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Road traffic accidents and injuries, 2018: a multi-centric epidemiological study from India

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Abstract: **Objective:** Road traffic injuries (RTIs) have been recognized globally as an important public health problem. Effective road safety initiatives should address the traffic system as a whole to find a solution and look at the traffic system as a collective to discuss interactions between vehicles, road users and road infrastructure. Therefore, epidemiological data from different geographies of the country should be available. Hence, an electronic-based comprehensive and integrated RTI surveillance system was established in five centres located across the country to assess the burden of RTIs, including the outcome.

Methods: This paper is a cross-sectional multi-centric study conducted using an electronic-based comprehensive and integrated RTI surveillance system.

Results: A total of 15,319 participants were enrolled under the surveillance of road traffic events for a period of one year. Self-fall/skid was the most common (34.87%) type of accident, followed by a crash between two vehicles (25.77%) and a crash with a pedestrian (16.59%). Among them, 88.94% were the injured, who were alive with or without rehabilitation, and 673 (4.43%) were dead. Mostly, two-wheelers (geared or non-geared) were involved in the accident as they shared a significant portion (75.54%) of the total accidents.

Conclusion: The study highlights the epidemiological issues related to road accidents and RTIs that need to be addressed in order to find appropriate solutions for reducing the RTI burden. It gives an understanding of the manner of trauma, the pattern of injuries, and the outcome of road traffic accidents required to adopt efficient preventive and comprehensive trauma care.

Keywords: Epidemiology; India; Road Traffic Injuries; Trauma; Surveillance

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1. Introduction

Road traffic Injuries claim more than 1.19 million lives per year and cause up to 50 million non-fatal injuries globally, many of which are disabled as a result of their injury (1). 92% of the world's road deaths occur in low- and middle-income countries, even though these areas own about 60% of the world's automobiles (2). Road traffic accidents (RTAs) in India killed almost 1.55 lakh people in the year 2019. A total of 446,768 road accident cases were recorded, rendering 423,158 persons injured and 171,100 deaths (3). India thus accounts for almost 11% of the world's accident-related deaths (4). In addition to death, RTAs also lead to a significant portion of serious injuries.

Most of the road incidents (62.6%) were due to overspeeding, causing 100,726 fatalities and 271,661 injuries (3). Globally, RTAs and road traffic injuries (RTIs) are significantly caused by overspeeding of vehicles. Research indicates that exceeding speed limits not only increases the likelihood of accidents but also the severity of injuries. For instance, a study highlights that overspeeding is a primary factor in fatal RTIs, particularly among young male drivers (5). Another study discusses how overspeeding influences braking distance, leading to higher chances of collisions (6). Furthermore, overspeeding is often linked to more severe crash outcomes due to the increased impact speed, which exacerbates the extent of injuries (7). Deaths and accidents from road traffic are preventable. The contribution of India to the global number of deaths due to RTAs is rising, and if trends continue until 2027 , the country is unlikely to meet the sustainable development goals targets. Establishing effective surveillance of RTIs is a significant priority because it allows policymakers to adopt policies that have proven effective in reducing them. Improving the data on RTAs and deaths is a key to effectively implement and monitor road safety programmes. We need to understand more to establish efficient preventive strategies. In particular, the number and types of accidents and the circumstances in which such injuries occur must be known. This information would demonstrate how serious the issue is and where preventive measures need to be implemented the most (8).

Epidemiological evidence is needed to determine the impairment and seriousness of injuries arising from RTAs. In addition, it may be useful to consider the characteristics and mechanisms of RTAs. Data is required for the planning, implementation and assessment of RTA control services and the proper allocation of priorities to those services (9).

In India, traffic police is the only data source for tracking road fatalities, as is the case in most countries. Police reports are also the basis of the country's official government statistics on road traffic incidents, published annually by the national crime records bureau (NCRB) as a compilation of standard statistical tables that provide national, state and city-level crash statistics (3). Although official figures contain non-fatal accident statistics, these are less commonly cited because police seriously underreport non-fatal incidents, as deviations between multiple departments can be noted (10). Thus, it is likely that a larger number of RTAs and RTIs go unreported (8). Underreporting of RTAs and RTIs is a global issue that significantly impacts the accuracy of data and the effectiveness of interventions. Studies indicate that underreporting is prevalent, particularly for non-fatal injuries and less severe accidents. For example, a study in Japan found significant underreporting of child vehicle occupant injuries by police, with actual incidence rates being twice as high as reported (11). Similarly, in Pakistan, an analysis revealed that underreporting rates by police and emergency services were 99% and 39% respectively (12). Additionally, in Nepal, a study showed that the actual burden of RTIs was much higher than official reports suggested, highlighting the extent of underreporting (13). These discrepancies indicate the need for improved reporting systems to better inform road safety policies and interventions.

Effective road safety initiatives should address the traffic system as a whole to find a solution and look at the traffic system as a collective to discuss interactions between vehicles, road users and road infrastructure. Therefore, epidemiological data from different geographies of the country should be available. This paper analyses data collected through a comprehensive and integrated electronic-based RTI surveillance system to determine the burden of RTAs and RTIs and their epidemiological factors, including the outcome.

2. Methods

An electronic-based comprehensive and integrated RTI surveillance system was established to assess the burden of road traffic injuries. The tool was developed based on WHO's recommended elements for the RTI surveillance system (14). This paper is based on the RTAs and RTIs-related data collected in a multi-centric study to develop and implement integrated RTI surveillance.

2.1. Study area

This cross-sectional data collection was conducted in 2018 as a part of a multi-centric project implemented in five participating centres: three major cities (Chennai, Delhi and Jaipur) and two rural cities (Chittoor and Tehri-Garhwal) located across the country. Detailed methodology and study area are available elsewhere (15).

2.2. The data

Data was usually collected at each centre under two categories, i.e. health facility and population. The research included one trauma centre and one private hospital under the health facility in major cities (Chennai, Delhi, and Jaipur), one district hospital and one private nursing home in rural cities (Chittoor and Tehri-Garhwal). For the study, a population of 10000 in major cities and two health sub-centres covering a population of 10000 in rural cities are included. Passive surveillance was conducted at the trauma centre/ district hospital, while active surveillance was performed at the private hospital/nursing home and communities/sub-health centres. Data on RTI time, place, person and identified details were collected by interviewing the RTI victim or their attender. Clinical details and injury-related data were collected from the patient's medical records. Any individual brought in with RTIs to any of the surveillance points was enrolled in the study. For this paper, data received from the patients who were enrolled under passive surveillance (trauma centre/district hospital) and active surveillance (the private hospital/nursing home) are included in the analysis. The details of the development of software and implementation of an electronic surveillance system are available elsewhere (15).

2.3. Statistical analysis

Data were analyzed in SPSS, v.26. The descriptive statistics were used, and the chi-squared test was used to test the significance of the difference between the study cities and outcome groups. A P-value of less than 0.05 was considered significant.

2.4. Ethical considerations

Ethical clearance was granted by the institutional ethics committees of the respective authors' institutes. Each of the five committees approved the study for the corresponding centre. All the study participants were informed about the purpose of the study, and written consent was obtained.

Table 1 Socio-demographic characteristics of study participants

Characteristics	Number (n=15,319)	%
District (state)		
Chennai (Tamil Nadu)	2231	14.6
Chittoor (Andhra Pradesh)	1463	9.6
Delhi (Delhi)	3876	25.3
Jaipur (Rajasthan)	7064	46.1
Tehri-Garhwal (Uttarakhand)	685	4.5
Gender		
Male	12762	83.3
Female	2556	16.7
Transgender	1	0.0
Age (in years)		
0 – 9	272	1.8
10 – 19	1506	9.8
20 – 39	8861	57.8
40 – 59	3566	23.3
60 & above	e 1096	7.2
No data	18	0.1
Occupation		
Business	264	1.7
Self-employed/medium business	1481	9.7
Professional/executive manager	207	1.4
Employee (Government/private)	3110	20.3
Skilled Manual (artisans, agriculture, fishery, forestry)	1706	11.1
Unskilled manual (labour)	2568	16.8
Homemaker	1435	9.4
Student	2932	19.1
Unemployed	897	5.9
Others	218	1.4
No data	406	2.6
Not applicable	95	0.6
Education		
Illiterate	2216	14.5
Primary	2966	19.4
High school	3499	22.8
Higher Secondary school	2912	19.0
Diploma/certified course	543	3.5
Graduate and above	2599	17.0
No data	584	3.8
Distribution of respondents by relationship with injured		
Self	4059	26.5
Family member	9148	59.7
Friend	1451	9.5
Driver	47	0.3
Co-passenger	13	0.1
Unknown passer-by	194	1.3
No data	111	0.7
Others	296	1.9

3. Results

3.1. Socio-demographic details of the RTI patients

Table 1 presents the socio-demographic characteristics of the participants. A total of 15,319 participants were enrolled under the surveillance of road traffic events. Males comprised more than three-fourths (83.3%) of total injuries during RTAs. About 58% of injured respondents are between 20 to 39 years of age. Around 28% of injured are either skilled or unskilled manual labour. One-fifth of the injured are students, and another one-fifth are working either in government or private sectors.

More than 65% of respondents have a high school education up to the 12^{th} standard, and 17% of respondents are graduates or above. Most (59.7%) of victims of RTIs are accompanied by their family members as they are respondents on behalf of the victim.

Table 2 Epidemiological characteristics of road traffic Injuries by study site

	Chennai (n=2231)	Chittoor (n=1463)	Delhi (n=3876)	Jaipur (n=7064)	Tehri-Garhwal (n=685)	X^2 for differences between cities	Total (n=15319)
Type of Accident							
Self fall/Skid	758 (33.98)	468 (31.99)	1424 (36.74)	2351 (33.28)	341 (49.78)	X^2 = 1799.06; P<0.001	5342 (34.87)
Crash with pedestrian	445 (19.95)	136 (9.30)	947 (24.43)	977 (13.83)	37 (5.40)		2542 (16.59)
Crash with parked vehicle	7 (0.31)	12 (0.82)	29 (0.75)	220 (3.11)	30 (4.38)		298 (1.95)
Crash with fixed obstacle	14 (0.63)	7 (0.48)	123 (3.17)	258 (3.65)	52 (7.59)		454 (2.96)
Crash with non-fixed obstacle	4 (0.18)	3 (0.21)	14 (0.36)	21 (0.30)	15 (2.19)		57 (0.37)
Crash between two vehicles	814 (36.49)	454 (31.03)	363 (9.37)	2259 (31.98)	58 (8.47)		3948 (25.77)
Crash with two or more vehicles	13 (0.58)	4 (0.27)	682 (17.60)	329 (4.66)	54 (7.88)		1082 (7.06)
Crash with animal	123 (5.51)	93 (6.36)	72 (1.86)	476 (6.74)	16 (2.34)		780 (5.09)
Overturn of vehicle	0 (0.00)	26 (1.78)	68 (1.75)	114 (1.61)	35 (5.11)		243 (1.59)
Others	17 (0.76)	259 (17.70)	41 (1.06)	20 (0.28)	46 (6.72)		383 (2.50)
No data	36 (1.61)	1 (0.07)	113 (2.92)	39 (0.55)	1 (0.15)		190 (1.24)
National highway	202 (9.05)	55 (3.76)	32 (0.83)	1201 (17.00)	248 (36.20)	X^2 = 4151.41; p <0.001	1738 (11.35)
State highway	816 (36.58)	481 (32.88)	109 (2.81)	1004 (14.21)	182 (26.57)		2592 (16.92)
Urban road	607 (27.21)	322 (22.01)	2791 (72.01)	3217 (45.54)	111 (16.20)		7048 (46.01)
Major district roads	76 (3.41)	235 (16.06)	532 (13.73)	293 (4.15)	27 (3.94)		1163 (7.59)
Rural road	4.62 (20.71)	369 (25.22)	303 (7.82)	1321 (18.70)	117 (17.08)		2572 (16.79)
No data	68 (3.05)	1 (0.07)	109 (2.81)	28 (0.40)	0 (0.00)		206 (1.34)
Type of Road							
National highway	202 (9.05)	55 (3.76)	32 (0.83)	1201 (17.00)	248 (36.20)	X^2 = 4151.41; p <0.001	1738 (11.35)
State highway	816 (36.58)	481 (32.88)	109 (2.81)	1004 (14.21)	182 (26.57)		2592 (16.92)
Urban road	607 (27.21)	322 (22.01)	2791 (72.01)	3217 (45.54)	111 (16.20)		7048 (46.01)
Major district roads	76 (3.41)	235 (16.06)	532 (13.73)	293 (4.15)	27 (3.94)		1163 (7.59)
Rural road	4.62 (20.71)	369 (25.22)	303 (7.82)	1321 (18.70)	117 (17.08)		2572 (16.79)
No data	68 (3.05)	1 (0.07)	109 (2.81)	28 (0.40)	0 (0.00)		206 (1.34)
Sub-type of the road*							
One-way road	666 (29.85)	61 (4.17)	655 (16.90)	626 (8.86)	154 (22.48)	X^2 = 5529.44; P<0.001	2162 (14.11)
Two-way road	1026 (45.99)	165 (11.28)	542 (13.98)	420 (5.95)	218 (31.82)		2371 (15.48)
Single lane	390 (17.48)	565 (38.62)	1350 (34.83)	1509 (21.36)	24 (3.50)		3838 (25.05)
Two lane road	418 (18.74)	710 (48.53)	995 (25.67)	2475 (35.04)	247 (36.06)		4845 (31.63)
four or above-lane road	71 (3.18)	4 (0.27)	43 (1.11)	2010 (28.45)	0 (0.00)		2128 (13.89)
Cross Road + Connector road	0 (0.00)	22 (1.50)	66 (1.70)	655 (9.27)	4 (0.58)		747 (4.88)
Roundabout	6 (0.27)	3 (0.21)	25 (0.64)	81 (1.15)	8 (1.17)		123 (0.80)
Railway crossing	0 (0.00)	2 (0.14)	2 (0.05)	13 (0.18)	0 (0.00)		17 (0.11)
Curve road/blind curve	0 (0.00)	2 (0.14)	8 (0.21)	3 (0.04)	9 (1.31)		22 (0.14)
Gradient road	0 (0.00)	0 (0.00)	3 (0.08)	2 (0.03)	18 (2.63)		23 (0.15)
T or staggered junction	0 (0.00)	1 (0.07)	17 (0.44)	18 (0.25)	0 (0.00)		36 (0.24)
Multiple Junction	2 (0.09)	22 (1.50)	2 (0.05)	29 (0.41)	0 (0.00)		55 (0.36)
No data	77 (3.45)	1 (0.07)	168 (4.33)	197 (2.79)	3 (0.44)		446 (2.91)
Road conditions at the accident site*							
Safe/dry	1842 (82.56)	1274 (87.08)	3240 (83.59)	6217 (88.01)	386 (56.35)	X^2 = 1186.50; P<0.001	12959 (84.59)
Slippery (wet/oily) (wet+oily)	23 (1.03)	76 (5.19)	196 (5.06)	184 (2.60)	59 (8.61)		538 (3.51)
Muddy	75 (3.36)	28 (1.91)	61 (1.57)	63 (0.89)	110 (16.06)		337 (2.20)
Rutted/potholed	159 (7.13)	65 (4.44)	166 (4.28)	508 (7.19)	68 (9.93)		966 (6.31)
Flooded	0 (0.00)	2 (0.14)	3 (0.08)	42 (0.59)	7 (1.02)		54 (0.35)
Snow	0 (0.00)	31 (2.12)	0 (0.00)	0 (0.00)	3 (0.44)		34 (0.22)
Work under progress	34 (1.52)	20 (1.37)	5 (0.13)	9 (0.13)	46 (6.72)		114 (0.74)
Others	9 (0.40)	3 (0.21)	5 (0.13)	18 (0.25)	2 (0.29)		37 (0.24)
Unknown	89 (3.99)	0 (0.00)	200 (5.16)	23 (0.33)	4 (0.58)		316 (2.06)
Weather conditions at the time of the accident							
Clear	2127 (95.34)	1362 (93.10)	3545 (91.46)	6481 (91.75)	467 (68.18)	X^2 = 1180.24; P<0.001	13982 (91.27)
Hot/dry weather	3 (0.13)	1 (0.07)	10 (0.26)	324 (4.59)	12 (1.75)		350 (2.28)
Rainy	29 (1.30)	49 (3.35)	134 (3.46)	210 (2.97)	125 (18.25)		547 (3.57)
Fog/mist/smoke/smog	8 (0.36)	3 (0.21)	64(1.65)	15(0.21)	61 (8.91)		151(0.99)
Severe winds	0 (0.00)	0 (0.00)	32 (0.83)	3 (0.04)	7 (1.02)		42 (0.27)
Landslide	4 (0.18)	0 (0.00)	6 (0.15)	2 (0.03)	4 (0.58)		16 (0.10)
Snow	0 (0.00)	48 (3.28)	0 (0.00)	25 (0.35)	4 (0.58)		77 (0.50)
Others	5 (0.22)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.29)		7 (0.05)
No data	55 (2.47)	0 (0.00)	85 (2.19)	4 (0.06)	3 (0.44)		147 (0.96)

Table 2 Epidemiological characteristics of road traffic Injuries by study site (continued)

	Chennai (n=2231)	Chittoor (n=1463)	Delhi (n=3876)	Jaipur (n=7064)	Tehri-Garhwal (n=685)	X^2 for differences between cities	Total (n=15319)
Light condition at the time of the accident							
Excess light	10 (0.45)	141 (9.64)	338 (8.72)	13 (0.18)	97 (14.16)	X^2 = 1640.73; P<0.001	599 (3.91)
Sufficient light/daylight	1858 (83.28)	785 (53.66)	1813 (46.78)	4832 (68.40)	408 (59.56)		9696 (63.29)
Partial light/semi-darkness	45 (2.02)	170 (11.62)	415 (10.71)	652 (9.23)	72 (10.51)		1354 (8.84)
Insufficient light/darkness	211 (9.46)	354 (24.20)	1025 (26.44)	1536 (21.74)	95 (13.87)		3221 (21.03)
Glare effect from front vehicle light	0 (0.00)	8 (0.55)	35 (0.90)	0 (0.00)	3 (0.44)		46 (0.30)
Fog/dust	0 (0.00)	4 (0.27)	4 (0.10)	0 (0.00)	5 (0.73)		13 (0.08)
Others	0 (0.00)	0 (0.00)	11 (0.28)	29 (0.41)	0 (0.00)		40 (0.26)
No data	107 (4.80)	1 (0.07)	235 (6.06)	2 (0.03)	5 (0.73)		350 (2.28)
Type of road user							
Driver	1355 (60.74)	870 (59.47)	2266 (58.46)	4279 (60.57)	327 (47.74)	X^2 = 832.91; P<0.001	9097 (59.38)
Passenger	460 (2062)	258 (17.63)	351 (9.06)	1232 (17.44)	290 (42.34)		2591 (16.91)
Pedestrian	409 (18.33)	264 (18.05)	922 (23.79)	965 (13.66)	33 (4.82)		2593 (16.93)
Pillion rider	0 (0.00)	69 (4.72)	220 (5.68)	539 (7.63)	32 (4.67)		860 (5.61)
No data	7 (0.31)	2 (0.14)	117(3.02)	49(0.69)	3 (0.44)		178(1.16)
Type of vehicle*							
Bicycle/cycle rickshaw	75 (3.36)	35 (2.39)	149 (3.84)	141 (2.00)	47 (6.86)	X^2 = 1106.62; P<0.001	447 (2.92)
Bullock cart	6 (0.27)	58 (3.96)	2 (0.05)	3 (0.04)	9 (1.31)		78 (0.51)
Two-wheeler geared	1627 (72.93)	993 (67.87)	2375 (61.27)	5228 (74.01)	221 (32.26)		10444 (68.18)
Two-wheeler non-geared	411 (18.42)	96 (6.56)	337 (8.69)	373 (5.28)	67 (9.78)		1284 (8.38)
Auto rickshaw	131 (5.87)	75 (5.13)	194 (5.01)	139 (1.97)	44 (6.42)		583 (3.81)
Car	316 (14.16)	93 (6.36)	516 (13.31)	567 (8.03)	145 (21.17)		1637 (10.69)
Tempo traveller/van/city ride	115 (5.15)	29 (1.98)	34 (0.88)	103 (1.46)	2 (0.29)		283 (1.85)
Bus/minibus	108 (4.84)	25 (1.71)	72 (1.86)	113 (1.60)	106 (15.47)		424 (2.77)
Trucks/tractors	29 (1.30)	19 (1.30)	47 (1.21)	158 (2.24)	37 (5.40)		290 (1.89)
Lorry	112 (5.02)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.15)		113 (0.74)
Juggad	0 (0.00)	0 (0.00)	0 (0.00)	7 (0.10)	3 (0.44)		10 (0.07)
Others	40 (1.79)	66 (4.51)	22 (0.57)	72 (1.02)	3 (0.44)		203 (1.33)
No data	90 (4.03)	2 (0.14)	115 (2.97)	132 (1.87)	0 (0.00)		339 (2.21)
Not applicable	0 (0.00)	3 (0.21)	13 (0.34)	28 (0.40)	0 (0.00)		44 (0.29)
Parts of the body injured*							
Head	1780 (79.78)	692 (47.30)	23 (0.59)	2272 (32.16)	239 (34.89)	X^2 = 3690.71; P<0.001	5006 (32.68)
Face	0 (0.00)	409 (27.96)	51 (1.32)	2174 (30.78)	109 (15.91)		2743 (17.91)
Eyes	0 (0.00)	79 (5.40)	144 (3.72)	437 (6.19)	37 (5.40)		697 (4.55)
Ear, nose and throat	0 (0.00)	127 (8.68)	76 (1.96)	441 (6.24)	31 (4.53)		675 (4.41)
Neck	55 (2.47)	51 (3.49)	28 (0.72)	212 (3.00)	75 (10.95)		421 (2.75)
Thorax /Chest	91 (4.08)	49 (3.35)	152 (3.92)	508 (7.19)	56 (8.18)		856 (5.59)
Abdomen, lower back, lumber, spine & pelvis	99 (4.44)	152 (10.39)	167 (4.31)	338 (4.78)	87 (12.70)		843 (5.50)
Shoulder & upper arm (upper limb)	245 (10.98)	560 (38.28)	953 (24.59)	4079 (57.74)	290 (42.34)		6127 (40.00)
Elbow & forearm	149 (6.68)	5 (0.34)	0 (0.00)	114 (1.61)	65 (9.49)		333 (2.17)
Wrist & hand	260 (11.65)	48 (3.28)	0 (0.00)	99 (1.40)	52 (7.59)		459 (3.00)
Hip & thigh	99 (4.44)	23 (1.57)	0 (0.00)	86 (1.22)	32 (4.67)		240 (1.57)
Knee &lower leg (lower limb)	599 (26.85)	195 (13.33)	17 (0.44)	3028 (42.87)	230 (33.58)		4069 (26.56)
Ankle & foot	214 (9.59)	35 (2.39)	0 (0.00)	132 (1.87)	37 (5.40)		418 (2.73)
Multiple body regions	143 (6.41)	27 (1.85)	0 (0.00)	3 (0.04)	101 (14.74)		274 (1.79)
Injuries to unspecified part of trunk limb and body	1 (0.04)	1 (0.07)	0 (0.00)	2 (0.03)	14 (2.04)		18 (0.12)
Genitalia	0 (0.00)	214 (14.63)	773 (19.94)	70 (0.99)	1 (0.15)		1058 (6.91)
Others	0 (0.00)	32 (2.19)	14 (0.36)	214 (3.03)	0 (0.00)		260 (1.70)
No data	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)		0 (0.00)
Unknown	0 (0.00)	5 (0.34)	0 (0.00)	0 (0.00)	0 (0.00)		5 (0.03)
Outcome							
Alive (alive with rehabilitation +alive without rehabilitation)	1736 (77.81)	1376 (94.05)	3850 (99.33)	6122 (86.66)	541 (78.98)	X^2 = 1692.06; P<0.001	13625 (88.94)
Dead	385 (17.26)	28 (1.91)	20 (0.52)	198 (2.80)	42 (6.13)		673 (4.39)
Others (referred to higher centre or absconded)	0 (0.00)	20 (1.37)	6 (0.15)	274 (3.88)	102 (14.89)		402 (2.62)
No data	110 (4.93)	39 (2.67)	0 (0.00)	470 (6.65)	0 (0.00)		619 (4.04)

*: Multiple responses are obtained

Figures in parentheses are percentages

Table 3 Epidemiological characteristics of road traffic Injuries by study site

	Alive (n= 13625)	Dead (n= 673)	Others (n= 402)		Total (n= 14700)
Type of accident					
Self-fall/skid	4882 (94.80)	168 (3.26)	100 (1.94)	X^2 = 241.35; P<0.001	5150 (35.03)
Crash with pedestrian	2266 (91.89)	136 (5.52)	64 (2.60)		2466 (16.78)
Crash with parked vehicle	278 (97.20)	4 (1.40)	4 (1.40)		286 (1.95)
Crash with fixed obstacle	404 (91.61)	13 (2.95)	24 (5.44)		441 (3.00)
Crash with non-fixed obstacle	49 (90.74)	2 (3.70)	3 (5.56)		54 (0.37)
Crash between two vehicles	2279 (90.33)	213 (8.44)	31 (1.23)		2523 (17.16)
Crash with two or more vehicles	2140 (93.41)	63 (2.75)	88 (3.84)		2291 (15.59)
Crash with animal	670 (92.41)	21 (2.90)	34 (4.69)		725 (4.93)
Overturn of vehicle	291 (88.45)	11(3.34)	27 (8.21)		329 (2.24)
Others	263 (84.29)	22 (7.05)	27 (8.65)		312 (2.12)
Unknown /no data	103 (83.74)	20 (16.26)	0(0.00)		123 (0.84)
Type of road					
National highway	1454 (87.22)	113 (6.78)	100 (6.00)	X^2 = 425.15; P<0.00001	1667(11.34)
State highway	2161 (88.20)	212 (8.65)	77 (3.14)		2450 (16.67)
Urban road (other district road)	5492 (96.55)	73 (1.28)	123 (2.16)		5688 (38.69)
Major district roads	2144 (94.24)	131(5.76)	0 (0.00)		2275 (15.48)
Rural road	2241 (90.99)	120 (4.87)	102 (4.14)		2463 (16.76)
Unknown/no data	133 (84.71)	24 (15.29)	0 (0.00)		157 (1.07)
Sub-type of the road #					
One-way road	1421 (92.51)	115 (7.49)	0 (0.00)	X^2 = 12.50; P<0.001	1536 (21.66)
Two-way road	2049 (90.82)	207 (9.18)	0 (0.00)		2256 (31.82)
Single lane	995 (91.37)	94 (8.63)	0 (0.00)		1089 (15.36)
Two lane road	1129 (91.12)	110 (8.88)	0 (0.00)		1239 (17.48)
four or above-lane road	656 (93.98)	42 (6.02)	0 (0.00)		698 (9.84)
Crossroad/connector road	38 (100.00)	0	0		38 (0.54)
Roundabout	26 (96.30)	1 (3.70)	0 (0.00)		27 (0.38)
Railway crossing	3 (100.0)	0 (0.00)	0 (0.00)		3 (0.04)
Curve road/blind curve	4 (100.0)	0 (0.00)	0 (0.00)		4 (0.06)
Gradient road	17 (94.44)	1 (5.55)	0 (0.00)		18 (0.25)
T or staggered junction	5 (100.0)	0 (0.00)	0 (0.00)		5 (0.07)
Multiple junctions	5 (100.0)	0 (0.00)	0 (0.00)		5 (0.07)
Unknown/no data	149 (1.01)	23 (13.37)	0 (0.00)		172 (2.43)
Road conditions at the accident site*					
Safe/dry	11497 (92.61)	559 (4.50)	359 (2.89)	X^2 = 94.88; P<0.001	12415 (83.83)
Slippery (wet/oily/wet+oily)	497 (95.39)	10 (1.92)	14 (2.69)		521 (3.52)
Muddy	311 (96.28)	11 (3.41)	1 (0.31)		323 (2.18)
Rutted/potholed	855 (94.06)	35 (3.85)	19 (2.09)		909 (6.14)
Flooded	45 (91.84)	0 (0.00)	4 (8.16)		49 (0.33)
Snow	34 (87.18)	2 (5.13)	3 (7.69)		39 (0.26)
Work under progress	90 (84.11)	17 (15.89)	0 (0.00)		107 (0.72)
Others	29 (54.72)	3 (5.66)	21 (39.62)		53 (0.36)
Unknown/no data	272 (69.21)	34 (8.65)	87 (22.14)		393 (2.65)
Weather conditions at the time of the accident					
Clear	12419 (92.63)	604 (4.51)	384 (2.86)	X^2 = 20.51; P<0.01	13407 (91.20)
Hot/dry weather	330 (97.06)	10 (2.94)	0 (0.00)		340 (2.31)
Rainy	494 (93.92)	26 (4.94)	6 (1.14)		526 (3.58)
Fog/mist/smoke/smog	138 (92.00)	4 (2.67)	8 (5.33)		150 (1.02)
Severe winds	40 (95.24)	0 (0.00)	2 (4.76)		42 (0.29)
Landslide	13 (86.67)	2 (13.33)	0 (0.00)		15 (0.10)
Snow	64 (91.43)	4 (5.71)	2 (2.86)		70 (0.48)
Others	3 (100.00)	0 (0.00)	0 (0.00)		3 (0.02)
Unknown/no data	124 (0.91)	23 (15.65)	0 (0.00)		145 (1.00)
Light condition at the time of the accident					
Excess light	630 (98.59)	9 (1.41)	0 (0.00)	X^2=1682.31; P<0.001	639 (4.34)
Sufficient light /daylight	8451 (91.77)	483 (5.25)	274 (2.98)		9208 (62.64)
Partial light/semi-darkness	1244 (94.81)	41(3.13)	27 (2.06)		1312 (8.92)
Insufficient light/darkness	2955 (93.96)	98 (3.12)	92 (2.93)		3145 (21.39)
Glare effect from front vehicle light	42 (93.33)	1 (2.22)	2 (4.44)		45 (0.31)
Fog/dust	8 (61.54)	2 (15.38)	3 (23.08)		13 (0.09)
Others	35 (87.50)	1 (2.50)	4 (10.00)		40 (0.27)
Unknown/no data	260 (87.25)	38 (12.75)	0 (0.00)		298 (2.03)

Table 3 Epidemiological characteristics of road traffic Injuries by study site (continued)

	Alive (n= 13625)	Dead (n= 673)	Others (n= 402)		Total (n= 14700)
Type of road user					
Driver	8124 (93.53)	358 (4.12)	204 (2.35)	X^2=132.43; P<0.001	8686 (59.09)
Passenger	2256 (90.68)	143 (5.75)	89 (3.58)		2488 (16.93)
Pedestrian	2314 (92.23)	134 (5.34)	61 (2.43)		2509 (17.07)
Pillion rider	786 (92.91)	13 (1.54)	47 (5.56)		846 (5.76)
Unknown/no data	135 (84.38)	24 (15.00)	1 (0.63)		160 (1.09)
Other	10 (90.91)	1 (9.09)	0(0.0)		11 (0.07)
Type of vehicle*					
Bicycle/ cycle rickshaw	394 (93.36)	11 (2.61)	17 (4.03)	X^2=106.35; P<0.001	422(2.87)
Bullock cart	34 (82.93)	5 (12.20)	2 (4.88)		41 (0.28)
Two-wheeler geared	9196 (93.75)	373 (3.80)	240 (2.45)		9809 (66.73)
Two-wheeler non-geared	1115 (92.68)	73 (6.07)	15 (1.25)		1203 (8.18)
Auto rickshaw	492 (93.71)	20 (3.81)	13 (2.48)		525 (3.57)
Car	1236 (89.05)	78 (5.62)	74 (5.33)		1388 (9.44)
Tempo traveller/van/city ride	189 (86.30)	22 (10.05)	8 (3.65)		219 (1.49)
Bus/minibus	316 (89.01)	24 (6.76)	15 (4.23)		355 (2.41)
Truck/tractors	181 (84.58)	23 (10.75)	10 (4.67)		214 (1.46)
Lorry	15 (78.95)	4 (21.05)	0 (0.00)		19 (0.13)
Juggad	0(0.00)	0 (0.00)	0 (0.00)		0 (0.00)
Others	198 (92.96)	8 (3.76)	7 (3.29)		213 (1.45)
Unknown/no data	227 (87.64)	31 (11.97)	1 (0.39)		259 (1.76)
Not applicable	32 (96.97)	1 (3.03)	0 (0.00)		33 (0.22)

*: Multiple responses are obtained
#: Data were available for 7090 cases only
Figures in parentheses are percentages

3.2. Accident details

The epidemiological details of RTIs are presented in table 2. Overall, the most prevalent kind of accident (34.87%) was a self-fall/skid, followed by a collision involving two cars (25.77%) and a collision with a pedestrian (16.59%). Approximately 7% of the collisions involved two or more cars. Accidents involving animals resulted in 5.09% of injuries, whereas static objects or parked cars accounted for 4.91% of injuries. Less than 1% of injuries occurred due to a collision with non-fixed barriers. In several cases, vehicle roll over was also reported as a mechanism of injury (1.60%). The largest number of self-fall/skid cases were reported in Tehri-Garhwal (49.78%). Chennai reported a crash between vehicles (36.49%) as the most common mechanism of accident, followed by self-fall/skid (33.98%) and a crash between pedestrians (19.95%). Delhi reported self-fall (36.74%) as the major type of accident, followed by a crash with a pedestrian and a crash with two or more vehicles. The differences across the sites in the distribution of type of accidents are significant (P<0.001).

3.3. Road-related details

The majority of injuries occurred on urban roads or other district roads (46.01%), followed by state highways (16.92%), rural roads (16.79%), and national highways, accounting for 11.35% of injuries (Table 2). Following the same pattern, Delhi and Jaipur reported the maximum number of injuries/accidents on urban roads. Unlike the overall scenario, national highways account for the maximum number of injuries in Tehri-Garhwal. State highways took one-third of the total accidents at Chennai and Chittoor. The distribution of the type of roads where RTAs occurred varies across the study sites, and this variation is significant (P<0.01).

The majority of accidents occurred on two-lane roads (31.63%), followed by single-lane roads (25.05%) and one-way roads (14.11%).

Around 15.5% occurred on two-way roads. Four or above lane roads contributed to 12.66% of injuries, and 4.88% occurred on the crossroads or the connector roads. The differences between the study sites in the distribution of sub-types of road are also significant (P<0.001).

Overall, road conditions were safe and dry at the accident site in 84.59% of cases, and 91.27% of cases were reported when the weather conditions were clear. The Tehri-Garhwal site contributes differently, and muddy roads accounting for 16.06% of cases followed by 9.93% of cases at rutted/potholed roads and 8.61% at slippery roads. Rainy weather accounted for 125 cases (18.25%) at Tehri-Garhwal which is four times the number of cases usually caused under rainy weather conditions. As in the hilly area, fog/mist/smog/smoke was also reported two times more than the overall proportion in Tehri-Garhwal. Excess light at the time of the accident was reported by 599 respondents (3.91%), whereas one in every four respondents (29.87%) reported insufficient or partial light at the time of the accident. The differences between the study sites by road, weather and light conditions are highly significant (P<0.001) (Table 2).

3.4. Person-related and vehicle-related information

In RTAs, the majority of victims are drivers (59.38%). Around one-third of the road users (33.94%) injured were either passengers or pedestrians. Pillion riders share 5.61% of the total injuries. Mostly, two-wheelers (geared or non-geared) were involved in the accident as they share the biggest percentage (75.54%) of the total accidents. Among the total injured, 65% were either drivers or pillion riders. There is variation across the sites in the type of road users and type of vehicle, and these differences are significant (P<0.001) (Table 2).

3.5. Injury-related information

The data revealed that multiple sites/body parts are involved, and the shoulder/upper arm is the most common body region injured (40%), followed by the head (32.68%) and lower limbs (26.56%) (Table 2). Injuries occur on the face in 17.91% of patients. Several body parts are injured due to RTAs, varying across the study sites (P<0.001). 4.39% of RTIs have resulted in death of individuals, 88.94% of individuals are alive, 2.62% have either been referred to other facilities or have absconded, and for 4.04% of the victims, no data is available. This distribution varies significantly across different sites (P<0.001).

3.6. Outcome of injury

The epidemiological characteristics of RTIs by outcome are presented in table 3. The analysis includes data from 14,700 injured individuals for whom outcomes were reported during surveillance. Of these, 13,625 (92.68%) were injured but alive, with or without rehabilitation; 673 (4.58%) had died, and 402 (2.73%) were either referred to a higher centre or absconded from the surveillance point. An additional 619 cases were not included in the table, as no data was available for 410 participants, and 209 reported unknown outcomes.
Of the types of accidents, higher proportions of victims in the group of crashes between two vehicles reported more deaths (8.44%), followed by crashes of vehicles with pedestrians (5.52%) (Table 3). Similarly, state (8.65%) and national highways (6.78%) contribute higher death rates than the other types of roads. Roads that were under construction (15.89%); and roads that had landslides contributed significantly (15.89% and 13.33% respectively). The climate with fog and dust caused more deaths among the RTI victims. These differences are significant (P<0.001). A higher proportion of passengers (5.75%), followed by pedestrians (5.34%), died more than other categories (Table 3). Drivers shared the higher proportion (93.5) victimized with RTIs. Two-wheelers, geared or non-geared, contribute to the maximum number of deaths (3.01%) among all types of vehicles involved in the accidents, followed by cars (0.53%). The differences in RTA outcome by vehicle type are also significant (P<0.001).

4. Discussion

RTIs are recognized globally as a significant public health problem. The need for care and injury characteristics vary across five different cities in India. The fatality rate among RTA victims depends on various factors such as climate, vehicle type, road conditions, and the health system's response. This study underscores the necessity for an effective trauma care system, highlighting a significant imbalance in trauma care capabilities among states during the capacity assessment of trauma care in India (16). Trauma care capacity varies significantly between developing and developed countries, impacting outcomes for injured individuals. In developing countries like India, Ghana, and Sierra Leone, trauma care systems often face substantial deficiencies in resources, training, and infrastructure. For instance, a study assessing trauma care in Ghana from 2004 to 2014 found significant improvements in available resources, yet critical shortages in chest tubes, diagnostics, and specialized care persisted (17). Similarly, trauma care facilities in Sierra Leone were found lacking in essential capabilities such as resuscitation and fracture repair (18). In contrast, developed countries typically have more robust trauma care systems with better access to necessary equipment and trained personnel (19). This disparity underscores the need for targeted interventions and international support to enhance trauma care capacity in low- and middle-income countries, ensuring timely and effective treatment to reduce preventable deaths and disabilities.
The personal characteristics of the victims also determine the outcome of the accident. The younger group (<40 years) is more involved in accidents and trauma, accounting for 69% of all patients. This is consistent with other research demonstrating that injuries occur more frequently in the productive age group, which is more vulnerable to injuries (20-23). Younger age groups are significantly involved in RTAs and trauma. Research shows that RTAs are a major cause of morbidity and mortality among children and adolescents. For instance, a study found that 59% of young victims of RTAs were pedestrians, while 41% were passengers, with significant psychological and physical impacts noted among these groups (24). Another study highlighted that children under 14 years involved in RTAs often suffered severe injuries, with the head and neck being the most commonly affected areas (25). Additionally, research indicated that young drivers and road users have higher injury severity and mortality rates compared to adults, emphasizing their vulnerability in traffic-related incidents (26). This study reported that the majority of the vehicles involved in the accidents were two-wheelers, geared or non-geared. These results are consistent with prior research (27,28). Two-wheelers are predominantly involved in RTAs, contributing significantly to RTIs and fatalities. Studies have shown that powered two-wheelers are at a higher risk of accidents due to their inherent vulnerability. In urban areas, powered two-wheelers account for a substantial proportion of traffic collisions, with issues such as poor visibility and the

lack of protective structures exacerbating their risk (29).
Research in Italy indicated that two-wheelers were frequently involved in RTAs, often resulting in severe injuries to the riders (30). Similarly, data from Europe highlight that powered two-wheelers represent a significant portion of road traffic fatalities, underscoring the critical safety challenges associated with their use (31). Males were primarily involved when contrasted with females in our data. Comparable results were seen in studies in India (32). Research indicates that young male drivers are significantly overrepresented in traffic accidents due to higher levels of risk-taking behaviour and lower perceptions of danger in hazardous situations (33). Data from France show that males account for 75% of traffic fatalities and are involved in more severe injuries across various modes of transport, including cars and two-wheelers (34). A study in Qatar found that male drivers had higher accident rates than female drivers, further supporting the trend of greater male involvement in RTAs (35). Additionally, research in Finland revealed that the pattern of accidents involving young and middle-aged male drivers remained consistent over a 16-year period, with males more likely to engage in high-risk behaviours like speeding and alcohol consumption (36).
Driver or pedestrian education programmes are essential to reduce crash rates. The only effective way to get most motorists to use safety belts and motorcyclists to wear helmets is with strict laws enforcing their use. Lack of safety measures and restraint system use (e.g., seat belt and helmet use) were also identified as major predictors of RTI severity and fatality (37). Casualty rates shifted strikingly across Indian states and association domains. Past investigations have discovered car accidents to be under-announced in India by 5% for deaths and over half for grave injuries (38). Partitioned four or two-lane roads are advocated on the premise that these would dispose head-on crashes. The main reason we do not find a reduction in these injuries implies that numerous vehicles drive on the incorrect route on partitioned roadways. This is presumably because farm trucks and different vehicles go the incorrect way when they exit from the side of the road organizations, and the cut in the middle is excessively far away (39). Thus, incorrect movement of vehicles on roads significantly contributes to road traffic accidents.
Studies indicate that human errors, such as improper vehicle control and poor decision-making, are critical factors leading to accidents. For example, an investigation into vehicle movements on curved sections of urban motorways identified that improper handling and eye movement coordination are linked to a higher frequency of accidents (40). Another study on complex vehicle movements during road transport expertise highlighted that incorrect manoeuvres, especially in non-standard conditions, often result in accidents (41). Additionally, research on the mechanical effects of vehicles at corners found that inappropriate speeds and oversteering or understeering during turns can lead to vehicle rollovers and collisions (42).
Another important finding of the study is that there are significant variations across the study sites located in different states of India. The study showed differences in the type of RTAs and resultant injuries. India exhibits substantial interstate variations in road accidents and road traffic injuries, influenced by a myriad of factors, including socioeconomic development, infrastructure quality, and enforcement of traffic regulations. Studies indicate that states like Tamil Nadu, Maharashtra, and Uttar Pradesh report higher incidence rates of road traffic accidents and fatalities compared to other regions. For instance, Tamil Nadu accounted for the highest number of road accidents in the country, while states like Kerala and Punjab have implemented more effective road safety measures, leading to relatively lower fatality rates (43).
Additionally, the disparity in economic development across states correlates with varying injury and death rates from road traffic incidents.
States with higher net domestic product often show higher injury and death rates, demonstrating an inverted U-shaped relationship between economic growth and road traffic injuries (44). The burden of road traffic injuries in India is not uniformly distributed, with significant variations observed in the patterns and outcomes of these incidents across different states (45).
human based factors rather than mechanical causes contribute to India's increasing number of RTAs. Our examination affirms that street conditions were protected and dry at the mishap site, and a larger part of the wounds happened on two-lane roads. It can be argued that the way forward in minimizing incidents around the country might be well-structured programs involving the general public. Social activism is, therefore, critical when political, economic, and social decisions are endorsed and affected by a person or community. In an adverse climate, such activism seeks to obtain support to make the desired change for the better. Social advocacy is basic when political, monetary, and social choices are supported and influenced by an individual or local area. In an antagonistic environment, such advocacy looks to acquire back to roll out the ideal improvement to improve things (46). Road traffic accidents in developing countries are caused by a combination of factors, including rapid motorization, poor road conditions, and inadequate enforcement of traffic regulations. A study highlighted that human errors, such as speeding and drunk driving, is a major contributor to accidents (47). Furthermore, mechanical failures, particularly tyre problems, are significant causes of fatal crashes (48). Poor infrastructure, such as inadequate road design and maintenance, exacerbates the problem (49).
The lack of institutional management and policy implementation also plays a critical role in the high incidence of road traffic accidents (50).

5. Conclusion

Road traffic fatalities in Indian states embrace a significant increase in motorization levels and urbanization. This study was carried out to better understand the method of trauma, the pattern of injuries, and the result of RTAs so that effective preventive and comprehensive management may be implemented. The burden of RTIs is partly due to an increase in vulnerable road users, such as pedestrians and two-wheelers. RTAs are the most common cause of trauma, affecting primarily adults of productive age. Study findings suggest more accidents occur in safe conditions.

6. Declarations

6.1. Acknowledgement

None.

6.2. Authors' contribution

All authors contributed equally to the study.

6.3. Conflict of interest

The Authors declare no conflict of interest.

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