bicycles at 30.56% and trucks/lorries at 16.67%. National highways accounted for the highest percentage of accidents at 24%, and rural and connecting roads collectively represented 20%. Concerning vehicle crashes, the majority (68%) included two vehicles, but single-vehicle and multi-vehicle incidents constituted a lesser proportion (20% and 12%, respectively). The data demonstrate that highways and urban roads are significant risk zones, particularly for passenger and freight vehicles.

Our findings align with current literature, emphasizing the significant role of roads in generating fatal road traffic accidents (RTAs) and the disproportionate involvement of freight and passenger vehicles. Research by Tiwari & Mohan (2022) [14] and the WHO (2018) [11] indicates that highways with elevated speed restrictions and vehicle density provide a greater risk of severe accidents, corroborating our finding that national highways account for 24% of fatal crashes. Existing data from high-volume corridors confirms a heightened risk to passenger vehicles, particularly cars (38.89%) and motorbikes (30.56%), attributing this to variables such as lane changes, weariness, and exceeding speed limits in fatal crashes (NHTSA, 2022). [15].

The frequency of injured areas reveals that the predominant sites of injury were head injuries (28.13%), lower limb injuries (17.97%), and injuries to both upper and lower limbs (13.28%). The predominant injuries among the casualties were chest injuries (7.81%) and whole body injuries (3.13%), whereas 7.03% of the patients sustained no injuries. The trend demonstrates the severity of brain injuries in road traffic accidents, hence reinforcing the necessity for protective gear such as helmets and seatbelts.

Gururaj (2002) [16] establishes that head injuries constitute the predominant cause of fatalities and permanent disabilities associated with road traffic accidents, corroborating our finding that 28.13% of our subjects experienced head trauma. This is especially alarming for motorcyclists, as the absence of helmet wear has been significantly associated with fatal head injuries (Liu et al., 2008) [17].

Grievous injuries were observed in 51.56% of cases, while mechanical injuries accounted for 32.03%. Minor injuries were observed in 8.59% of cases, whereas 7.81% of the victims sustained no injuries. These figures demonstrate the severity of road traffic accidents, since more than fifty percent of the victims sustained serious injuries necessitating medical intervention.

Mitra et al. (2018) [18] conducted a study revealing that severe injuries occurred in approximately 50% of high-speed accident cases, in contrast to our figure of 51.56%. These severe injuries are more prevalent in high-impact collisions occurring on highways and metropolitan areas, where vehicle speeds are higher.

Conversely, mechanical trauma, including lacerations, abrasions, and contusions, accounted for 32.03% of our cases. According to research by Roy et al. (2021) [19], although this damage is not lethal, it significantly adds to long-term impairment and psychological suffering in survivors. This aligns with the widespread apprehension that non-fatal road traffic accident injuries may place a significant strain on healthcare systems.

An analysis of the fatal injuries reveals that 46.88% were non-fatal, with head injuries constituting the most lethal category at 15.63%. Combined head and chest injuries, together with thoracic injuries, each accounted for 14.58%, illustrating the fatal consequences of high-impact trauma in the upper body region. various injuries accounted for 8.33% of fatal cases, reflecting the aggregate effect of various trauma sites on death.

Similarly, the cumulative impact of cranial and thoracic injuries (14.58%) and thoracic trauma (14.58%) is corroborated by the research of Kent et al. (2005) [20], which posits that high-energy collisions, particularly at elevated speeds or involving substantial automobiles, frequently result in fatal upper-body injuries. The thorax, housing essential organs such as the heart and lungs, is highly susceptible to blunt force damage during high-impact collisions, making thoracic injuries a leading cause of mortality.

Ultimately, these findings indicate that road traffic accidents (RTAs) predominantly involve young males, the most active users of four-wheel vehicles, with head injuries being the most common and lethal type of injury. This underscores the necessity for stringent safety protocols, enhanced road infrastructure, and targeted interventions to address RTA-related morbidity and mortality.

Conclusion

The examination of pedestrian injury trends in road traffic fatalities underscores the considerable influence of vehicle type, road conditions, and injury severity on victim outcomes. Pedestrians constituted a significant percentage of fatalities, with cranial injuries as the predominant cause of death. The predominant fatal incidents included crashes with four-wheeled or heavy vehicles, frequently occurring on national routes. A considerable proportion of victims incurred severe or mechanical injuries, with head and chest injuries playing a crucial role in fatal results. The results highlight the necessity for augmented pedestrian safety protocols, improved road infrastructure, and more stringent traffic restrictions to reduce fatalities and serious injuries in vehicular accidents.

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