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Road traffic injury mortality and its mechanisms in India: nationally representative mortality survey of 1.1 million homes

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Keywords: Road traffic injury; verbal autopsy; India; low- and middle-income countries

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ABSTRACT:

Objectives: To quantify and describe the mechanism of road traffic injury (RTI) deaths in India.

Design: We conducted a nationally representative mortality survey where at least two physicians coded each non-medical field staff's verbal autopsy reports. RTI mechanism data were extracted from the narrative section of these reports.

Setting: 1.1 million homes in India.

Participants: Over 122 000 deaths at all ages from 2001-2003.

Primary and secondary outcome measures: Age- and sex-specific mortality rates, place and timing of death, modes of transportation, and injuries sustained.

Results: The 2299 RTI deaths in the survey correspond to an estimated 183 600 RTI deaths or about 2% of all deaths in 2005 nationally, of which 65% occurred in males between the ages of 15-59 years. The age-adjusted mortality rate was greater in males than in females, in urban than in rural areas, and was notably higher than that estimated from national police records. Pedestrians (68 000), motorcyclists (36 000), and other vulnerable road users (20 000) constituted 68% of RTI deaths (124 000). The majority of all RTI deaths occurred at the scene of collision (1005/1733, 58%), within minutes of collision (883/1596, 55%), and/or involved a head injury (691/1124, 62%). Compared to non-pedestrian RTI deaths, about 55 000 (81%) of pedestrian deaths were associated with less education and living in poorer neighbourhoods.

Conclusions: In India, RTI cause a substantial number of deaths, particularly among pedestrians and other vulnerable road users. Interventions to prevent collisions and reduce injuries might address over half of the RTI deaths. Improved pre-hospital transport and hospital trauma care might address just over a third of the RTI deaths.

ARTICLE SUMMARY

Article focus

- To directly estimate the age- and sex-specific mortality rates and describe the place and timing of death, modes of transportation, and injuries sustained for road traffic injury (RTI) deaths in India using a nationally representative mortality survey of 1.1 million homes.

Key messages

- Road traffic injuries cause a substantial number of avertable deaths, particularly in males of productive working age and among pedestrians and other vulnerable road users.
- Preventative interventions should be emphasized as the majority of all RTI deaths occurred at the scene of collision, within minutes of collision, and/or involved a head injury.
- Properly designed mortality survey with verbal autopsy narratives can provide much-needed data to assist RTI prevention efforts.

Strengths and limitations of this study

- This study is the first nationally representative survey of the causes of death in India and overcomes limitations of existing data sources including regional injury surveys, hospital series, and national police reports.
- Limitations of the study include potential misclassification of deaths by physician coders, the use of layperson narratives with a potential for recall bias and inaccuracies, and limited ability to forward project study results given the rapid changes in motorization in India.

INTRODUCTION

Road traffic injuries (RTI) are a large and growing public health burden, especially in low-and middle-income countries (LMIC) where 90% of the world's RTI deaths are estimated to occur.[1] There are few high-quality epidemiologic data on RTI to guide the development, implementation, and surveillance of evidence-based policy and programs in LMICs.[2-4]

The number of RTI deaths in India is projected to rise with increasing motorization.[1,5] Aside from a few regional injury surveys,[6-11] the current data on the numbers and mechanisms of RTI deaths in India rely on police or hospital records, both of which can substantially underestimate death rates in the poor, rural, and uneducated people who still constitute large proportions of the Indian population.[2-4,12,13]

The World Health Organization (WHO), using indirect modeling methods, estimated about 202 000 RTI deaths in India in 2004.[14,15] No study has validated this estimate with direct measurement nor documented detailed RTI mechanism for India nationally. Here, we estimate the regional, age- and sex-specific mortality rate and risk of RTI death in India using data from the Million Death Study (MDS). We also report the modes of transportation, place and timing of death, and injuries sustained in RTI deaths.

METHODS

Study Design: The MDS is an on-going nationally representative survey designed to determine the causes and risk factors of death in India, organized by the Registrar General of India (RGI). The design, methodology, and preliminary findings of the MDS have been described elsewhere.[16-19] In brief, the MDS used an enhanced version of verbal autopsy (known as the routine, reliable, representative, re-sampled household investigation of mortality with medical evaluation or RHIME) to monitor a nationally representative sample of 1.1 million households in the Sample Registration System (SRS). Within six months of every death occurring in these households from 2001-3, a trained, nonmedical RGI surveyor interviewed a relative or close-acquaintance of the deceased to obtain the symptoms and events around the death using structured questions and a local language narrative guided by a specific symptom list. These records were converted into electronic records and emailed to two of 140 trained physicians who, independently and anonymously, assigned an underlying cause of death (with allocation determined randomly based only on the physician's ability to read the local language), using guidelines for the major causes of death.[20] Records were assigned cause of death in three-digit International Classification of Diseases and Related Health Problems, 10th revision (ICD-10).[21] Records where coders disagreed on the cause of death underwent anonymous reconciliation. Continuing disagreements were adjudicated by a third senior physician. Five percent of households were randomly resurveyed and the results were consistent within families of ICD-10 codes.[16] Participation in the SRS is on a voluntary basis and oral consent was obtained under the confidentiality and consent procedures of the Registration of Births and Deaths Act, 1969.

Road Traffic Injury Deaths: The RTI deaths in this study were of people who died between 2001 and 2003 with a final assigned ICD-10 code within V01-V89. We translated the open-ended narratives into English from 14 local languages, and systematically extracted the modes

of transportation, place and timing of death, and injuries sustained from the narratives. For these four data elements, there were substantial inter-rater agreement (kappa statistic > 0.69) between two investigators and two research assistants who were trained and independently extracted data from the narratives of a random 10% of RTI deaths (data not shown). The two research assistants then independently extracted data from all narratives. Adjudication was done by an investigator (M.H) for discrepancies in extracted data.

Analysis: The age and sex-specific proportion of RTI deaths within the 2001-2003 survey was applied to the 2005 United Nations (UN) estimates of the number of deaths from all causes in India, after weighting for sampling probability.[22] The 2005 UN death estimates were used so as to correct for the slight undercounts reported in the total death rates in the SRS[23,24] and to account for the 12% of enumerated deaths without completed field visits (mostly due to out-migration of the family or from incomplete field records). The proportion of these missed deaths was similarly dispersed across sex, age, and states. Use of 2003 or 2004 UN death totals yielded nearly identical results (data not shown). The 99% confidence intervals (99%CI) for mortality rate were calculated based on the weighted number of study deaths. State- and rural/urban-specific estimates of the number, mortality rate, and lifetime risk of RTI death were calculated by partitioning the UN national death totals according to relative SRS death rates as previously described.[18,25,26] Urban and rural status was defined according to the Census of India. Logistic regression was used to compare the socio-demographic traits of pedestrian and non-pedestrian RTI deaths. Household fuel type was used as a measure of community wealth: high asset neighbourhoods had >50% of households that used gas, electricity, or kerosene; low asset or poor neighbourhoods used primarily coal, firewood, or other. Attributable proportion was calculated for traits of pedestrian deaths compared to non-pedestrian RTI deaths.

The MDS received ethics approval from the review boards of the Post-Graduate Institute of Medical Education and Research in Chandigarh, India; St Michael's Hospital in Toronto, Canada; and the Indian Council of Medical Research's Health Ministry's Screening Committee.

RESULTS

The 2299 RTI deaths in the 2001-2003 survey correspond to an estimated 183 600 (99%CI 173 800-193 400) RTI deaths in India in 2005. The majority of these RTI deaths occurred in males (152 100 deaths, 82.8%; table 1). The age-standardized RTI mortality rate for males (26.2 per 100 000, 24.6-27.7) was higher than for females (5.7 per 100 000, 5.0-6.4). While the RTI mortality rate increased with age in both genders, the largest number of RTI deaths occurred in males between 15-59 years of age (118 900, 64.8%).

At these death rates and in the theoretical absence of other causes of death, males in India had a 2.1% (2.0-2.3) risk of dying from RTI before age 70, with the highest risks at ages 30-59 years; females had a 0.5% (0.4-0.5) risk of dying from RTI before age 70. Males in Haryana, Punjab, Tamil Nadu, and Uttar Pradesh had significantly higher risks (3.0-4.1%) than the national risk (figure 1). In contrast, males in Bihar, Jharkhand, Andhra Pradesh, Orissa, Gujarat, and West Bengal had significantly lower risks (1.3-1.6%) than the national risk of RTI deaths. Males living in urban areas had slightly higher age-standardized mortality rates and risks of RTI deaths (27.6 per 100 000; 2.4%, 2.1-2.6) compared to males living in rural areas (24.9 per 100 000; 2.0%, 1.8-2.1). By contrast, female RTI mortality rates and risks before age 70 varied much less across states and were similar in rural and urban areas (data not shown).

	Study deaths, 2001-2003				All India, 2005			
	Number of RTI deaths / all coded deaths	Proportion RTI*	Rural (%**)	Two coders immediately agree	All deaths / population (millions, 2005 UN estimates)	Estimated RTI deaths§, thousands	RTI death rateΨ per 100 000 (99% CI)	Period risk for RTI death†
Male - age in years								
0-4	44 / 11719	0.4%	37 (76.7)	44	1.2 / 67	4.9	7.4 (6.5-8.4)¶	0.04%
5-14	97 / 1926	5.2%	86 (84.1)	87	0.2 / 129	8.5	6.6 (4.9-8.3)	0.1%
15-29	605 / 4727	13.0%	462 (68.9)	558	0.4 / 163	47.1	28.9 (25.9-31.9)	0.4%
30-44	529 / 6817	7.7%	385 (67.0)	477	0.6 / 115	43.8	37.9 (33.7-42.1)	0.6%
45-59	356 / 11731	3.0%	249 (60.9)	312	0.9 / 73	28.0	38.4 (33.2-43.6)	0.6%
60-69	149 / 12120	1.2%	117 (71.8)	133	0.9 / 24	10.6	44.0 (34.6-53.4)	0.5%
>70	123 / 18732	0.6%	106 (81.2)	98	1.3 / 14	9.1	64.5 (49.1-80.0)	--
All ages	1903 / 67772	2.8%	1442 (68.9)	1709	5.3 / 585	152.1	26.2	2.1%†
(% or 99% CI)				(89.8%)		(143.2-161.0)	(24.6-27.7)	(2.0-2.3)
Female - age in years								
0-4	50 / 11492	0.4%	46 (93.4)	45	1.2 / 61	5.0	8.1 (7.1-9.1)¶	0.04%
5-14	44 / 1955	2.3%	38 (80.1)	43	0.2 / 118	3.8	3.2 (2.0-4.4)	0.03%
15-29	72 / 4394	1.5%	53 (60.5)	63	0.3 / 150	5.3	3.5 (2.4-4.6)	0.1%
30-44	59 / 4055	1.4%	39 (59.0)	50	0.3 / 106	4.4	4.1 (2.7-5.5)	0.1%
45-59	70 / 6402	1.1%	55 (70.9)	61	0.5 / 69	6.0	8.6 (5.9-11.3)	0.1%
60-69	54 / 9016	0.6%	42 (68.6)	52	0.6 / 25	3.7	14.8 (9.8-19.9)	0.2%
>70	47 / 17343	0.3%	33 (61.8)	35	1.3 / 16	3.5	21.6 (13.4-29.9)	--
All ages	396 / 54657	0.7%	306 (69.8)	349	4.5 / 546	31.5	5.7	0.5%†
(% or 99% CI)				(88.1%)		(27.5-35.6)	(5.0-6.4)	(0.4-0.5)
Total male and female, <70 years	2129 / 86354	2.4%	1609 (68.5)	1925	7.2 / 1100	171.0	15.5	1.3%†
(% or 99% CI)				(90.4%)		(161.5-180.4)	(14.7-16.4)	(1.3-1.4)
Total male and female, all ages	2299 / 122429	1.8%	1748 (69.0)	2058	9.8 / 1131	183.6	16.2	1.3%†
(% or 99% CI)				(89.5%)		(173.8-193.4)	(15.4-17.1)	(1.3-1.4)

Table 1: Road traffic injury deaths in the present study and estimated national totals for 2005, by age and gender. *Proportion of RTI deaths compared to all deaths, weighted by state and residence (rural/urban). **Percentage rural is weighted by state and residence (rural/urban). §Obtained by multiplying the United Nations estimated total deaths in 2005 by the weighted proportions. ΨAge standardized to the 2005 United Nations estimated Indian population; 99% CI shown are calculated based on weighted number of study deaths, which result in wider CI than those based on physician agreement. †Annual RTI death rate multiplied by the duration of age range, except for the lifetime risk which is calculated between 0-69 years by summation of the age specific period risks. ¶Crude death rate.

Vulnerable road users are those without a rigid barrier protecting against traumatic forces and include pedestrians, motorcyclists, bicyclists, and three-wheelers. They constituted a majority (68%; n=124 000, 99%CI 115 000-131 000) of RTI deaths, led by pedestrians (37%; n=68 000, 62 000-73 000) and motorcyclists (20%; n=36 000, 31 000-40 000) (figure 2). Drivers and passengers of motorized four-wheelers comprised 16% (n=31 000, 27 000-35 000) of RTI deaths. By contrast, the 2005 police reports, which use a different but compatible classification system to ICD-10, recorded only 33 000 vulnerable road user deaths and only 9000 pedestrian deaths. The most common types of vehicle to collide into the decedents were heavy transport vehicles and buses (37%; n=68 000, 61 000-74 000), followed by cars and vans (15%; n=28 000, 24 000-32 000). Single-vehicle incidents comprised 9% of deaths (n=17 000, 14 000-20 000). The most frequent combinations, resulting in 23% (n=42 000, 37 000-47 000) of RTI deaths, were collisions of heavy transport vehicles or buses with pedestrians and motorcyclists (data not shown).

The place and timing of death were described in the narratives of 1733 (75%) and 1596 (69%) of the RTI deaths respectively (figure 2; see supplementary table 1 for a summary of missing data from the narratives with respect to deceased characteristics). For these narratives, only the study proportion and not national estimates were made. Most RTI deaths occurred at the scene of collision (58%, 1005/1733) or instantly, defined as within 5 minutes (55%, 883/1596). Only 3% (45/1733) were labeled as potentially avertable with better pre-hospital transport as they occurred on scene but not instantly. Another 35% of deaths occurred en route (7%, 124/1733) or in hospital (28%, 481/1733).

Injuries sustained by the deceased were reported from 1124 narratives (49%). Head injuries were the most commonly reported (62%, 691/1124), of which 76% (524/691) were reported as isolated head injuries (figure 3). A greater percentage of motorcyclists (78%, 188/241) had head injuries reported compared to non-motorcyclists (57%, 457/807). After adjusting for age, sex, rural/urban, neighbourhood asset, and education, bicyclists and motorcyclists were more likely to have head injuries reported compared to non-vulnerable road users (adjusted OR 1.7, 1.2-2.5) (supplementary table 2).

Compared to non-pedestrian RTI deaths, pedestrian deaths occurred to those who had less education (or in the case of children age <15 years, have less educated parents) (adjusted OR 2.9, 99%CI 2.0-4.2), lived in poorer neighbourhoods (1.7, 1.1-2.5), were children or elderly adults (<15 years: 2.9, 1.8-4.5; >59 years: 1.7, 1.2-2.4), were female (1.5, 1.2-2.2), and lived in urban areas (1.5, 1.1-2.2) (table 2). If pedestrian deaths had the same proportion of secondary or higher education as non-pedestrian RTI deaths, there would be 406/825 (49%) fewer pedestrian deaths, corresponding to approximately 33 000 deaths nationally in 2005. The corresponding attributable proportion for living in richer versus poorer neighbourhoods would be 265/825 (32%) or approximately 22 000 deaths nationally. Within the narratives we could code, there were no differences between pedestrians and non-pedestrian RTI deaths in timing of death, place of death, reported injuries, or reported routine use of alcohol or smoking (data not shown).

	Pedestrian / Non-Pedestrian Total=825/1280	Adjusted OR^ (99% CI)	Attributable Pedestrian Deaths (% of all 825 pedestrian deaths)
Education*			
Secondary or higher	112/382	ref	
Primary or middle	248/450	1.8 (1.3-2.6)	110] 406 (49%)
Below primary	451/423	2.9 (2.0-4.2)	296
Unknown	14/25	1.6 (0.6-4.2)	N/A
Neighbourhood Asset			
High	137/320	ref	
Low	643/895	1.7 (1.1-2.5)	265 (32%)
Unknown	45/65	1.5 (0.8-2.8)	N/A
Age in years			
15-59 (driving ages)	497/1046	ref	
<15 (children)	144/74	2.9 (1.8-4.5)	94] 170 (21%)
>59 (elderly adults)	184/160	1.7 (1.2-2.4)	76
Sex			
Male	621/1121	ref	
Female	204/159	1.5 (1.1-2.2)	68 (8%)
Location			
Rural	643/962	ref	
Urban	182/318	1.5 (1.1-2.2)	61 (7%)
Occupation			
Salaried / Wage Earner / Professional	229/517	ref	
Cultivator / Agricultural labour / Other	162/300	0.9 (0.6-1.3)	N/A
Non-worker / Children <15 years	433/463	1.2 (0.9-1.6)	N/A
Unknown	1/0	N/A	N/A
Routine Alcohol Use**			
No	494/877	ref	
Yes	145/260	1.1 (0.7-1.5)	N/A
Unknown	42/69	1.0 (0.5-1.9)	N/A

Table 2: Characteristics of pedestrian RTI deaths and attributable proportions. *Education of deceased adults or, in cases of deceased children <15 years, education of respondent. **Excludes 218 children. ^Odds ratios are adjusted for all other variables in this table except for alcohol use; the odds ratios for alcohol use are adjusted for all other variables in this table.

DISCUSSION

RTI is an important cause of death in India, causing 183 600 deaths in 2005, or about 2% of all deaths. Much of the deceased were men between ages 15-59 years. Males had a four-fold higher cumulative risk of RTI death compared to females before the age of 70. Among the major

states, there was approximately 3-fold variation in the age-standardized RTI death rate and cumulative risk for males.

Our estimated number of RTI deaths is more than 50% greater than the 118 265 deaths reported in the official police statistics of the National Crime Records Bureau (NCRB) in 2005.[27] Compared to our estimates, the extent of under-reporting of the crude death rate in major states by NCRB ranged from <1% to about 80% (supplementary table 3). Existing regional population-based injury surveys in India support our findings and also report higher crude RTI death rates than NCRB statistics.[8,11] Under-reporting of RTI deaths in police statistics has been reported in India and other LMIC.[28-30] A study in urban India comparing both hospital- and community-based RTI data to police records identified factors contributing to under-reporting that included the deceased believed to be at fault, collision resulting from hit-and-runs, limited police resources, and the lack of a standard police reporting protocol by hospitals.[28] The factors contributing to police under-reporting, especially in rural India, require further examination. Our estimated number of RTI deaths in 2005 was consistent with the WHO estimate for 2004.[14] However, we observed a slightly higher male proportion (83% MDS vs. 77% WHO, all ages) and a higher proportion of male deaths between 15-59 years (65% MDS vs. 61% WHO).

Almost three-quarters of all RTI deaths in India were of pedestrians and other vulnerable road users. In contrast, a much lower proportion (27%) was reported by the NCRB (figure 2). This difference equated to 59 000 pedestrian and 32 000 other vulnerable road user deaths that were not included in the 2005 NCRB records. Existing RTI studies based on regional surveys and hospital series also reported a high proportion (>60%) of vulnerable road user deaths similar to our findings.[11,12,30-32] Since the majority of vulnerable road users were pedestrians, our findings suggested that RTI deaths in individuals who were less educated, poor, female or live in urban areas may have been disproportionally excluded from the NCRB records. While poverty and education are not likely to be in the direct causal pathway of pedestrian deaths, they nonetheless point to other associated risk factors. Indeed, 55 000 pedestrian deaths in 2005 (81%) was associated with lower education or living in poorer neighbourhoods compared to non-pedestrian RTI deaths. While the less educated and the poor likely travelled more often by foot, they might also be exposed to undetermined environmental (neighbourhoods with unsafe roads), biological (poor vision or decreased mobility due to poor health), and behavioral (alcohol or other substance use) risk factors for pedestrian death.[12,33,34] Further studies are needed to better understand pedestrian deaths in LMIC.

Over half of RTI deaths occurred instantly at the scene of collision and/or had head injury reported. Thus, investments in primary and secondary prevention could potentially avert the greatest proportion of RTI deaths. To address the high proportion of instant deaths and head injuries among RTI deaths in India, specific interventions that are effective and based on studies in LMIC should be emphasized; these may include speed bumps, motorcycle helmets, and increasing fines and license suspensions for rule infractions.[33] In contrast, improving pre-hospital transport and hospital trauma care, could only potentially affect the 38% who died on scene with delayed hospital transport (3%), en route to hospital (7%), or in hospital (28%).

Our study is the first nationally representative survey of the causes of death in India. The simple descriptive statistics provide clear evidence on the large and avertable burden from RTI, particularly among productive age adults and pedestrians. To the best of our knowledge, only one recent study in Vietnam has used similar methods to analyze RTI deaths and policy implications on a national scale.[35]

Our study faced certain limitations. First, we might have misclassified certain causes of death including suicide as RTI deaths. However, the extent of misclassification should be minimal since the RHIME verbal autopsy method was shown to be robust in discerning between types of injury deaths[36] and since the immediate two-physician agreement was high for RTI deaths (89.5%, table 1). Furthermore, suicides cause about 200 000 deaths in India annually but few are due to RTI.[19] Second, since the modes of transportation, place and timing of death, and injuries sustained were extracted from layperson open-ended narratives, the data accuracy may be in question. For example with the deceased mode of transportation, the extent of misclassification (by our study) or misreporting (by NCRB) that contributed to the differences between the two sources is uncertain. With reported injuries, our findings from these narratives most likely undercounted less visible injuries (chest, abdomen, and spine) compared to highly visible injuries such as bleeding and deformity for head and extremity injuries. Nevertheless, our findings are consistent with available Indian regional surveys and hospital series on the mode of transportation[11,12,30-32] place and timing of death,[1,37-39] and injuries sustained.[12,40,41] Third, since the narrative was not designed specifically to capture RTI death characteristics, over 25% of deaths had missing data for mode of transportation, place of death, timing of death, or reported injuries (supplementary table 1). Thus, our findings for these elements extracted from the narratives may be less representative of the decedents who lived in rural or poor areas. Finally, reliable forward projection of the number of RTI deaths beyond 2005 was not possible since the increase in the NCRB reported number of RTI deaths of 140% from 2005 to 2011 appeared to outpace the rate of population growth.[42] As the proportion of vulnerable road user deaths remained stable during this period in the NCRB reports, we postulated that this increase represented an actual increase in RTI death totals rather than more accurate reporting. Furthermore, given the rapid economic expansion and concurrent changes in motorization including the types of vehicle sharing the road and road infrastructure,[43,44] our results on deceased mode of transportation, place and timing of death, and injuries sustained may not reflect the current Indian scenario. An analysis of the trend from 2001-2014 is planned pending ongoing data collection in the MDS.

In India, RTI is a significant cause of preventable death, particularly in males of productive working age and among pedestrians, bicyclists, and motorcyclist. We have shown that properly designed simple verbal autopsy narratives can document the much needed surveillance data on the numbers, rates, risks, and basic RTI mechanism such as modes of transportation, timing of death, place of death, and injuries sustained. Our findings suggested that investment in primary and secondary prevention could address a large proportion of avoidable RTI deaths.

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COMPETING INTERESTS

We declare that we have no competing interests.

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The senior author had full access to all the data in the study and had final responsibility for the decision to submit this study for publication.

AUTHOR'S CONTRIBUTION

PJ and the MDS Collaborators (appendix) designed, planned, the executed the MDS in close collaboration with the Office of the Registrar General of India (RGI). MH and PJ performed the data analysis. All authors contributed to data interpretation, revisions of the manuscript, and provided final approval. PJ is the guarantor for this report.

DATA SHARING STATEMENT

Data used in this study is the property of the Registrar General of India. Application for data access can be made to the Office of the Registrar General of India.

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FIGURE LEGENDS

Figure 1: Road traffic injury deaths, age-standardized death rate, and cumulative risk (age 0-69 years) across states and regions of India, by gender.

Death rates are standardized to the 2005 United Nations estimated Indian population. Symbol size is proportional to sample size. Northeast states include Sikkim, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura, and Meghalaya. Total estimates include the 80 male and 19 female deaths from Pondicherry, Chandigarh, Uttarakhand, Dadra & Nagar Haveli, A&N Islands, Daman & Diu, Lakshadweep, and Goa. CHT=Chhatisgarh.

Figure 2: Deceased mode of transportation, place of death, and timing of death.

(A) Deceased mode of transportation in present study compared to National Crime Records Bureau 2005 Report. Shaded line represents vulnerable road users (defined as road users without a rigid barrier protecting against traumatic forces, i.e. pedestrian, bicyclist, motorcyclist, and three wheelers). Percentages from present study are weighted by state and rural/urban residence. T=estimated/reported number of deaths in 2005 (in thousands). (B) Place of death and (C) timing of death based on verbal autopsy narratives. Shaded lines represent deaths that are reported as occurring at the scene of collision or occurring instantly (defined as within 5 minutes).

Figure 3: Reported injuries from 1124 verbal autopsy narratives (49% of all 2299 RTI deaths).

Percentages refer to those in each row with given injury (columns). *Values in bold denote two by two chi square tests with $p<0.05$ (excluding unknowns). Abdominal and spinal injuries were also reported but not shown due to small numbers (61 and 25 cases, respectively).

	Narrative section			Timing of Death			Place of Death			Deceased Mode of Transportation			Injury Reported		
	Missing n (%)	Not missing n (%)	p	Missing n (%)	Not missing n (%)	p	Missing n (%)	Not missing n (%)	p	Missing n (%)	Not missing n (%)	p	Missing n (%)	Not missing n (%)	p
all RTI (n=2299)	142 (6.2)	2157 (93.8)		703 (30.6)	1596 (69.4)		566 (24.6)	1733 (75.4)		194 (8.4)	2105 (91.6)		1175 (51.1)	1124 (48.9)	
age															
<20 years	12 (2.9)	402 (97.1)	0.002	106 (25.6)	308 (74.4)	0.015	90 (21.7)	324 (78.0)	0.133	37 (8.9)	377 (91.1)	0.687	199 (48.1)	215 (51.9)	0.172
≥20 years	130 (6.9)	1755 (93.1)		597 (31.7)	1288 (68.3)		476 (25.3)	1409 (75.0)		157 (8.3)	1728 (91.7)		976 (51.8)	909 (48.2)	
sex															
male	118 (6.2)	1785 (93.8)	0.916	582 (30.6)	1321 (69.4)	0.991	461 (24.2)	1442 (75.8)	0.336	161 (8.5)	1742 (91.5)	0.934	972 (51.1)	931 (48.9)	0.946
female	24 (6.1)	372 (93.9)		121 (30.6)	275 (69.4)		105 (26.5)	291 (73.5)		33 (8.3)	363 (91.7)		203 (51.3)	193 (48.7)	
location															
rural	125 (7.2)	1623 (92.9)	0.001	559 (32.0)	1189 (68.0)	0.009	456 (26.1)	1292 (73.9)	0.004	143 (8.2)	1605 (91.8)	0.429	896 (51.3)	852 (48.7)	0.799
urban	17 (3.1)	534 (96.9)		144 (26.1)	407 (73.9)		110 (20.0)	441 (80.0)		51 (9.3)	500 (90.7)		279 (50.6)	272 (49.4)	
neighbourhood asset															
low	126 (7.5)	1548 (92.5)	0.001	552 (33.0)	1122 (67.0)	0.000	451 (26.9)	1223 (73.1)	0.001	136 (8.1)	1538 (91.9)	0.468	883 (52.8)	791 (47.3)	0.057
high	16 (3.2)	487 (96.8)		121 (24.1)	382 (75.9)		97 (19.3)	406 (80.7)		46 (9.2)	457 (90.9)		241 (47.9)	262 (52.1)	
missing	0 (0.0)	122 (100.0)		30 (24.6)	92 (75.4)		18 (14.8)	104 (85.3)		12 (9.8)	110 (90.2)		51 (41.8)	71 (58.2)	
education															
below primary	38 (4.0)	916 (96)	0.000	289 (30.3)	665 (69.7)	0.894	230 (24.1)	724 (75.9)	0.719	80 (8.4)	874 (91.6)	0.757	468 (49.1)	486 (50.9)	0.094
primary and above	100 (7.7)	1196 (92.3)		396 (30.6)	900 (69.4)		321 (24.8)	975 (75.2)		104 (8.0)	1192 (92.0)		682 (52.6)	614 (47.4)	
missing	4 (8.2)	45 (91.8)		18 (36.7)	31 (63.3)		15 (30.6)	34 (69.4)		10 (20.4)	39 (79.6)		25 (51.0)	24 (49.0)	
occupation															
non-worker	60 (8.1)	679 (91.9)	0.006	243 (32.9)	496 (67.1)	0.094	205 (27.7)	534 (72.3)	0.016	60 (8.1)	679 (91.9)	0.701	381 (51.6)	358 (48.4)	0.757
worker	81 (5.2)	1478 (94.8)		459 (29.4)	1100 (70.6)		360 (23.1)	1199 (76.9)		134 (8.6)	1425 (91.4)		793 (50.9)	766 (49.1)	
missing	1 (100.0)	0 (0.0)		1 (100.0)	0 (0.0)		1 (100.0)	0 (0.0)		0 (0.0)	1 (100.0)		1 (100.0)	0 (0.0)	

Supplementary Table 1: Summary of missing data. There are no missing values for age, sex, and location in the study population. The chi square test was used to determine the p values and excluded deaths with missing neighbourhood asset, education, or occupation.

	Timing of Death was Instant			Place of Death was Prehospital			Head Injury was Reported		
Deceased Mode of Transportation	n (%)	Adjusted OR	99% CI	n (%)	Adjusted OR	99% CI	n (%)	Adjusted OR	99% CI
non-vulnerable road users	170 (58.6)	ref	--	223 (69.5)	ref	--	125 (31.5)	ref	--
vulnerable road users:									
pedestrian	338 (58.5)	1.1	0.7-1.7	425 (69.1)	1.1	0.7-1.7	192 (24.9)	0.8	0.5-1.1
bicyclist & motorcyclist	245 (52.0)	0.8	0.5-1.1	306 (59.2)	0.6	0.4-1.0	256 (43.5)	**1.7***	**1.2-2.5***
three wheelers & animal riders	93 (56.4)	0.9	0.5-1.6	117 (67.6)	0.9	0.5-1.7	72 (33.0)	1.2	0.7-1.9
unknown	37 (40.2)	0.5	0.3-1.0	55 (51.4)	0.5	0.3-1.0	46 (25.1)	0.8	0.5-1.4

Supplementary Table 2: Association between deceased mode of transportation and the timing of death, place of death, and head injuries reported. Odds ratios are adjusted for deceased's age, sex, rural/urban, neighbourhood asset, and education. *Value in bold denote statistically significant difference between comparison groups.

	2005 UN population estimates (in '000)	Number of RTI deaths in 2005*		Crude RTI Death Rate in 2005 (per 100,000)*		% Under-reporting of Crude RTI Death Rate
		MDS	NCRB	MDS	NCRB	
Northeast States	13211	3610	724	27.3	5.5	79.9
Punjab	26455	7380	1622	27.9	6.1	78.0
Bihar + Jharkhand	122181	13172	3430	10.8	2.8	74.0
Uttar Pradesh	186591	33287	9860	17.8	5.3	70.4
Jammu & Kashmir	11120	2335	857	21.0	7.7	63.3
Other States	14121	4037	1589	28.6	11.3	60.6
Assam	29150	3277	1456	11.2	5.0	55.6
West Bengal	86499	9363	4364	10.8	5.0	53.4
Madhya Pradesh + CDH	90568	15726	7686	17.4	8.5	51.1
Haryana	23688	6128	3282	25.9	13.9	46.4
Orissa	39485	5083	2895	12.9	7.3	43.0
Kerala	33785	5051	3161	15.0	9.4	37.4
Maharashtra	106386	16638	10613	15.6	10.0	36.2
Rajasthan	63375	9237	6793	14.6	10.7	26.5
Gujarat	55926	6987	5264	12.5	9.4	24.7
Himachal Pradesh	6559	1077	854	16.4	13.0	20.7
Karnataka	57141	8172	6876	14.3	12.0	15.9
Delhi	16289	2161	2023	13.3	12.4	6.4
Tamil Nadu	66154	14808	13961	22.4	21.1	5.7
Andhra Pradesh	81934	10991	10944	13.4	13.4	0.4
Total	1130618	178520	98254	15.8	8.7	45.0

Supplementary Table 3: Comparison between present study (MDS) estimates and National Crime Records Bureau (NCRB) police reports of the number of RTI deaths and crude death rate, by state. *Excludes railroad deaths since NCRB does not publish state-level railroad death figures. Northeast States include Sikkim, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura, and Meghalaya. Other States include Pondicherry, Chandigarh, Uttaranchal, Dadra & Nagar Haveli, A & N Islands, Daman & Diu, Lakshadweep, and Goa. CDH = Chhatisgarh. % under reporting = (MDS death rate - NCRB death rate) / MDS death rate *100%.

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Road traffic injury mortality and its mechanisms in India: nationally representative mortality survey of 1.1 million homes

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Road traffic injury mortality and its mechanisms in India: nationally representative mortality survey of 1.1 million homes

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ABSTRACT:

Objectives: To quantify and describe the mechanism of road traffic injury (RTI) deaths in India.

Design: We conducted a nationally representative mortality survey where at least two physicians coded each non-medical field staff's verbal autopsy reports.RTI mechanism data were extracted from the narrative section of these reports.

Setting:1.1 million homes in India.

Participants: Over 122 000 deaths at all ages from 2001-2003.

Primary and secondary outcome measures: Age- and sex-specific mortality rates, place and timing of death, modes of transportation, and injuries sustained.

Results: The 2299 RTI deaths in the survey correspond to an estimated 183 600 RTI deaths or about 2% of all deaths in 2005 nationally, of which 65% occurred in males between the ages of 15-59 years. The age-adjusted mortality rate was greater in males than in females, in urban than in rural areas, and was notably higher than that estimated from national police records. Pedestrians (68 000), motorcyclists (36 000), and other vulnerable road users (20 000) constituted 68% of RTI deaths (124 000) nationally. Among the study sample, the majority of all RTI deaths occurred at the scene of collision (1005/1733, 58%), within minutes of collision (883/1596, 55%), and/or involved a head injury (691/1124, 62%). Compared to non-pedestrian RTI deaths, about 55 000 (81%) of pedestrian deaths were associated with less education and living in poorer neighbourhoods.

Conclusions: In India, RTI cause a substantial number of deaths, particularly among pedestrians and other vulnerable road users. Interventions to prevent collisions and reduce injuries might address over half of the RTI deaths. Improved pre-hospital transport and hospital trauma care might address just over a third of the RTI deaths.

ARTICLE SUMMARY

Article focus

- To directly estimate the age- and sex-specific mortality rates and describe the place and timing of death, modes of transportation, and injuries sustained for road traffic injury (RTI) deaths in India using a nationally representative mortality survey of 1.1 million homes.

Key messages

- Road traffic injuries cause a substantial number of avertable deaths, particularly in males of productive working age and among pedestrians and other vulnerable road users.
- Preventative interventions should be emphasized as the majority of all RTI deaths occurred at the scene of collision, within minutes of collision, and/or involved a head injury.
- Properly designed mortality survey with verbal autopsy narratives can provide much-needed data to assist RTI prevention efforts.

Strengths and limitations of this study

- This study is the first nationally representative survey of the causes of death in India and overcomes limitations of existing data sources including regional injury surveys, hospital series, and national police reports.
- Limitations of the study include potential misclassification of deaths by physician coders, the use of layperson narratives with a potential for recall bias and inaccuracies, and limited ability to forward project study results given the rapid changes in motorization in India.

INTRODUCTION

Road traffic injuries (RTI) area large and growing public health burden, especially in low-and middle-income countries (LMIC) where 90% of the world's deaths due to RTI are estimated to occur.[1] There are few high-quality epidemiologic data on RTI to guide the development, implementation, and surveillance of evidence-based policy and programs in LMICs.[2-4]

The number of deaths due to RTI in India is projected to rise with increasing motorization.[1,5]Aside from a few regional injury surveys,[6-11] the current data on the numbers and mechanisms of RTI deaths in India rely on police or hospital records, both of which can substantially underestimate death rates in the poor, rural, and uneducated people who still constitute large proportions of the Indian population.[2-4,12,13]

The World Health Organization (WHO), using indirect modeling methods, estimated about 202 000 RTI deaths in India in 2004.[14,15] No study has validated this estimate with direct measurement nor documented detailed RTI mechanism for India nationally. Here, we estimate the regional, age- and sex-specific mortality rate and risk of RTI death in India using data from the Million Death Study (MDS). We also report the modes of transportation, place and timing of death, and injuries sustained in RTI deaths.

METHODS

Study Design: The MDS is an on-going nationally representative survey designed to determine the causes and risk factors of death in India, organized by the Registrar General of India (RGI). The design, methodology, and preliminary findings of the MDS have been described elsewhere.[16-19]In brief, the MDS used an enhanced version of verbal autopsy (known as the routine, reliable, representative, re-sampled household investigation of mortality with medical evaluation or RHIME) to monitor a nationally representative sample of 1.1 million households in the Sample Registration System (SRS). Within six months of every death occurring in these households from 2001-3, a trained, nonmedical RGI surveyor interviewed a relative or close-acquaintance of the deceased to obtain the symptoms and events around the death using structured questions and a local language narrative guided by a specific symptom list. These records were converted into electronic records and emailed to two of 140 trained physicians who, independently and anonymously, assigned an underlying cause of death (with allocation determined randomly based only on the physician's ability to read the local language), using guidelines for the major causes of death.[20]Records were assigned cause of death in three-digit International Statistical Classification of Diseases and Related Health Problems, 10th revision (ICD-10).[21] Records where coders disagreed on the cause of death underwent anonymous reconciliation. Continuing disagreements were adjudicated by a third senior physician. Five percent of households were randomly resurveyed and the results were consistent within families of ICD-10 codes.[16] Participation in the SRS is on a voluntary basis and oral consent was obtained under the confidentiality and consent procedures of the Registration of Births and Deaths Act, 1969.

Road Traffic Injury Deaths: The RTI deaths in this study were of people who died between 2001 and 2003 with a final assigned ICD-10 code within V01-V89. We translated the open-ended narratives into English from 14 local languages, and systematically extracted the modes

of transportation, place and timing of death, and injuries sustained from 2157 of the 2299 RTI deaths using a standardized data extraction tool and procedure (the remaining 142 deaths, 6%, had missing or illegible narratives). For these four data elements, there were substantial inter-rater agreement between two investigators and two research assistants who were trained and independently extracted data from the narratives of a random 10% of RTI deaths (lowest kappa statistic was greater than 0.69 for all pair-wise comparisons between the four data extractors; data not shown). The two research assistants then independently extracted data from all narratives. Adjudication was done by an investigator (MH) for discrepancies in extracted data.

Analysis: The age and sex-specific proportion of RTI deaths within the 2001-2003 survey was applied to the 2005 United Nations (UN) estimates of the number of deaths from all causes in India, after weighting for sampling probability.[22] The 2005 UN death estimates were used so as to correct for the slight undercounts reported in the total death rates in the SRS[23,24] and to account for the 12% of enumerated deaths without completed field visits (mostly due to out-migration of the family or from incomplete field records). The proportion of these missed deaths was similarly dispersed across sex, age, and states. Use of 2003 or 2004 UN death totals yielded nearly identical results (data not shown). The 99% confidence intervals (99%CI) for mortality rate were calculated based on the weighted number of study deaths. State- and rural/urban-specific estimates of the number, mortality rate, and lifetime risk of RTI death were calculated by partitioning the UN national death totals according to relative SRS death rates as previously described.[18,25,26]Urban and rural status was defined according to the Census of India. Logistic regression was used to compare the socio-demographic traits of pedestrian and non-pedestrian RTI deaths. Household fuel type was used as a measure of community wealth, based on earlier principal component analyses [18]: high asset neighbourhoods had >50% of households that used gas, electricity, or kerosene; low asset or poor neighbourhoods used primarily coal, firewood, or other. Attributable proportion was calculated for traits of pedestrian deaths compared to non-pedestrian RTI deaths.

The MDS received ethics approval from the review boards of the Post-Graduate Institute of Medical Education and Research in Chandigarh, India; St Michael's Hospital in Toronto, Canada; and the Indian Council of Medical Research's Health Ministry's Screening Committee.

RESULTS

The 2299 RTI deaths in the 2001-2003 survey correspond to an estimated 183 600 (99%CI 173 800-193 400) RTI deaths in India in 2005. The majority of these RTI deaths occurred in males (152 100 deaths, 82.8%; table 1). The age-standardized RTI mortality rate for males (26.2 per 100 000, 24.6-27.7) was higher than for females (5.7 per 100 000, 5.0-6.4). While the RTI mortality rate increased with age in both genders, the largest number of RTI deaths occurred in males between 15-59 years of age (118 900, 64.8%).

At these death rates and in the theoretical absence of other causes of death, males in India had a 2.1% (2.0-2.3) risk of dying from RTI before age 70, with the highest risks at ages 30-59 years; females had a 0.5% (0.4-0.5) risk of dying from RTI before age 70. Males in Haryana, Punjab, Tamil Nadu, and Uttar Pradesh had significantly higher risks (3.0-4.1%) than the national risk (figure 1). In contrast, males in Bihar, Jharkhand, Andhra Pradesh, Orissa, Gujarat, and West Bengal had significantly lower risks (1.3-1.6%) than the national risk of RTI deaths. Males living in urban areas had slightly higher age-standardized mortality rates and risks of RTI deaths (27.6 per 100 000; 2.4%, 2.1-2.6) compared to males living in rural areas (24.9 per 100 000; 2.0%, 1.8-2.1). By contrast, female RTI mortality rates and risks before age 70 varied much less across states and were similar in rural and urban areas (data not shown).

	Study deaths, 2001-2003				All India, 2005			
	Number of RTI deaths / all coded deaths	Proportion RTI*	Rural (%**)	Two coders immediately agree	All deaths / population (millions, 2005 UN estimates)	Estimated RTI deaths§, thousands	RTI death rateΨ per 100 000 (99% CI)	Period risk for RTI death†
Male - age in years								
0-4	44 / 11719	0.4%	37 (76.7)	44	1.2 / 67	4.9	7.4 (6.5-8.4)¶	0.04%
5-14	97 / 1926	5.2%	86 (84.1)	87	0.2 / 129	8.5	6.6 (4.9-8.3)	0.1%
15-29	605 / 4727	13.0%	462 (68.9)	558	0.4 / 163	47.1	28.9 (25.9-31.9)	0.4%
30-44	529 / 6817	7.7%	385 (67.0)	477	0.6 / 115	43.8	37.9 (33.7-42.1)	0.6%
45-59	356 / 11731	3.0%	249 (60.9)	312	0.9 / 73	28.0	38.4 (33.2-43.6)	0.6%
60-69	149 / 12120	1.2%	117 (71.8)	133	0.9 / 24	10.6	44.0 (34.6-53.4)	0.5%
>70	123 / 18732	0.6%	106 (81.2)	98	1.3 / 14	9.1	64.5 (49.1-80.0)	--
All ages	1903 / 67772	2.8%	1442 (68.9)	1709	5.3 / 585	152.1	26.2	2.1%†
(% or 99% CI)				(89.8%)		(143.2-161.0)	(24.6-27.7)	(2.0-2.3)
Female - age in years								
0-4	50 / 11492	0.4%	46 (93.4)	45	1.2 / 61	5.0	8.1 (7.1-9.1)¶	0.04%
5-14	44 / 1955	2.3%	38 (80.1)	43	0.2 / 118	3.8	3.2 (2.0-4.4)	0.03%
15-29	72 / 4394	1.5%	53 (60.5)	63	0.3 / 150	5.3	3.5 (2.4-4.6)	0.1%
30-44	59 / 4055	1.4%	39 (59.0)	50	0.3 / 106	4.4	4.1 (2.7-5.5)	0.1%
45-59	70 / 6402	1.1%	55 (70.9)	61	0.5 / 69	6.0	8.6 (5.9-11.3)	0.1%
60-69	54 / 9016	0.6%	42 (68.6)	52	0.6 / 25	3.7	14.8 (9.8-19.9)	0.2%
>70	47 / 17343	0.3%	33 (61.8)	35	1.3 / 16	3.5	21.6 (13.4-29.9)	--
All ages	396 / 54657	0.7%	306 (69.8)	349	4.5 / 546	31.5	5.7	0.5%†
(% or 99% CI)				(88.1%)		(27.5-35.6)	(5.0-6.4)	(0.4-0.5)
Total male and female, <70 years	2129 / 86354	2.4%	1609 (68.5)	1925	7.2 / 1100	171.0	15.5	1.3%†
(% or 99% CI)				(90.4%)		(161.5-180.4)	(14.7-16.4)	(1.3-1.4)
Total male and female, all ages	2299 / 122429	1.8%	1748 (69.0)	2058	9.8 / 1131	183.6	16.2	1.3%†
(% or 99% CI)				(89.5%)		(173.8-193.4)	(15.4-17.1)	(1.3-1.4)

Table 1: Road traffic injury deaths in the present study and estimated national totals for 2005, by age and gender. *Proportion of RTI deaths compared to all deaths, weighted by state and residence (rural/urban). **Percentage rural is weighted by state and residence (rural/urban). §Obtained by multiplying the United Nations estimated total deaths in 2005 by the weighted proportions. ΨAge standardized to the 2005 United Nations estimated Indian population; 99% CI shown are calculated based on weighted number of study deaths, which result in wider CI than those based on physician agreement. †Annual RTI death rate multiplied by the duration of age range, except for the lifetime risk which is calculated between 0-69 years by summation of the age specific period risks. ¶Crude death rate.

The deceased mode of transportation was described in the narratives of 2105 (92%) of the RTI deaths. National estimates for the deceased mode of transportation were calculated, as those with unknown and known modes of transportation did not appear to differ with respect to the major socio-demographic traits (Supplementary Table 1).Vulnerable road users are those without a rigid barrier protecting against traumatic forces and include pedestrians, motorcyclists, bicyclists, and three-wheelers. They constituted a majority (68%; n=124 000, 99%CI 115 000-131 000) of RTI deaths, led by pedestrians (37%; n=68 000, 62 000-73 000) and motorcyclists (20%; n=36 000, 31 000-40 000) (figure 2). Drivers and passengers of motorized four-wheelers comprised 16% (n=31 000, 27 000-35 000) of RTI deaths. By contrast, the 2005 police reports, which use a different but compatible classification system to ICD-10, recorded only 33000 vulnerable road user deaths and only9000 pedestrian deaths.[27] The most common types of vehicle to collide into the decedents were heavy transport vehicles and buses (37%; n=68 000, 61 000-74 000), followed by cars and vans (15%; n=28 000, 24 000-32 000). Single-vehicle incidents comprised 9% of deaths (n=17 000, 14 000-20 000). The most frequent combinations, resulting in 23% (n=42 000, 37 000-47 000) of RTI deaths, were collisions of heavy transport vehicles or buses with pedestrians and motorcyclists (data not shown).

The place and timing of death were described in the narratives of 1733 (75%) and 1596 (69%) of the RTI deaths respectively (figure 2; see supplementary table 1 for a summary of missing data from the narratives with respect to deceased characteristics).For these narratives, only the study proportion and not national estimates were made. Most RTI deaths occurred at the scene of collision (58%, 1005/1733) or instantly, defined as within 5 minutes (55%, 883/1596). Only 3% (45/1733) were labeled as potentially avertable with better pre-hospital transport as they occurred on scene but not instantly. Another 35% of deaths occurred en route (7%, 124/1733) or in hospital (28%, 481/1733).

Injuries sustained by the deceased were reported from1124 narratives (49%). Head injuries were the most commonly reported (62%, 691/1124), of which 76% (524/691) were reported as isolated head injuries (figure 3). A greater percentage of motorcyclists (78%, 188/241) had head injuries reported compared to non-motorcyclists (57%, 457/807). After adjusting for age, sex, rural/urban, neighbourhood asset, and education, bicyclists and motorcyclists were more likely to have head injuries reported compared to non-vulnerable road users (adjusted OR 1.7, 1.2-2.5) (supplementary table 2).

Compared to non-pedestrian RTI deaths, pedestrian deaths occurred to those who had less education (or in the case of children age <15 years, have less educated parents) (adjusted OR 2.9, 99%CI 2.0-4.2), lived in poorer neighbourhoods (1.7, 1.1-2.5),were children or elderly adults (<15 years: 2.9, 1.8-4.5; >59 years: 1.7, 1.2-2.4), were female (1.5, 1.2-2.2), and lived in urban areas (1.5, 1.1-2.2) (table 2). If pedestrian deaths had the same proportion of secondary or higher education as non-pedestrian RTI deaths, there would be 406/825 (49%) fewer pedestrian deaths, corresponding to approximately 33 000 deaths nationally in 2005. The corresponding attributable proportion for living in richer versus poorer neighbourhoods would be 265/825 (32%) or approximately 22 000 deaths nationally. Within the narratives we could code, there were no differences between pedestrians and non-pedestrian RTI deaths in timing of death, place of death, reported injuries, or reported routine use of alcohol or smoking (data not shown).

	Pedestrian / Non-Pedestrian Total=825/1280	Adjusted OR^ (99% CI)	Attributable Pedestrian Deaths (% of all 825 pedestrian deaths)
Education*			
Secondary or higher	112/382	ref	
Primary or middle	248/450	1.8 (1.3-2.6)	110] 406 (49%)
Below primary	451/423	2.9 (2.0-4.2)	296
Unknown	14/25	1.6 (0.6-4.2)	N/A
Neighbourhood Asset			
High	137/320	ref	
Low	643/895	1.7 (1.1-2.5)	265 (32%)
Unknown	45/65	1.5 (0.8-2.8)	N/A
Age in years			
15-59 (driving ages)	497/1046	ref	
<15 (children)	144/74	2.9 (1.8-4.5)	94] 170 (21%)
>59 (elderly adults)	184/160	1.7 (1.2-2.4)	76
Sex			
Male	621/1121	ref	
Female	204/159	1.5 (1.1-2.2)	68 (8%)
Location			
Rural	643/962	ref	
Urban	182/318	1.5 (1.1-2.2)	61 (7%)
Occupation			
Salaried / Wage Earner / Professional	229/517	ref	
Cultivator / Agricultural labour / Other	162/300	0.9 (0.6-1.3)	N/A
Non-worker / Children <15 years	433/463	1.2 (0.9-1.6)	N/A
Unknown	1/0	N/A	N/A
Routine Alcohol Use**			
No	494/877	ref	
Yes	145/260	1.1 (0.7-1.5)	N/A
Unknown	42/69	1.0 (0.5-1.9)	N/A

Table 2: Characteristics of pedestrian RTI deaths and attributable proportions. *Education of deceased adults or, in cases of deceased children <15 years, education of respondent. **Excludes 218 children. ^Odds ratios are adjusted for all other variables in this table except for alcohol use; the odds ratios for alcohol use are adjusted for all other variables in this table.

DISCUSSION

RTI is an important cause of death in India, causing 183 600 deaths in 2005, or about 2% of all deaths.[22] Much of the deceased were men between ages 15-59 years. Males had a four-fold higher cumulative risk of RTI death compared to females before the age of 70. Among the major

states, there was approximately 3-fold variation in the age-standardized RTI death rate and cumulative risk for males.

Our estimated number of RTI deaths is more than 50% greater than the 118 265 deaths reported in the official police statistics of the National Crime Records Bureau (NCRB) in 2005.[27] Compared to our estimates, the extent of under-reporting of the crude death rate in major states by NCRB ranged from <1% to about 80% (supplementary table 3). Existing regional population-based injury surveys in India support our findings and also report higher crude RTI death rates than NCRB statistics.[8,11]Under-reporting of RTI deaths in police statistics has been reported in India and other LMIC.[28-30]A study in urban India comparing both hospital- and community-based RTI data to police records identified factors contributing to under-reporting that included the deceased believed to be at fault, collision resulting from hit-and-runs, limited police resources, and the lack of a standard police reporting protocol by hospitals.[28] The factors contributing to police under-reporting, especially in rural India, require further examination. Our estimated number of RTI deaths in 2005 was consistent with the WHO estimate for 2004.[14] However, we observed a slightly higher male proportion (83% MDS vs. 77% WHO, all ages) and a higher proportion of male deaths between 15-59 years (65% MDS vs. 61% WHO).

Almost three-quarters of all RTI deaths in India were of pedestrians and other vulnerable road users. In contrast, a much lower proportion (27%) was reported by the NCRB (figure 2).This difference equated to 59 000 pedestrian and 32 000 other vulnerable road user deaths that were not included in the 2005 NCRB records. Existing RTI studies based on regional surveys and hospital series also reported a high proportion (>60%) of vulnerable road user deaths similar to our findings.[11,12,30-32]Since the majority of vulnerable road users were pedestrians, our findings suggested that RTI deaths in individuals who were less educated, poor, female or live in urban areas may have been disproportionally excluded from the NCRB records. While poverty and education are not likely to be in the direct causal pathway of pedestrian deaths, they nonetheless point to other associated risk factors. Indeed, 55 000 pedestrian deaths in 2005 (81%) was associated with lower education or living in poorer neighbourhoods compared to non-pedestrian RTI deaths. While the less educated and the poor likely travelled more often by foot, they might also be exposed to undetermined environmental (neighbourhoods with unsafe roads), biological (poor vision or decreased mobility due to poor health), and behavioral (alcohol or other substance use) risk factors for pedestrian death.[12, 33, 34]Further studies are needed to better understand pedestrian deaths in LMIC.

Over half of RTI deaths occurred instantly at the scene of collision and/or had head injury reported. These findings, together with existing RTI hospital series and regional surveys in India, make a strong argument that investments in primary and secondary prevention could potentially avert the greatest proportion of RTI deaths. To address the high proportion of instant deaths and head injuries among RTI deaths in India, specific interventions that are effective and based on studies in LMIC should be emphasized; these may include speed bumps, motorcycle helmets, and increasing fines and license suspensions for rule infractions.[33]In contrast, improving pre-hospital transport and hospital trauma care, could only potentially affect the 38%who died on scene with delayed hospital transport (3%), en route to hospital (7%), or in hospital (28%).

Our study is the first nationally representative survey of the causes of death in India. The simple descriptive statistics provide clear evidence on the large and avertable burden from RTI, particularly among productive age adults and pedestrians. To the best of our knowledge, only one recent study in Vietnam has used similar methods to analyze RTI deaths and policy implications on a national scale.[35]

Our study faced certain limitations. First, we might have misclassified certain causes of death including suicide as RTI deaths. However, the extent of misclassification should be minimal since the RHIME verbal autopsy method was shown to be robust in discerning between types of injury deaths[36]and since the immediate two-physician agreement was high for RTI deaths(89.5%, table 1). Furthermore, suicides cause about 200 000 deaths in India annually but few are due to RTI.[19] Second, since the modes of transportation, place and timing of death, and injuries sustained were extracted from layperson open-ended narratives, the data accuracy may be in question. For example with the deceased mode of transportation, the extent of misclassification (by our study) or misreporting (by NCRB) that contributed to the differences between the two sources is uncertain. With reported injuries, our findings from these narratives most likely undercounted less visible injuries (chest, abdomen, and spine) compared to highly visible injuries such as bleeding and deformity for head and extremity injuries. Nevertheless, our findings are consistent with available Indian regional surveys and hospital series on the mode of transportation[11,12,30-32,37] place and timing of death,[1,37-41] and injuries sustained.[12,37,42,43]Third, since the narrative was not designed specifically to capture RTI death characteristics, over 25% of deaths had missing data for mode of transportation, place of death, timing of death, or reported injuries(supplementary table 1).Thus, our findings for these elements extracted from the narratives may be less representative of the decedents who lived in rural or poor areas. Finally, reliable forward projection of the number of RTI deaths beyond 2005 was not possible since the increase in the NCRB reported number of RTI deaths of140% from 2005 to 2011 appeared to outpace the rate of population growth.[44] As the proportion of vulnerable road user deaths remained stable during this period in the NCRB reports, we postulated that this increase represented an actual increase in RTI death totals rather than more accurate reporting. Furthermore, given the rapid economic expansion and concurrent changes in motorization including the types of vehicle sharing the road and road infrastructure,[45,46]our results on deceased mode of transportation, place and timing of death, and injuries sustained may not reflect the current Indian scenario. An analysis of the trend from 2001-2014 is planned pending ongoing data collection in the MDS.

In India, RTI is a significant cause of preventable death, particularly in males of productive working age and among pedestrians, bicyclists, and motorcyclist. We have shown that properly designed simple verbal autopsy narratives can document the much needed surveillance data on the numbers, rates, risks, and basic RTI mechanism such as modes of transportation, timing of death, place of death, and injuries sustained. Our findings suggested that investment in primary and secondary prevention could address a large proportion of avoidable RTI deaths.

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COMPETING INTERESTS

We declare that we have no competing interests.

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The senior author had full access to all the data in the study and had final responsibility for the decision to submit this study for publication.

AUTHOR'S CONTRIBUTION

PJ and the MDS Collaborators (appendix) designed, planned, the executed the MDS in close collaboration with the Office of the Registrar General of India (RGI). MH and PJ performed the data analysis. All authors contributed to data interpretation, revisions of the manuscript, and provided final approval. PJ is the guarantor for this report.

DATA SHARING STATEMENT

Data used in this study are the property of the Registrar General of India and the overall mortality results have been published in 2009.[47] This specific analyses is produced under an agreement with CGHR.

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FIGURE LEGENDS

Figure 1: Road traffic injury deaths, age-standardized death rate, and cumulative risk (age 0-69 years) across states and regions of India, by gender.

Death rates are standardized to the 2005 United Nations estimated Indian population. Symbol size is proportional to sample size. Northeast states include Sikkim, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura, and Meghalaya. Total estimates include the 80 male and 19 female deaths from Pondicherry, Chandigarh, Uttarakhand, Dadra & Nagar Haveli, A&N Islands, Daman & Diu, Lakshadweep, and Goa. CHT=Chhatisgarh.

Figure 2: Deceased mode of transportation, place of death, and timing of death.

(A) Deceased mode of transportation in present study compared to National Crime Records Bureau 2005 Report. Shaded line represents vulnerable road users (defined as road users without a rigid barrier protecting against traumatic forces, i.e. pedestrian, bicyclist, motorcyclist, and three wheelers). Percentages from present study are weighted by state and rural/urban residence. T=estimated/reported number of deaths in 2005 (in thousands). (B) Place of death and (C) timing of death based on verbal autopsy narratives. Shaded lines represent deaths that are reported as occurring at the scene of collision or occurring instantly (defined as within 5 minutes).

Figure 3: Reported injuries from 1124 verbal autopsy narratives (49% of all 2299 RTI deaths).

Percentages refer to those in each row with given injury (columns). *Values in bold denote two by two chi square tests with $p<0.05$ (excluding unknowns). Abdominal and spinal injuries were also reported but not shown due to small numbers (61 and 25 cases, respectively).

LIST OF ACRONYMS

CI	Confidence interval
ICD-10	International Statistical Classification of Diseases and Related Health Problems, 10th Revision
LMIC	Low- and middle-income countries
MDS	Million Death Study
NCRB	National Crime Records Bureau
RGI	Registrar General of India
RTI	Road traffic injury
SRS	Sample registration system
UN	United Nations
WHO	World Health Organization

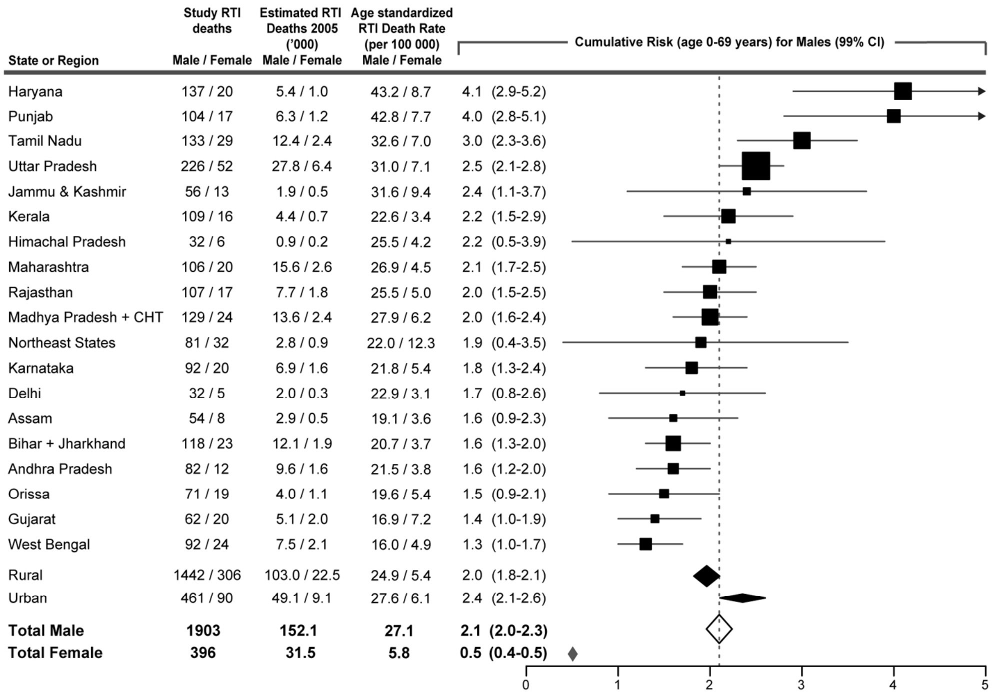


Figure 1: Road traffic injury deaths, age-standardized death rate, and cumulative risk (age 0-69 years) across states and regions of India, by gender.
Death rates are standardized to the 2005 United Nations estimated Indian population. Symbol size is proportional to sample size. Northeast states include Sikkim, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura, and Meghalaya. Total estimates include the 80 male and 19 female deaths from Pondicherry, Chandigarh, Uttarakhand, Dadra & Nagar Haveli, A&N Islands, Daman & Diu, Lakshadweep, and Goa. CHT=Chhatisgarh.

160x111mm (300 x 300 DPI)

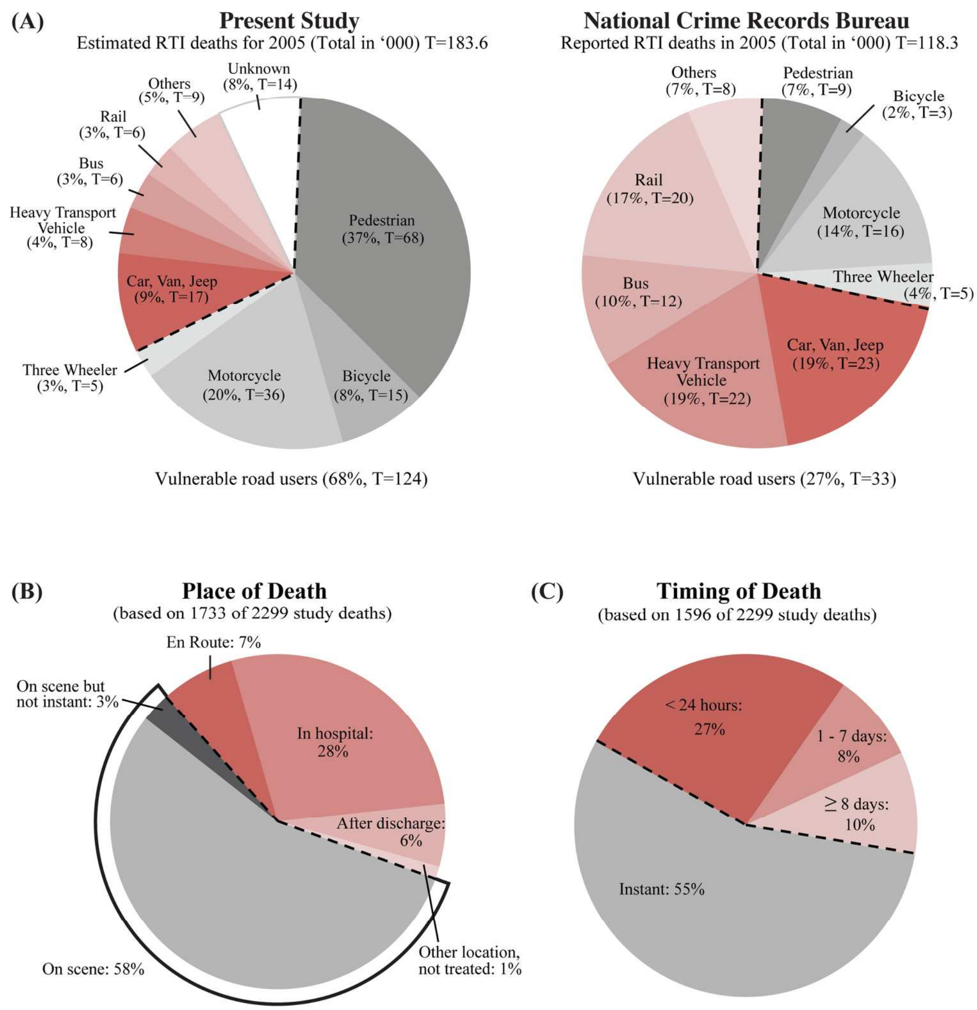
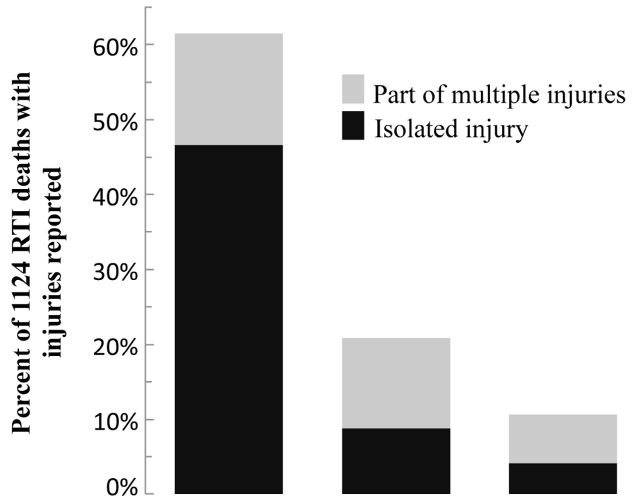


Figure 2: Deceased mode of transportation, place of death, and timing of death.
(A) Deceased mode of transportation in present study compared to National Crime Records Bureau 2005 Report. Shaded line represents vulnerable road users (defined as road users without a rigid barrier protecting against traumatic forces, i.e. pedestrian, bicyclist, motorcyclist, and three wheelers). Percentages from present study are weighted by state and rural/urban residence. T=estimated/reported number of deaths in 2005 (in thousands). (B) Place of death and (C) timing of death based on verbal autopsy narratives. Shaded lines represent deaths that are reported as occurring at the scene of collision or occurring instantly (defined as within 5 minutes).

178x182mm (300 x 300 DPI)



	Head n (%)	Extremity n (%)	Chest n (%)
RTI deaths with reported injuries (N=1124)	691 (62)	235 (21)	120 (11)
Sex			
Male (N=931)	584 (63)	194 (21)	105 (11)
Female (N=193)	107 (55)	41 (21)	15 (8)
Place of Death			
Pre-hospital (N=492)	322 (65)	**56 (11)***	44 (9)
Hospital or other (N=457)	291 (64)	**142 (31)***	58 (13)
Unknown (N=175)	78 (45)	37 (21)	18 (10)
Timing of Death			
Instant (N=347)	216 (62)	**28 (8)***	29 (8)
Later (N=521)	344 (66)	**145 (28)***	62 (12)
Unknown (N=256)	131 (51)	62 (24)	29 (11)
Mode of Transportation			
Motorcycle (N=241)	**188 (78)***	51 (21)	18 (7)
Non-motorcycle (N=807)	**457 (57)***	160 (20)	95 (12)
Unknown (N=76)	46 (61)	24 (32)	7 (9)

Figure 3: Reported injuries from 1124 verbal autopsy narratives (49% of all 2299 RTI deaths). Percentages refer to those in each row with given injury (columns). *Values in bold denote two by two chi square tests with p<0.05 (excluding unknowns). Abdominal and spinal injuries were also reported but not shown due to small numbers (61 and 25 cases, respectively).
141x191mm (300 x 300 DPI)

	Narrative section			Timing of Death			Place of Death			Deceased Mode of Transportation			Injury Reported		
	Missing n (%)	Not missing n (%)	p	Missing n (%)	Not missing n (%)	p	Missing n (%)	Not missing n (%)	p	Missing n (%)	Not missing n (%)	p	Missing n (%)	Not missing n (%)	p
all RTI (n=2299)	142 (6.2)	2157 (93.8)		703 (30.6)	1596 (69.4)		566 (24.6)	1733 (75.4)		194 (8.4)	2105 (91.6)		1175 (51.1)	1124 (48.9)	
age															
<20 years	12 (2.9)	402 (97.1)	0.002	106 (25.6)	308 (74.4)	0.015	90 (21.7)	324 (78.0)	0.133	37 (8.9)	377 (91.1)	0.687	199 (48.1)	215 (51.9)	0.172
≥20 years	130 (6.9)	1755 (93.1)		597 (31.7)	1288 (68.3)		476 (25.3)	1409 (75.0)		157 (8.3)	1728 (91.7)		976 (51.8)	909 (48.2)	
sex															
male	118 (6.2)	1785 (93.8)	0.916	582 (30.6)	1321 (69.4)	0.991	461 (24.2)	1442 (75.8)	0.336	161 (8.5)	1742 (91.5)	0.934	972 (51.1)	931 (48.9)	0.946
female	24 (6.1)	372 (93.9)		121 (30.6)	275 (69.4)		105 (26.5)	291 (73.5)		33 (8.3)	363 (91.7)		203 (51.3)	193 (48.7)	
location															
rural	125 (7.2)	1623 (92.9)	0.001	559 (32.0)	1189 (68.0)	0.009	456 (26.1)	1292 (73.9)	0.004	143 (8.2)	1605 (91.8)	0.429	896 (51.3)	852 (48.7)	0.799
urban	17 (3.1)	534 (96.9)		144 (26.1)	407 (73.9)		110 (20.0)	441 (80.0)		51 (9.3)	500 (90.7)		279 (50.6)	272 (49.4)	
neighbourhood asset															
low	126 (7.5)	1548 (92.5)	0.001	552 (33.0)	1122 (67.0)	0.000	451 (26.9)	1223 (73.1)	0.001	136 (8.1)	1538 (91.9)	0.468	883 (52.8)	791 (47.3)	0.057
high	16 (3.2)	487 (96.8)		121 (24.1)	382 (75.9)		97 (19.3)	406 (80.7)		46 (9.2)	457 (90.9)		241 (47.9)	262 (52.1)	
missing	0 (0.0)	122 (100.0)		30 (24.6)	92 (75.4)		18 (14.8)	104 (85.3)		12 (9.8)	110 (90.2)		51 (41.8)	71 (58.2)	
education															
below primary	38 (4.0)	916 (96)	0.000	289 (30.3)	665 (69.7)	0.894	230 (24.1)	724 (75.9)	0.719	80 (8.4)	874 (91.6)	0.757	468 (49.1)	486 (50.9)	0.094
primary and above	100 (7.7)	1196 (92.3)		396 (30.6)	900 (69.4)		321 (24.8)	975 (75.2)		104 (8.0)	1192 (92.0)		682 (52.6)	614 (47.4)	
missing	4 (8.2)	45 (91.8)		18 (36.7)	31 (63.3)		15 (30.6)	34 (69.4)		10 (20.4)	39 (79.6)		25 (51.0)	24 (49.0)	
occupation															
non-worker	60 (8.1)	679 (91.9)	0.006	243 (32.9)	496 (67.1)	0.094	205 (27.7)	534 (72.3)	0.016	60 (8.1)	679 (91.9)	0.701	381 (51.6)	358 (48.4)	0.757
worker	81 (5.2)	1478 (94.8)		459 (29.4)	1100 (70.6)		360 (23.1)	1199 (76.9)		134 (8.6)	1425 (91.4)		793 (50.9)	766 (49.1)	
missing	1 (100.0)	0 (0.0)		1 (100.0)	0 (0.0)		1 (100.0)	0 (0.0)		0 (0.0)	1 (100.0)		1 (100.0)	0 (0.0)	

Supplementary Table 1: Summary of missing data. There are no missing values for age, sex, and location in the study population. The chi square test was used to determine the p values and excluded deaths with missing neighbourhood asset, education, or occupation.

Deceased Mode of Transportation	Timing of Death was Instant			Place of Death was Prehospital			Head Injury was Reported		
	n (%)	Adjusted OR	99% CI	n (%)	Adjusted OR	99% CI	n (%)	Adjusted OR	99% CI
non-vulnerable road users	170 (58.6)	ref	--	223 (69.5)	ref	--	125 (31.5)	ref	--
vulnerable road users:									
pedestrian	338 (58.5)	1.1	0.7-1.7	425 (69.1)	1.1	0.7-1.7	192 (24.9)	0.8	0.5-1.1
bicyclist & motorcyclist	245 (52.0)	0.8	0.5-1.1	306 (59.2)	0.6	0.4-1.0	256 (43.5)	**1.7***	**1.2-2.5***
three wheelers & animal riders	93 (56.4)	0.9	0.5-1.6	117 (67.6)	0.9	0.5-1.7	72 (33.0)	1.2	0.7-1.9
unknown	37 (40.2)	0.5	0.3-1.0	55 (51.4)	0.5	0.3-1.0	46 (25.1)	0.8	0.5-1.4

Supplementary Table 2: Association between deceased mode of transportation and the timing of death, place of death, and head injuries reported. Odds ratios are adjusted for deceased's age, sex, rural/urban, neighbourhood asset, and education. *Value in bold denote statistically significant difference between comparison groups.

	2005 UN population estimates (in '000)	Number of RTI deaths in 2005*		Crude RTI Death Rate in 2005 (per 100,000)*		% Under-reporting of Crude RTI Death Rate
		MDS	NCRB	MDS	NCRB	
Northeast States	13211	3610	724	27.3	5.5	79.9
Punjab	26455	7380	1622	27.9	6.1	78.0
Bihar + Jharkhand	122181	13172	3430	10.8	2.8	74.0
Uttar Pradesh	186591	33287	9860	17.8	5.3	70.4
Jammu & Kashmir	11120	2335	857	21.0	7.7	63.3
Other States	14121	4037	1589	28.6	11.3	60.6
Assam	29150	3277	1456	11.2	5.0	55.6
West Bengal	86499	9363	4364	10.8	5.0	53.4
Madhya Pradesh + CDH	90568	15726	7686	17.4	8.5	51.1
Haryana	23688	6128	3282	25.9	13.9	46.4
Orissa	39485	5083	2895	12.9	7.3	43.0
Kerala	33785	5051	3161	15.0	9.4	37.4
Maharashtra	106386	16638	10613	15.6	10.0	36.2
Rajasthan	63375	9237	6793	14.6	10.7	26.5
Gujarat	55926	6987	5264	12.5	9.4	24.7
Himachal Pradesh	6559	1077	854	16.4	13.0	20.7
Karnataka	57141	8172	6876	14.3	12.0	15.9
Delhi	16289	2161	2023	13.3	12.4	6.4
Tamil Nadu	66154	14808	13961	22.4	21.1	5.7
Andhra Pradesh	81934	10991	10944	13.4	13.4	0.4
Total	1130618	178520	98254	15.8	8.7	45.0

Supplementary Table 3: Comparison between present study (MDS) estimates and National Crime Records Bureau (NCRB) police reports of the number of RTI deaths and crude death rate, by state. *Excludes railroad deaths since NCRB does not publish state-level railroad death figures. Northeast States include Sikkim, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura, and Meghalaya. Other States include Pondicherry, Chandigarh, Uttaranchal, Dadra & Nagar Haveli, A & N Islands, Daman & Diu, Lakshadweep, and Goa. CDH = Chhatisgarh. % under reporting = (MDS death rate - NCRB death rate) / MDS death rate *100%.

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Road traffic injury mortality and its mechanisms in India: nationally representative mortality survey of 1.1 million homes

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Keywords: Road traffic injury; verbal autopsy; India; low- and middle-income countries

Word count: Text:~~3211~~3440

ABSTRACT:

Objectives: To quantify and describe the mechanism of road traffic injury (RTI) deaths in India.

Design: We conducted a nationally representative mortality survey where at least two physicians coded each non-medical field staff's verbal autopsy reports.RTI mechanism data were extracted from the narrative section of these reports.

Setting:1.1 million homes in India.

Participants: Over 122 000 deaths at all ages from 2001-2003.

Primary and secondary outcome measures: Age- and sex-specific mortality rates, place and timing of death, modes of transportation, and injuries sustained.

Results: The 2299 RTI deaths in the survey correspond to an estimated 183 600 RTI deaths or about 2% of all deaths in 2005 nationally, of which 65% occurred in males between the ages of 15-59 years. The age-adjusted mortality rate was greater in males than in females, in urban than in rural areas, and was notably higher than that estimated from national police records. Pedestrians (68 000), motorcyclists (36 000), and other vulnerable road users (20 000) constituted 68% of RTI deaths (124 000) nationally. Among the study sample, t~~T~~he majority of all RTI deaths occurred at the scene of collision (1005/1733, 58%), within minutes of collision (883/1596, 55%), and/or involved a head injury (691/1124, 62%). Compared to non-pedestrian RTI deaths, about 55 000 (81%) of pedestrian deaths were associated with less education and living in poorer neighbourhoods.

Conclusions: In India, RTI cause a substantial number of deaths, particularly among pedestrians and other vulnerable road users. Interventions to prevent collisions and reduce injuries might address over half of the RTI deaths. Improved pre-hospital transport and hospital trauma care might address just over a third of the RTI deaths.

ARTICLE SUMMARY

Article focus

- To directly estimate the age- and sex-specific mortality rates and describe the place and timing of death, modes of transportation, and injuries sustained for road traffic injury (RTI) deaths in India using a nationally representative mortality survey of 1.1 million homes.

Key messages

- Road traffic injuries cause a substantial number of avertable deaths, particularly in males of productive working age and among pedestrians and other vulnerable road users.
- Preventative interventions should be emphasized as the majority of all RTI deaths occurred at the scene of collision, within minutes of collision, and/or involved a head injury.
- Properly designed mortality survey with verbal autopsy narratives can provide much-needed data to assist RTI prevention efforts.

Strengths and limitations of this study

- This study is the first nationally representative survey of the causes of death in India and overcomes limitations of existing data sources including regional injury surveys, hospital series, and national police reports.
- Limitations of the study include potential misclassification of deaths by physician coders, the use of layperson narratives with a potential for recall bias and inaccuracies, and limited ability to forward project study results given the rapid changes in motorization in India.

INTRODUCTION

Road traffic injuries (RTI) area large and growing public health burden, especially in low-and middle-income countries (LMIC) where 90% of the world's ~~RTI~~ deaths due to RTI are estimated to occur.[1] There are few high-quality epidemiologic data on RTI to guide the development, implementation, and surveillance of evidence-based policy and programs in LMICs.[2-4]

The number of ~~RTI~~ deaths due to RTI in India is projected to rise with increasing motorization.[1,5]Aside from a few regional injury surveys,[6-11] the current data on the numbers and mechanisms of RTI deaths in India rely on police or hospital records, both of which can substantially underestimate death rates in the poor, rural, and uneducated people who still constitute large proportions of the Indian population.[2-4,12,13]

The World Health Organization (WHO), using indirect modeling methods, estimated about 202 000 RTI deaths in India in 2004.[14,15] No study has validated this estimate with direct measurement nor documented detailed RTI mechanism for India nationally. Here, we estimate the regional, age- and sex-specific mortality rate and risk of RTI death in India using data from the Million Death Study (MDS). We also report the modes of transportation, place and timing of death, and injuries sustained in RTI deaths.

METHODS

Study Design: The MDS is an on-going nationally representative survey designed to determine the causes and risk factors of death in India, organized by the Registrar General of India (RGI). The design, methodology, and preliminary findings of the MDS have been described elsewhere.[16-19]In brief, the MDS used an enhanced version of verbal autopsy (known as the routine, reliable, representative, re-sampled household investigation of mortality with medical evaluation or RHIME) to monitor a nationally representative sample of 1.1 million households in the Sample Registration System (SRS). Within six months of every death occurring in these households from 2001-3, a trained, nonmedical RGI surveyor interviewed a relative or close-acquaintance of the deceased to obtain the symptoms and events around the death using structured questions and a local language narrative guided by a specific symptom list. These records were converted into electronic records and emailed to two of 140 trained physicians who, independently and anonymously, assigned an underlying cause of death (with allocation determined randomly based only on the physician's ability to read the local language), using guidelines for the major causes of death.[20]Records were assigned cause of death in three-digit International Statistical Classification of Diseases and Related Health Problems, 10th revision (ICD-10).[21] Records where coders disagreed on the cause of death underwent anonymous reconciliation. Continuing disagreements were adjudicated by a third senior physician. Five percent of households were randomly resurveyed and the results were consistent within families of ICD-10 codes.[16] Participation in the SRS is on a voluntary basis and oral consent was obtained under the confidentiality and consent procedures of the Registration of Births and Deaths Act, 1969.

Road Traffic Injury Deaths: The RTI deaths in this study were of people who died between 2001 and 2003 with a final assigned ICD-10 code within V01-V89. We translated the open-ended narratives into English from 14 local languages, and systematically extracted the modes

of transportation, place and timing of death, and injuries sustained from ~~the~~ 2157 of the 2299 RTI ~~narratives~~deaths using a standardized data extraction tool and procedure (the remaining 142 deaths, 6%, had missing or illegible narratives). For these four data elements, there were substantial inter-rater agreement ~~(kappa statistic > 0.69)~~ between two investigators and two research assistants who were trained and ~~independentlyextracted~~independently extracted data from the narratives of a random 10% of RTI deaths (lowest kappa statistic was greater than 0.69 for all pair-wise comparisons between the ~~fourdata~~four data extractors; data not shown). The two research assistants then independently extracted data from all narratives. Adjudication was done by an investigator (M~~.~~H) for discrepancies in extracted data.

Analysis: The age and sex-specific proportion of RTI deaths within the 2001-2003 survey was applied to the 2005 United Nations (UN) estimates of the number of deaths from all causes in India, after weighting for sampling probability.[22] The 2005 UN death estimates were used so as to correct for the slight undercounts reported in the total death rates in the SRS[23,24] and to account for the 12% of enumerated deaths without completed field visits (mostly due to out-migration of the family or from incomplete field records). The proportion of these missed deaths was similarly dispersed across sex, age, and states. Use of 2003 or 2004 UN death totals yielded nearly identical results (data not shown). The 99% confidence intervals (99%CI) for mortality rate were calculated based on the weighted number of study deaths. State- and rural/urban-specific estimates of the number, mortality rate, and lifetime risk of RTI death were calculated by partitioning the UN national death totals according to relative SRS death rates as previously described.[18,25,26]Urban and rural status was defined according to the Census of India. Logistic regression was used to compare the socio-demographic traits of pedestrian and non-pedestrian RTI deaths. Household fuel type was used as a measure of community wealth, based on earlier principal component analyses [18]: high asset neighbourhoods had >50% of households that used gas, electricity, or kerosene; low asset or poor neighbourhoods used primarily coal, firewood, or other. Attributable proportion was calculated for traits of pedestrian deaths compared to non-pedestrian RTI deaths.

The MDS received ethics approval from the review boards of the Post-Graduate Institute of Medical Education and Research in Chandigarh, India; St Michael's Hospital in Toronto, Canada; and the Indian Council of Medical Research's Health Ministry's Screening Committee.

RESULTS

The 2299 RTI deaths in the 2001-2003 survey correspond to an estimated 183 600 (99%CI 173 800-193 400) RTI deaths in India in 2005. The majority of these RTI deaths occurred in males (152 100 deaths, 82.8%; table 1). The age-standardized RTI mortality rate for males (26.2 per 100 000, 24.6-27.7) was higher than for females (5.7 per 100 000, 5.0-6.4). While the RTI mortality rate increased with age in both genders, the largest number of RTI deaths occurred in males between 15-59 years of age (118 900, 64.8%).

At these death rates and in the theoretical absence of other causes of death, males in India had a 2.1% (2.0-2.3) risk of dying from RTI before age 70, with the highest risks at ages 30-59 years; females had a 0.5% (0.4-0.5) risk of dying from RTI before age 70. Males in Haryana, Punjab, Tamil Nadu, and Uttar Pradesh had significantly higher risks (3.0-4.1%) than the national risk (figure 1). In contrast, males in Bihar, Jharkhand, Andhra Pradesh, Orissa, Gujarat, and West Bengal had significantly lower risks (1.3-1.6%) than the national risk of RTI deaths. Males living in urban areas had slightly higher age-standardized mortality rates and risks of RTI deaths (27.6 per 100 000; 2.4%, 2.1-2.6) compared to males living in rural areas (24.9 per 100 000; 2.0%, 1.8-2.1). By contrast, female RTI mortality rates and risks before age 70 varied much less across states and were similar in rural and urban areas (data not shown).

	Study deaths, 2001-2003				All India, 2005			
	Number of RTI deaths / all coded deaths	Proportion RTI*	Rural (%**)	Two coders immediately agree	All deaths / population (millions, 2005 UN estimates)	Estimated RTI deaths§, thousands	RTI death rateΨ per 100 000 (99% CI)	Period risk for RTI death†
Male - age in years								
0-4	44 / 11719	0.4%	37 (76.7)	44	1.2 / 67	4.9	7.4 (6.5-8.4)¶	0.04%
5-14	97 / 1926	5.2%	86 (84.1)	87	0.2 / 129	8.5	6.6 (4.9-8.3)	0.1%
15-29	605 / 4727	13.0%	462 (68.9)	558	0.4 / 163	47.1	28.9 (25.9-31.9)	0.4%
30-44	529 / 6817	7.7%	385 (67.0)	477	0.6 / 115	43.8	37.9 (33.7-42.1)	0.6%
45-59	356 / 11731	3.0%	249 (60.9)	312	0.9 / 73	28.0	38.4 (33.2-43.6)	0.6%
60-69	149 / 12120	1.2%	117 (71.8)	133	0.9 / 24	10.6	44.0 (34.6-53.4)	0.5%
>70	123 / 18732	0.6%	106 (81.2)	98	1.3 / 14	9.1	64.5 (49.1-80.0)	--
All ages	1903 / 67772	2.8%	1442 (68.9)	1709	5.3 / 585	152.1	26.2	2.1%†
(% or 99% CI)				(89.8%)		(143.2-161.0)	(24.6-27.7)	(2.0-2.3)
Female - age in years								
0-4	50 / 11492	0.4%	46 (93.4)	45	1.2 / 61	5.0	8.1 (7.1-9.1)¶	0.04%
5-14	44 / 1955	2.3%	38 (80.1)	43	0.2 / 118	3.8	3.2 (2.0-4.4)	0.03%
15-29	72 / 4394	1.5%	53 (60.5)	63	0.3 / 150	5.3	3.5 (2.4-4.6)	0.1%
30-44	59 / 4055	1.4%	39 (59.0)	50	0.3 / 106	4.4	4.1 (2.7-5.5)	0.1%
45-59	70 / 6402	1.1%	55 (70.9)	61	0.5 / 69	6.0	8.6 (5.9-11.3)	0.1%
60-69	54 / 9016	0.6%	42 (68.6)	52	0.6 / 25	3.7	14.8 (9.8-19.9)	0.2%
>70	47 / 17343	0.3%	33 (61.8)	35	1.3 / 16	3.5	21.6 (13.4-29.9)	--
All ages	396 / 54657	0.7%	306 (69.8)	349	4.5 / 546	31.5	5.7	0.5%†
(% or 99% CI)				(88.1%)		(27.5-35.6)	(5.0-6.4)	(0.4-0.5)
Total male and female, <70 years	2129 / 86354	2.4%	1609 (68.5)	1925	7.2 / 1100	171.0	15.5	1.3%†
(% or 99% CI)				(90.4%)		(161.5-180.4)	(14.7-16.4)	(1.3-1.4)
Total male and female, all ages	2299 / 122429	1.8%	1748 (69.0)	2058	9.8 / 1131	183.6	16.2	1.3%†
(% or 99% CI)				(89.5%)		(173.8-193.4)	(15.4-17.1)	(1.3-1.4)

Table 1: Road traffic injury deaths in the present study and estimated national totals for 2005, by age and gender. *Proportion of RTI deaths compared to all deaths, weighted by state and residence (rural/urban). **Percentage rural is weighted by state and residence (rural/urban). §Obtained by multiplying the United Nations estimated total deaths in 2005 by the weighted proportions. ΨAge standardized to the 2005 United Nations estimated Indian population; 99% CI shown are calculated based on weighted number of study deaths, which result in wider CI than those based on physician agreement. †Annual RTI death rate multiplied by the duration of age range, except for the lifetime risk which is calculated between 0-69 years by summation of the age specific period risks. ¶Crude death rate.

The deceased mode of transportation was described in the narratives of 2105 (92%) of the RTI deaths. National estimates for the deceased mode of transportation were calculated, as those with unknown and known modes of transportation did not appear to differ with respect to the major socio-demographic traits (Supplementary Table 1).Vulnerable road users are those without a rigid barrier protecting against traumatic forces and include pedestrians, motorcyclists, bicyclists, and three-wheelers. They constituted a majority (68%; n=124 000, 99%CI 115 000-131 000) of RTI deaths, led by pedestrians (37%; n=68 000, 62 000-73 000) and motorcyclists (20%; n=36 000, 31 000-40 000) (figure 2). Drivers and passengers of motorized four-wheelers comprised 16% (n=31 000, 27 000-35 000) of RTI deaths. By contrast, the 2005 police reports, which use a different but compatible classification system to ICD-10, recorded only 33000 vulnerable road user deaths and only9000 pedestrian deaths.[27] The most common types of vehicle to collide into the decedents were heavy transport vehicles and buses (37%; n=68 000, 61 000-74 000), followed by cars and vans (15%; n=28 000, 24 000-32 000). Single-vehicle incidents comprised 9% of deaths (n=17 000, 14 000-20 000). The most frequent combinations, resulting in 23% (n=42 000, 37 000-47 000) of RTI deaths, were collisions of heavy transport vehicles or buses with pedestrians and motorcyclists (data not shown).

The place and timing of death were described in the narratives of 1733 (75%) and 1596 (69%) of the RTI deaths respectively (figure 2; see supplementary table 1 for a summary of missing data from the narratives with respect to deceased characteristics).For these narratives, only the study proportion and not national estimates were made. Most RTI deaths occurred at the scene of collision (58%, 1005/1733) or instantly, defined as within 5 minutes (55%, 883/1596). Only 3% (45/1733) were labeled as potentially avertable with better pre-hospital transport as they occurred on scene but not instantly. Another 35% of deaths occurred en route (7%, 124/1733) or in hospital (28%, 481/1733).

Injuries sustained by the deceased were reported from1124 narratives (49%). Head injuries were the most commonly reported (62%, 691/1124), of which 76% (524/691) were reported as isolated head injuries (figure 3). A greater percentage of motorcyclists (78%, 188/241) had head injuries reported compared to non-motorcyclists (57%, 457/807). After adjusting for age, sex, rural/urban, neighbourhood asset, and education, bicyclists and motorcyclists were more likely to have head injuries reported compared to non-vulnerable road users (adjusted OR 1.7, 1.2-2.5) (supplementary table 2).

Compared to non-pedestrian RTI deaths, pedestrian deaths occurred to those who had less education (or in the case of children age <15 years, have less educated parents) (adjusted OR 2.9, 99%CI 2.0-4.2), lived in poorer neighbourhoods (1.7, 1.1-2.5),were children or elderly adults (<15 years: 2.9, 1.8-4.5; >59 years: 1.7, 1.2-2.4), were female (1.5, 1.2-2.2), and lived in urban areas (1.5, 1.1-2.2) (table 2). If pedestrian deaths had the same proportion of secondary or higher education as non-pedestrian RTI deaths, there would be 406/825 (49%) fewer pedestrian deaths, corresponding to approximately 33 000 deaths nationally in 2005. The corresponding attributable proportion for living in richer versus poorer neighbourhoods would be 265/825 (32%) or approximately 22 000 deaths nationally. Within the narratives we could code, there were no differences between pedestrians and non-pedestrian RTI deaths in timing of death, place of death, reported injuries, or reported routine use of alcohol or smoking (data not shown).

	Pedestrian / Non-Pedestrian Total=825/1280	Adjusted OR^ (99% CI)	Attributable Pedestrian Deaths (% of all 825 pedestrian deaths)
Education*			
Secondary or higher	112/382	ref	
Primary or middle	248/450	1.8 (1.3-2.6)	110] 406 (49%)
Below primary	451/423	2.9 (2.0-4.2)	296
Unknown	14/25	1.6 (0.6-4.2)	N/A
Neighbourhood Asset			
High	137/320	ref	
Low	643/895	1.7 (1.1-2.5)	265 (32%)
Unknown	45/65	1.5 (0.8-2.8)	N/A
Age in years			
15-59 (driving ages)	497/1046	ref	
<15 (children)	144/74	2.9 (1.8-4.5)	94] 170 (21%)
>59 (elderly adults)	184/160	1.7 (1.2-2.4)	76
Sex			
Male	621/1121	ref	
Female	204/159	1.5 (1.1-2.2)	68 (8%)
Location			
Rural	643/962	ref	
Urban	182/318	1.5 (1.1-2.2)	61 (7%)
Occupation			
Salaried / Wage Earner / Professional	229/517	ref	
Cultivator / Agricultural labour / Other	162/300	0.9 (0.6-1.3)	N/A
Non-worker / Children <15 years	433/463	1.2 (0.9-1.6)	N/A
Unknown	1/0	N/A	N/A
Routine Alcohol Use**			
No	494/877	ref	
Yes	145/260	1.1 (0.7-1.5)	N/A
Unknown	42/69	1.0 (0.5-1.9)	N/A

Table 2: Characteristics of pedestrian RTI deaths and attributable proportions. *Education of deceased adults or, in cases of deceased children <15 years, education of respondent. **Excludes 218 children. ^Odds ratios are adjusted for all other variables in this table except for alcohol use; the odds ratios for alcohol use are adjusted for all other variables in this table.

DISCUSSION

RTI is an important cause of death in India, causing 183 600 deaths in 2005, or about 2% of all deaths.[22] Much of the deceased were men between ages 15-59 years. Males had a four-fold higher cumulative risk of RTI death compared to females before the age of 70. Among the major

states, there was approximately 3-fold variation in the age-standardized RTI death rate and cumulative risk for males.

Our estimated number of RTI deaths is more than 50% greater than the 118 265 deaths reported in the official police statistics of the National Crime Records Bureau (NCRB) in 2005.[27] Compared to our estimates, the extent of under-reporting of the crude death rate in major states by NCRB ranged from <1% to about 80% (supplementary table 3). Existing regional population-based injury surveys in India support our findings and also report higher crude RTI death rates than NCRB statistics.[8,11]Under-reporting of RTI deaths in police statistics has been reported in India and other LMIC.[28-30]A study in urban India comparing both hospital- and community-based RTI data to police records identified factors contributing to under-reporting that included the deceased believed to be at fault, collision resulting from hit-and-runs, limited police resources, and the lack of a standard police reporting protocol by hospitals.[28] The factors contributing to police under-reporting, especially in rural India, require further examination. Our estimated number of RTI deaths in 2005 was consistent with the WHO estimate for 2004.[14] However, we observed a slightly higher male proportion (83% MDS vs. 77% WHO, all ages) and a higher proportion of male deaths between 15-59 years (65% MDS vs. 61% WHO).

Almost three-quarters of all RTI deaths in India were of pedestrians and other vulnerable road users. In contrast, a much lower proportion (27%) was reported by the NCRB (figure 2).This difference equated to 59 000 pedestrian and 32 000 other vulnerable road user deaths that were not included in the 2005 NCRB records. Existing RTI studies based on regional surveys and hospital series also reported a high proportion (>60%) of vulnerable road user deaths similar to our findings.[11,12,30-32]Since the majority of vulnerable road users were pedestrians, our findings suggested that RTI deaths in individuals who were less educated, poor, female or live in urban areas may have been disproportionally excluded from the NCRB records. While poverty and education are not likely to be in the direct causal pathway of pedestrian deaths, they nonetheless point to other associated risk factors. Indeed, 55 000 pedestrian deaths in 2005 (81%) was associated with lower education or living in poorer neighbourhoods compared to non-pedestrian RTI deaths. While the less educated and the poor likely travelled more often by foot, they might also be exposed to undetermined environmental (neighbourhoods with unsafe roads), biological (poor vision or decreased mobility due to poor health), and behavioral (alcohol or other substance use) risk factors for pedestrian death.[12, 33, 34]Further studies are needed to better understand pedestrian deaths in LMIC.

Over half of RTI deaths occurred instantly at the scene of collision and/or had head injury reported. ~~Thus~~These findings, together with existing RTI hospital series and regional surveys in India, make a strong argument that ~~,~~ investments in primary and secondary prevention could potentially avert the greatest proportion of RTI deaths. To address the high proportion of instant deaths and head injuries among RTI deaths in India, specific interventions that are effective and based on studies in LMIC should be emphasized; these may include speed bumps, motorcycle helmets, and increasing fines and license suspensions for rule infractions.[33]In contrast, improving pre-hospital transport and hospital trauma care, could only potentially affect the 38%who died on scene with delayed hospital transport (3%), en route to hospital (7%), or in hospital (28%).

Our study is the first nationally representative survey of the causes of death in India. The simple descriptive statistics provide clear evidence on the large and avertable burden from RTI, particularly among productive age adults and pedestrians. To the best of our knowledge, only one recent study in Vietnam has used similar methods to analyze RTI deaths and policy implications on a national scale.[35]

Our study faced certain limitations. First, we might have misclassified certain causes of death including suicide as RTI deaths. However, the extent of misclassification should be minimal since the RHIME verbal autopsy method was shown to be robust in discerning between types of injury deaths[36]and since the immediate two-physician agreement was high for RTI deaths(89.5%, table 1). Furthermore, suicides cause about 200 000 deaths in India annually but few are due to RTI.[19] Second, since the modes of transportation, place and timing of death, and injuries sustained were extracted from layperson open-ended narratives, the data accuracy may be in question. For example with the deceased mode of transportation, the extent of misclassification (by our study) or misreporting (by NCRB) that contributed to the differences between the two sources is uncertain. With reported injuries, our findings from these narratives most likely undercounted less visible injuries (chest, abdomen, and spine) compared to highly visible injuries such as bleeding and deformity for head and extremity injuries. Nevertheless, our findings are consistent with available Indian regional surveys and hospital series on the mode of transportation[11,12,30-32,37]~~[11,12,30-32]~~ place and timing of death,[1,37-41]~~[1,37-39]~~ and injuries sustained.[12,37,42,43]~~[12,40,41]~~Third, since the narrative was not designed specifically to capture RTI death characteristics, over 25% of deaths had missing data for mode of transportation, place of death, timing of death, or reported injuries(supplementary table 1).Thus, our findings for these elements extracted from the narratives may be less representative of the decedents who lived in rural or poor areas. Finally, reliable forward projection of the number of RTI deaths beyond 2005 was not possible since the increase in the NCRB reported number of RTI deaths of140% from 2005 to 2011 appeared to outpace the rate of population growth.[44] As the proportion of vulnerable road user deaths remained stable during this period in the NCRB reports, we postulated that this increase represented an actual increase in RTI death totals rather than more accurate reporting. Furthermore, given the rapid economic expansion and concurrent changes in motorization including the types of vehicle sharing the road and road infrastructure,[45,46]our results on deceased mode of transportation, place and timing of death, and injuries sustained may not reflect the current Indian scenario. An analysis of the trend from 2001-2014 is planned pending ongoing data collection in the MDS.

In India, RTI is a significant cause of preventable death, particularly in males of productive working age and among pedestrians, bicyclists, and motorcyclist. We have shown that properly designed simple verbal autopsy narratives can document the much needed surveillance data on the numbers, rates, risks, and basic RTI mechanism such as modes of transportation, timing of death, place of death, and injuries sustained. Our findings suggested that investment in primary and secondary prevention could address a large proportion of avoidable RTI deaths.

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COMPETING INTERESTS

We declare that we have no competing interests.

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collection, analysis, interpretation; writing of the manuscript; or decision to submit for publication. The senior author had full access to all the data in the study and had final responsibility for the decision to submit this study for publication.

AUTHOR'S CONTRIBUTION

PJ and the MDS Collaborators (appendix) designed, planned, the executed the MDS in close collaboration with the Office of the Registrar General of India (RGI). MH and PJ performed the data analysis. All authors contributed to data interpretation, revisions of the manuscript, and provided final approval. PJ is the guarantor for this report.

DATA SHARING STATEMENT

Data used in this study ~~is~~ are the property of the Registrar General of India and the overall mortality results have been published in 2009.[47] This specific analyses is produced under an agreement with CGHR. ~~Application for data access can be made to the Office of the Registrar General of India.~~

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FIGURE LEGENDS

Figure 1: Road traffic injury deaths, age-standardized death rate, and cumulative risk (age 0-69 years) across states and regions of India, by gender.

Death rates are standardized to the 2005 United Nations estimated Indian population. Symbol size is proportional to sample size. Northeast states include Sikkim, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura, and Meghalaya. Total estimates include the 80 male and 19 female deaths from Pondicherry, Chandigarh, Uttarakhand, Dadra & Nagar Haveli, A&N Islands, Daman & Diu, Lakshadweep, and Goa. CHT=Chhatisgarh.

Figure 2: Deceased mode of transportation, place of death, and timing of death.

(A) Deceased mode of transportation in present study compared to National Crime Records Bureau 2005 Report. Shaded line represents vulnerable road users (defined as road users without a rigid barrier protecting against traumatic forces, i.e. pedestrian, bicyclist, motorcyclist, and three wheelers). Percentages from present study are weighted by state and rural/urban residence. T=estimated/reported number of deaths in 2005 (in thousands). (B) Place of death and (C) timing of death based on verbal autopsy narratives. Shaded lines represent deaths that are reported as occurring at the scene of collision or occurring instantly (defined as within 5 minutes).

Figure 3: Reported injuries from 1124 verbal autopsy narratives (49% of all 2299 RTI deaths).

Percentages refer to those in each row with given injury (columns). *Values in bold denote two by two chi square tests with $p<0.05$ (excluding unknowns). Abdominal and spinal injuries were also reported but not shown due to small numbers (61 and 25 cases, respectively).

LIST OF ACRONYMS

CI	Confidence interval
ICD-10	International Statistical Classification of Diseases and Related Health Problems, 10th Revision
LMIC	Low- and middle-income countries
MDS	Million Death Study
NCRB	National Crime Records Bureau
RGI	Registrar General of India
RTI	Road traffic injury
SRS	Sample registration system
UN	United Nations
WHO	World Health Organization

Road traffic injury mortality and its mechanisms in India: nationally representative mortality survey of 1.1 million homes

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Road traffic injury mortality and its mechanisms in India: nationally representative mortality survey of 1.1 million homes

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ABSTRACT:

Objectives: To quantify and describe the mechanism of road traffic injury (RTI) deaths in India.

Design: We conducted a nationally representative mortality survey where at least two physicians coded each non-medical field staff's verbal autopsy reports. RTI mechanism data were extracted from the narrative section of these reports.

Setting: 1.1 million homes in India.

Participants: Over 122 000 deaths at all ages from 2001-2003.

Primary and secondary outcome measures: Age- and sex-specific mortality rates, place and timing of death, modes of transportation, and injuries sustained.

Results: The 2299 RTI deaths in the survey correspond to an estimated 183 600 RTI deaths or about 2% of all deaths in 2005 nationally, of which 65% occurred in males between the ages of 15-59 years. The age-adjusted mortality rate was greater in males than in females, in urban than in rural areas, and was notably higher than that estimated from national police records. Pedestrians (68 000), motorcyclists (36 000), and other vulnerable road users (20 000) constituted 68% of RTI deaths (124 000) nationally. Among the study sample, the majority of all RTI deaths occurred at the scene of collision (1005/1733, 58%), within minutes of collision (883/1596, 55%), and/or involved a head injury (691/1124, 62%). Compared to non-pedestrian RTI deaths, about 55 000 (81%) of pedestrian deaths were associated with less education and living in poorer neighbourhoods.

Conclusions: In India, RTI cause a substantial number of deaths, particularly among pedestrians and other vulnerable road users. Interventions to prevent collisions and reduce injuries might address over half of the RTI deaths. Improved pre-hospital transport and hospital trauma care might address just over a third of the RTI deaths.

ARTICLE SUMMARY

Article focus

- To directly estimate the age- and sex-specific mortality rates and describe the place and timing of death, modes of transportation, and injuries sustained for road traffic injury (RTI) deaths in India using a nationally representative mortality survey of 1.1 million homes.

Key messages

- Road traffic injuries cause a substantial number of avertable deaths, particularly in males of productive working age and among pedestrians and other vulnerable road users.
- Preventative interventions should be emphasized as the majority of all RTI deaths occurred at the scene of collision, within minutes of collision, and/or involved a head injury.
- Properly designed mortality survey with verbal autopsy narratives can provide much-needed data to assist RTI prevention efforts.

Strengths and limitations of this study

- This study is the first nationally representative survey of the causes of death in India and overcomes limitations of existing data sources including regional injury surveys, hospital series, and national police reports.
- Limitations of the study include potential misclassification of deaths by physician coders, the use of layperson narratives with a potential for recall bias and inaccuracies, and limited ability to forward project study results given the rapid changes in motorization in India.

INTRODUCTION

Road traffic injuries (RTI) area large and growing public health burden, especially in low-and middle-income countries (LMIC) where 90% of the world's deaths due to RTI are estimated to occur.[1] There are few high-quality epidemiologic data on RTI to guide the development, implementation, and surveillance of evidence-based policy and programs in LMICs.[2-4]

The number of deaths due to RTI in India is projected to rise with increasing motorization.[1,5] Aside from a few regional injury surveys,[6-11] the current data on the numbers and mechanisms of RTI deaths in India rely on police or hospital records, both of which can substantially underestimate death rates in the poor, rural, and uneducated people who still constitute large proportions of the Indian population.[2-4,12,13]

The World Health Organization (WHO), using indirect modeling methods, estimated about 202 000 RTI deaths in India in 2004.[14,15] No study has validated this estimate with direct measurement nor documented detailed RTI mechanism for India nationally. Here, we estimate the regional, age- and sex-specific mortality rate and risk of RTI death in India using data from the Million Death Study (MDS). We also report the modes of transportation, place and timing of death, and injuries sustained in RTI deaths.

METHODS

Study Design: The MDS is an on-going nationally representative survey designed to determine the causes and risk factors of death in India, organized by the Registrar General of India (RGI). The design, methodology, and preliminary findings of the MDS have been described elsewhere.[16-19] In brief, the MDS used an enhanced version of verbal autopsy (known as the routine, reliable, representative, re-sampled household investigation of mortality with medical evaluation or RHIME) to monitor a nationally representative sample of 1.1 million households in the Sample Registration System (SRS). Within six months of every death occurring in these households from 2001-3, a trained, nonmedical RGI surveyor interviewed a relative or close-acquaintance of the deceased to obtain the symptoms and events around the death using structured questions and a local language narrative guided by a specific symptom list. These records were converted into electronic records and emailed to two of 140 trained physicians who, independently and anonymously, assigned an underlying cause of death (with allocation determined randomly based only on the physician's ability to read the local language), using guidelines for the major causes of death.[20] Records were assigned cause of death in three-digit International Statistical Classification of Diseases and Related Health Problems, 10th revision (ICD-10).[21] Records where coders disagreed on the cause of death underwent anonymous reconciliation. Continuing disagreements were adjudicated by a third senior physician. Five percent of households were randomly resurveyed and the results were consistent within families of ICD-10 codes.[16] Participation in the SRS is on a voluntary basis and oral consent was obtained under the confidentiality and consent procedures of the Registration of Births and Deaths Act, 1969.

Road Traffic Injury Deaths: The RTI deaths in this study were of people who died between 2001 and 2003 with a final assigned ICD-10 code within V01-V89. We translated the open-ended narratives into English from 14 local languages, and systematically extracted the modes

of transportation, place and timing of death, and injuries sustained from 2157 of the 2299 RTI deaths using a standardized data extraction tool and procedure (the remaining 142 deaths, 6%, had missing or illegible narratives). For these four data elements, there were substantial inter-rater agreement between two investigators and two research assistants who were trained and independently extracted data from the narratives of a random 10% of RTI deaths (lowest kappa statistic was greater than 0.69 for all pair-wise comparisons between the four data extractors; data not shown). The two research assistants then independently extracted data from all narratives. Adjudication was done by an investigator (MH) for discrepancies in extracted data.

Analysis: The age and sex-specific proportion of RTI deaths within the 2001-2003 survey was applied to the 2005 United Nations (UN) estimates of the number of deaths from all causes in India, after weighting for sampling probability for each rural or urban stratum per state (although such weighting made little difference because the study was nationally representative).[18,22] The 2005 UN death estimates were used so as to correct for the slight undercounts reported in the total death rates in the SRS [23,24] and to account for the 12% of enumerated deaths without completed field visits (mostly due to out-migration of the family or from incomplete field records). The proportion of these missed deaths was similarly dispersed across sex, age, and states. Use of 2003 or 2004 UN death totals yielded nearly identical results (data not shown). The 99% confidence intervals (99%CI) for mortality rate were calculated based on the weighted number of study deaths. State- and rural/urban-specific estimates of the number, mortality rate, and lifetime risk of RTI death were calculated by partitioning the UN national death totals according to relative SRS death rates as previously described.[18,25,26] Urban and rural status was defined according to the Census of India. Logistic regression was used to compare the socio-demographic traits of pedestrian and non-pedestrian RTI deaths. Household fuel type was used as a measure of community wealth, based on earlier principal component analyses [18]: high asset neighbourhoods had >50% of households that used gas, electricity, or kerosene; low asset or poor neighbourhoods used primarily coal, firewood, or other. Attributable proportion was calculated for traits of pedestrian deaths compared to non-pedestrian RTI deaths.

The MDS received ethics approval from the review boards of the Post-Graduate Institute of Medical Education and Research in Chandigarh, India; St Michael's Hospital in Toronto, Canada; and the Indian Council of Medical Research's Health Ministry's Screening Committee.

RESULTS

The 2299 RTI deaths in the 2001-2003 survey correspond to an estimated 183 600 (99%CI 173 800-193 400) RTI deaths in India in 2005. The majority of these RTI deaths occurred in males (152 100 deaths, 82.8%; table 1). The age-standardized RTI mortality rate for males (26.2 per 100 000, 24.6-27.7) was higher than for females (5.7 per 100 000, 5.0-6.4). While the RTI mortality rate increased with age in both genders, the largest number of RTI deaths occurred in males between 15-59 years of age (118 900, 64.8%).

At these death rates and in the theoretical absence of other causes of death, males in India had a 2.1% (2.0-2.3) risk of dying from RTI before age 70, with the highest risks at ages 30-59 years; females had a 0.5% (0.4-0.5) risk of dying from RTI before age 70. Males in Haryana, Punjab, Tamil Nadu, and Uttar Pradesh had significantly higher risks (3.0-4.1%) than the national risk (figure 1). In contrast, males in Bihar, Jharkhand, Andhra Pradesh, Orissa, Gujarat, and West Bengal had significantly lower risks (1.3-1.6%) than the national risk of RTI deaths. Males living in urban areas had slightly higher age-standardized mortality rates and risks of RTI deaths (27.6 per 100 000; 2.4%, 2.1-2.6) compared to males living in rural areas (24.9 per 100 000; 2.0%, 1.8-2.1). By contrast, female RTI mortality rates and risks before age 70 varied much less across states and were similar in rural and urban areas (data not shown).

	Study deaths, 2001-2003				All India, 2005			
	Number of RTI deaths / all coded deaths	Proportion RTI*	Rural (%**)	Two coders immediately agree	All deaths / population (millions, 2005 UN estimates)	Estimated RTI deaths§, thousands	RTI death rateΨ per 100 000 (99% CI)	Period risk for RTI death†
Male - age in years								
0-4	44 / 11719	0.4%	37 (76.7)	44	1.2 / 67	4.9	7.4 (6.5-8.4)¶	0.04%
5-14	97 / 1926	5.2%	86 (84.1)	87	0.2 / 129	8.5	6.6 (4.9-8.3)	0.1%
15-29	605 / 4727	13.0%	462 (68.9)	558	0.4 / 163	47.1	28.9 (25.9-31.9)	0.4%
30-44	529 / 6817	7.7%	385 (67.0)	477	0.6 / 115	43.8	37.9 (33.7-42.1)	0.6%
45-59	356 / 11731	3.0%	249 (60.9)	312	0.9 / 73	28.0	38.4 (33.2-43.6)	0.6%
60-69	149 / 12120	1.2%	117 (71.8)	133	0.9 / 24	10.6	44.0 (34.6-53.4)	0.5%
>70	123 / 18732	0.6%	106 (81.2)	98	1.3 / 14	9.1	64.5 (49.1-80.0)	--
All ages	1903 / 67772	2.8%	1442 (68.9)	1709	5.3 / 585	152.1	26.2	2.1%†
(% or 99% CI)				(89.8%)		(143.2-161.0)	(24.6-27.7)	(2.0-2.3)
Female - age in years								
0-4	50 / 11492	0.4%	46 (93.4)	45	1.2 / 61	5.0	8.1 (7.1-9.1)¶	0.04%
5-14	44 / 1955	2.3%	38 (80.1)	43	0.2 / 118	3.8	3.2 (2.0-4.4)	0.03%
15-29	72 / 4394	1.5%	53 (60.5)	63	0.3 / 150	5.3	3.5 (2.4-4.6)	0.1%
30-44	59 / 4055	1.4%	39 (59.0)	50	0.3 / 106	4.4	4.1 (2.7-5.5)	0.1%
45-59	70 / 6402	1.1%	55 (70.9)	61	0.5 / 69	6.0	8.6 (5.9-11.3)	0.1%
60-69	54 / 9016	0.6%	42 (68.6)	52	0.6 / 25	3.7	14.8 (9.8-19.9)	0.2%
>70	47 / 17343	0.3%	33 (61.8)	35	1.3 / 16	3.5	21.6 (13.4-29.9)	--
All ages	396 / 54657	0.7%	306 (69.8)	349	4.5 / 546	31.5	5.7	0.5%†
(% or 99% CI)				(88.1%)		(27.5-35.6)	(5.0-6.4)	(0.4-0.5)
Total male and female, <70 years	2129 / 86354	2.4%	1609 (68.5)	1925	7.2 / 1100	171.0	15.5	1.3%†
(% or 99% CI)				(90.4%)		(161.5-180.4)	(14.7-16.4)	(1.3-1.4)
Total male and female, all ages	2299 / 122429	1.8%	1748 (69.0)	2058	9.8 / 1131	183.6	16.2	1.3%†
(% or 99% CI)				(89.5%)		(173.8-193.4)	(15.4-17.1)	(1.3-1.4)

Table 1: Road traffic injury deaths in the present study and estimated national totals for 2005, by age and gender. *Proportion of RTI deaths compared to all deaths, weighted by state and residence (rural/urban). **Percentage rural is weighted by state and residence (rural/urban). §Obtained by multiplying the United Nations estimated total deaths in 2005 by the weighted proportions. ΨAge standardized to the 2005 United Nations estimated Indian population; 99% CI shown are calculated based on weighted number of study deaths, which result in wider CI than those based on physician agreement. †Annual RTI death rate multiplied by the duration of age range, except for the lifetime risk which is calculated between 0-69 years by summation of the age specific period risks. ¶Crude death rate.

The deceased mode of transportation was described in the narratives of 2105 (92%) of the RTI deaths. National estimates for the deceased mode of transportation were calculated, as those with unknown and known modes of transportation did not appear to differ with respect to the major socio-demographic traits (Supplementary Table 1). Vulnerable road users are those without a rigid barrier protecting against traumatic forces and include pedestrians, motorcyclists, bicyclists, and three-wheelers. They constituted a majority (68%; n=124 000, 99%CI 115 000-131 000) of RTI deaths, led by pedestrians (37%; n=68 000, 62 000-73 000) and motorcyclists (20%; n=36 000, 31 000-40 000) (figure 2). Drivers and passengers of motorized four-wheelers comprised 16% (n=31 000, 27 000-35 000) of RTI deaths. By contrast, the 2005 police reports, which use a different but compatible classification system to ICD-10, recorded only 33000 vulnerable road user deaths and only 9000 pedestrian deaths.[27] The most common types of vehicle to collide into the decedents were heavy transport vehicles and buses (37%; n=68 000, 61 000-74 000), followed by cars and vans (15%; n=28 000, 24 000-32 000). Single-vehicle incidents comprised 9% of deaths (n=17 000, 14 000-20 000). The most frequent combinations, resulting in 23% (n=42 000, 37 000-47 000) of RTI deaths, were collisions of heavy transport vehicles or buses with pedestrians and motorcyclists (data not shown).

The place and timing of death were described in the narratives of 1733 (75%) and 1596 (69%) of the RTI deaths respectively (figure 2; see supplementary table 1 for a summary of missing data from the narratives with respect to deceased characteristics). For these narratives, only the study proportion and not national estimates were made. Most RTI deaths occurred at the scene of collision (58%, 1005/1733) or instantly, defined as within 5 minutes (55%, 883/1596). Only 3% (45/1733) were labeled as potentially avertable with better pre-hospital transport as they occurred on scene but not instantly. Another 35% of deaths occurred en route (7%, 124/1733) or in hospital (28%, 481/1733).

Injuries sustained by the deceased were reported from1124 narratives (49%). Head injuries were the most commonly reported (62%, 691/1124), of which 76% (524/691) were reported as isolated head injuries (figure 3). A greater percentage of motorcyclists (78%, 188/241) had head injuries reported compared to non-motorcyclists (57%, 457/807). After adjusting for age, sex, rural/urban, neighbourhood asset, and education, bicyclists and motorcyclists were more likely to have head injuries reported compared to non-vulnerable road users (adjusted OR 1.7, 1.2-2.5) (supplementary table 2).

Compared to non-pedestrian RTI deaths, pedestrian deaths occurred to those who had less education (or in the case of children age <15 years, have less educated parents) (adjusted OR 2.9, 99%CI 2.0-4.2), lived in poorer neighbourhoods (1.7, 1.1-2.5), were children or elderly adults (<15 years: 2.9, 1.8-4.5; >59 years: 1.7, 1.2-2.4), were female (1.5, 1.2-2.2), and lived in urban areas (1.5, 1.1-2.2) (table 2). If pedestrian deaths had the same proportion of secondary or higher education as non-pedestrian RTI deaths, there would be 406/825 (49%) fewer pedestrian deaths, corresponding to approximately 33 000 deaths nationally in 2005. The corresponding attributable proportion for living in richer versus poorer neighbourhoods would be 265/825 (32%) or approximately 22 000 deaths nationally. Within the narratives we could code, there were no differences between pedestrians and non-pedestrian RTI deaths in timing of death, place of death, reported injuries, or reported routine use of alcohol or smoking (data not shown).

	Pedestrian / Non-Pedestrian Total=825/1280	Adjusted OR^ (99% CI)	Attributable Pedestrian Deaths (% of all 825 pedestrian deaths)	
Education*				
Secondary or higher	112/382	ref		
Primary or middle	248/450	1.8 (1.3-2.6)	110	406 (49%)
Below primary	451/423	2.9 (2.0-4.2)	296	
Unknown	14/25	1.6 (0.6-4.2)	N/A	
Neighbourhood Asset				
High	137/320	ref		
Low	643/895	1.7 (1.1-2.5)	265 (32%)	
Unknown	45/65	1.5 (0.8-2.8)	N/A	
Age in years				
15-59 (driving ages)	497/1046	ref		
<15 (children)	144/74	2.9 (1.8-4.5)	94	170 (21%)
>59 (elderly adults)	184/160	1.7 (1.2-2.4)	76	
Sex				
Male	621/1121	ref		
Female	204/159	1.5 (1.1-2.2)	68 (8%)	
Location				
Rural	643/962	ref		
Urban	182/318	1.5 (1.1-2.2)	61 (7%)	
Occupation				
Salaried / Wage Earner / Professional	229/517	ref		
Cultivator / Agricultural labour / Other	162/300	0.9 (0.6-1.3)	N/A	
Non-worker / Children <15 years	433/463	1.2 (0.9-1.6)	N/A	
Unknown	1/0	N/A	N/A	
Routine Alcohol Use**				
No	494/877	ref		
Yes	145/260	1.1 (0.7-1.5)	N/A	
Unknown	42/69	1.0 (0.5-1.9)	N/A	

Table 2: Characteristics of pedestrian RTI deaths and attributable proportions. *Education of deceased adults or, in cases of deceased children <15 years, education of respondent. **Excludes 218 children. ^Odds ratios are adjusted for all other variables in this table except for alcohol use; the odds ratios for alcohol use are adjusted for all other variables in this table.

DISCUSSION

RTI is an important cause of death in India, causing 183 600 deaths in 2005, or about 2% of all deaths.[22] Much of the deceased were men between ages 15-59 years. Males had a four-fold higher cumulative risk of RTI death compared to females before the age of 70. Among the major states, there was approximately 3-fold variation in the age-standardized RTI death rate and cumulative risk for males.

Our estimated number of RTI deaths is more than 50% greater than the 118 265 deaths reported in the official police statistics of the National Crime Records Bureau (NCRB) in 2005.[27] Compared to our estimates, the extent of under-reporting of the crude death rate in major states by NCRB ranged from <1% to about 80% (supplementary table 3). Existing regional population-based injury surveys in India support our findings and also report higher crude RTI death rates than NCRB statistics.[8,11] Under-reporting of RTI deaths in police statistics has been reported in India and other LMIC.[28-30] A study in urban India comparing both hospital- and community-based RTI data to police records identified factors contributing to under-reporting that included the deceased believed to be at fault, collision resulting from hit-and-runs, limited police resources, and the lack of a standard police reporting protocol by hospitals.[28] The factors contributing to police under-reporting, especially in rural India, require further examination. Our estimated number of RTI deaths in 2005 was consistent with the WHO estimate for 2004.[14] However, we observed a slightly higher male proportion (83% MDS vs. 77% WHO, all ages) and a higher proportion of male deaths between 15-59 years (65% MDS vs. 61% WHO).

Almost three-quarters of all RTI deaths in India were of pedestrians and other vulnerable road users. In contrast, a much lower proportion (27%) was reported by the NCRB (figure 2). This difference equated to 59 000 pedestrian and 32 000 other vulnerable road user deaths that were not included in the 2005 NCRB records. Existing RTI studies based on regional surveys and hospital series also reported a high proportion (>60%) of vulnerable road user deaths similar to our findings.[11,12,30-32] Since the majority of vulnerable road users were pedestrians, our findings suggested that RTI deaths in individuals who were less educated, poor, female or live in urban areas may have been disproportionally excluded from the NCRB records. While poverty and education are not likely to be in the direct causal pathway of pedestrian deaths, they nonetheless point to other associated risk factors. Indeed, 55 000 pedestrian deaths in 2005 (81%) was associated with lower education or living in poorer neighbourhoods compared to non-pedestrian RTI deaths. While the less educated and the poor likely travelled more often by foot, they might also be exposed to undetermined environmental (neighbourhoods with unsafe roads), biological (poor vision or decreased mobility due to poor health), and behavioral (alcohol or other substance use) risk factors for pedestrian death.[12, 33, 34] Further studies are needed to better understand pedestrian deaths in LMIC.

Over half of RTI deaths occurred instantly at the scene of collision and/or had head injury reported. These findings, together with existing RTI hospital series and regional surveys in India, make a strong argument that investments in primary and secondary prevention could potentially avert the greatest proportion of RTI deaths. To address the high proportion of instant deaths and head injuries among RTI deaths in India, specific interventions that are effective and based on studies in LMIC should be emphasized; these may include speed bumps, motorcycle helmets, and increasing fines and license suspensions for rule infractions.[33] In contrast, improving pre-hospital transport and hospital trauma care, could only potentially affect the 38%who died on scene with delayed hospital transport (3%), en route to hospital (7%), or in hospital (28%).

Our study is the first nationally representative survey of the causes of death in India. The simple descriptive statistics provide clear evidence on the large and avertable burden from RTI, particularly among productive age adults and pedestrians. To the best of our knowledge, only one recent study in Vietnam has used similar methods to analyze RTI deaths and policy implications on a national scale.[35]

Our study faced certain limitations. First, we might have misclassified certain causes of death including suicide as RTI deaths. However, the extent of misclassification should be minimal since the RHIME verbal autopsy method was shown to be robust in discerning between types of injury deaths[36] and since the immediate two-physician agreement was high for RTI deaths(89.5%, table 1). Furthermore, suicides cause about 200 000 deaths in India annually but few are due to RTI.[19] Second, since the modes of transportation, place and timing of death, and injuries sustained were extracted from layperson open-ended narratives, the data accuracy may be in question. For example with the deceased mode of transportation, the extent of misclassification (by our study) or misreporting (by NCRB) that contributed to the differences between the two sources is uncertain. With reported injuries, our findings from these narratives most likely undercounted less visible injuries (chest, abdomen, and spine) compared to highly visible injuries such as bleeding and deformity for head and extremity injuries. Nevertheless, our findings are consistent with available Indian regional surveys and hospital series on the mode of transportation[11,12,30-32,37] place and timing of death,[1,37-41] and injuries sustained.[12,37,42,43] Third, since the narrative was not designed specifically to capture RTI death characteristics, over 25% of deaths had missing data for mode of transportation, place of death, timing of death, or reported injuries (supplementary table 1). Thus, our findings for these elements extracted from the narratives may be less representative of the decedents who lived in rural or poor areas. Finally, reliable forward projection of the number of RTI deaths beyond 2005 was not possible since the increase in the NCRB reported number of RTI deaths of 140% from 2005 to 2011 appeared to outpace the rate of population growth.[44] As the proportion of vulnerable road user deaths remained stable during this period in the NCRB reports, we postulated that this increase represented an actual increase in RTI death totals rather than more accurate reporting. Furthermore, given the rapid economic expansion and concurrent changes in motorization including the types of vehicle sharing the road and road infrastructure,[45,46] our results on deceased mode of transportation, place and timing of death, and injuries sustained may not reflect the current Indian scenario. An analysis of the trend from 2001-2014 is planned pending ongoing data collection in the MDS.

In India, RTI is a significant cause of preventable death, particularly in males of productive working age and among pedestrians, bicyclists, and motorcyclist. We have shown that properly designed simple verbal autopsy narratives can document the much needed surveillance data on the numbers, rates, risks, and basic RTI mechanism such as modes of transportation, timing of death, place of death, and injuries sustained. Our findings suggested that investment in primary and secondary prevention could address a large proportion of avoidable RTI deaths.

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COMPETING INTERESTS

We declare that we have no competing interests.

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collection, analysis, interpretation; writing of the manuscript; or decision to submit for publication. The senior author had full access to all the data in the study and had final responsibility for the decision to submit this study for publication.

AUTHOR'S CONTRIBUTION

PJ and the MDS Collaborators (appendix) designed, planned, the executed the MDS in close collaboration with the Office of the Registrar General of India (RGI). MH and PJ performed the data analysis. All authors contributed to data interpretation, revisions of the manuscript, and provided final approval. PJ is the guarantor for this report.

DATA SHARING STATEMENT

Data used in this study are the property of the Registrar General of India and the overall mortality results have been published in 2009.[47] This specific analyses is produced under an agreement with CGHR.

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FIGURE LEGENDS

Figure 1: Road traffic injury deaths, age-standardized death rate, and cumulative risk (age 0-69 years) across states and regions of India, by gender.

Death rates are standardized to the 2005 United Nations estimated Indian population. Symbol size is proportional to sample size. Northeast states include Sikkim, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura, and Meghalaya. Total estimates include the 80 male and 19 female deaths from Pondicherry, Chandigarh, Uttarakhand, Dadra & Nagar Haveli, A&N Islands, Daman & Diu, Lakshadweep, and Goa. CHT=Chhatisgarh.

Figure 2: Deceased mode of transportation, place of death, and timing of death.

(A) Deceased mode of transportation in present study compared to National Crime Records Bureau 2005 Report. Shaded line represents vulnerable road users (defined as road users without a rigid barrier protecting against traumatic forces, i.e. pedestrian, bicyclist, motorcyclist, and three wheelers). Percentages from present study are weighted by state and rural/urban residence. T=estimated/reported number of deaths in 2005 (in thousands). (B) Place of death and (C) timing of death based on verbal autopsy narratives. Shaded lines represent deaths that are reported as occurring at the scene of collision or occurring instantly (defined as within 5 minutes).

Figure 3: Reported injuries from 1124 verbal autopsy narratives (49% of all 2299 RTI deaths).

Percentages refer to those in each row with given injury (columns). *Values in bold denote two by two chi square tests with p<0.05 (excluding unknowns). Abdominal and spinal injuries were also reported but not shown due to small numbers (61 and 25 cases, respectively).

LIST OF ACRONYMS

CI	Confidence interval
ICD-10	International Statistical Classification of Diseases and Related Health Problems, 10th Revision
LMIC	Low- and middle-income countries
MDS	Million Death Study
NCRB	National Crime Records Bureau
RGI	Registrar General of India
RTI	Road traffic injury
SRS	Sample registration system
UN	United Nations
WHO	World Health Organization

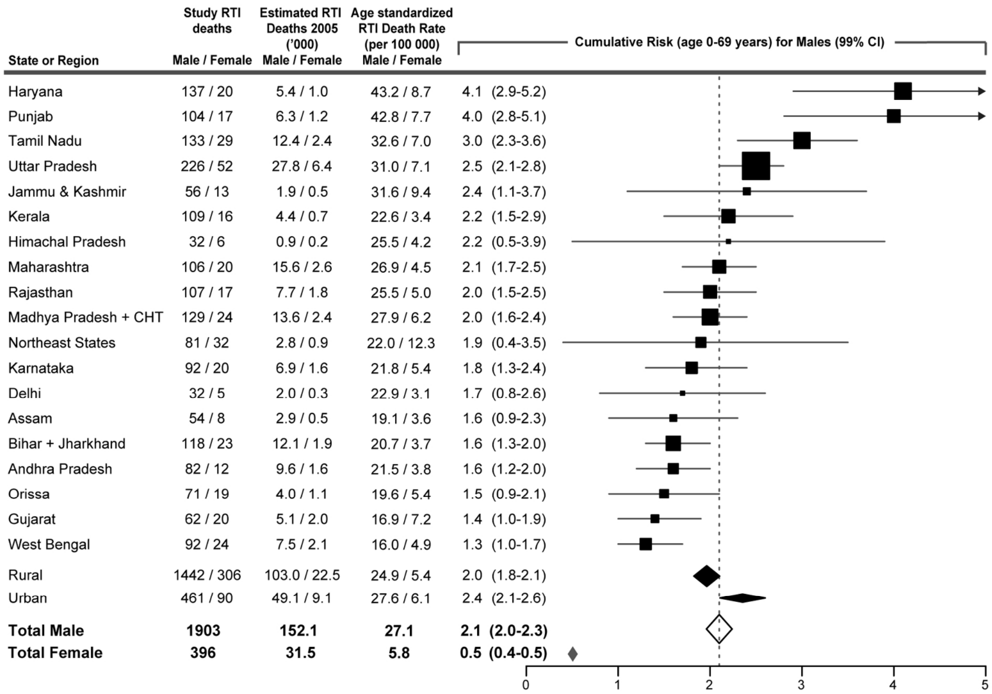

Figure 1: Road traffic injury deaths, age-standardized death rate, and cumulative risk (age 0-69 years) across states and regions of India, by gender.
Death rates are standardized to the 2005 United Nations estimated Indian population. Symbol size is proportional to sample size. Northeast states include Sikkim, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura, and Meghalaya. Total estimates include the 80 male and 19 female deaths from Pondicherry, Chandigarh, Uttarakhand, Dadra & Nagar Haveli, A&N Islands, Daman & Diu, Lakshadweep, and Goa. CHT=Chhatisgarh.

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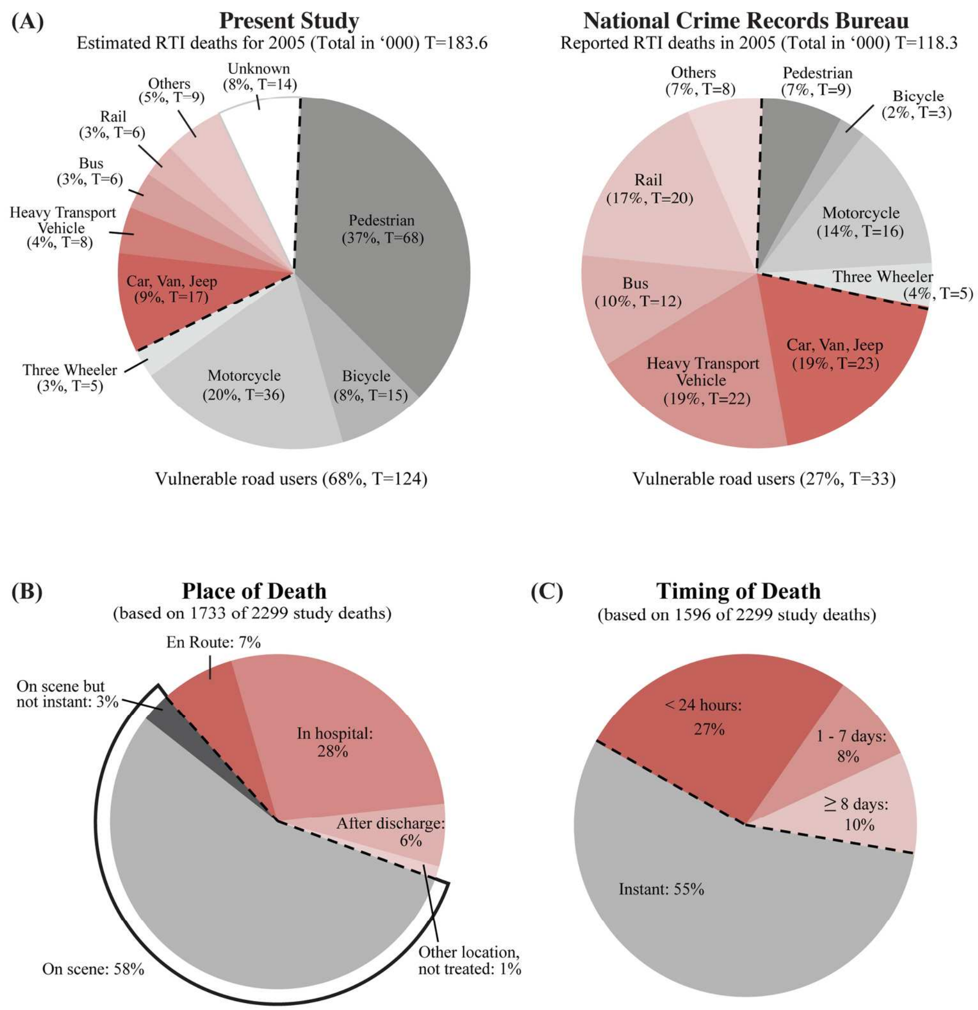

Figure 2: Deceased mode of transportation, place of death, and timing of death. (A) Deceased mode of transportation in present study compared to National Crime Records Bureau 2005 Report. Shaded line represents vulnerable road users (defined as road users without a rigid barrier protecting against traumatic forces, i.e. pedestrian, bicyclist, motorcyclist, and three wheelers). Percentages from present study are weighted by state and rural/urban residence. T=estimated/reported number of deaths in 2005 (in thousands). (B) Place of death and (C) timing of death based on verbal autopsy narratives. Shaded lines represent deaths that are reported as occurring at the scene of collision or occurring instantly (defined as within 5 minutes).

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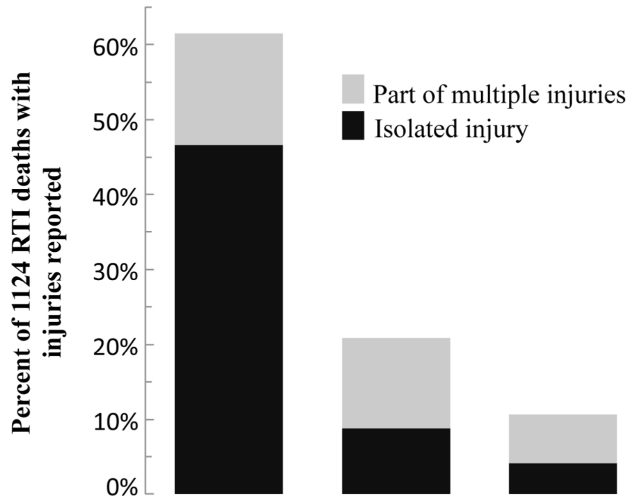

	Head n (%)	Extremity n (%)	Chest n (%)
RTI deaths with reported injuries (N=1124)	691 (62)	235 (21)	120 (11)
Sex			
Male (N=931)	584 (63)	194 (21)	105 (11)
Female (N=193)	107 (55)	41 (21)	15 (8)
Place of Death			
Pre-hospital (N=492)	322 (65)	**56 (11)***	44 (9)
Hospital or other (N=457)	291 (64)	**142 (31)***	58 (13)
Unknown (N=175)	78 (45)	37 (21)	18 (10)
Timing of Death			
Instant (N=347)	216 (62)	**28 (8)***	29 (8)
Later (N=521)	344 (66)	**145 (28)***	62 (12)
Unknown (N=256)	131 (51)	62 (24)	29 (11)
Mode of Transportation			
Motorcycle (N=241)	**188 (78)***	51 (21)	18 (7)
Non-motorcycle (N=807)	**457 (57)***	160 (20)	95 (12)
Unknown (N=76)	46 (61)	24 (32)	7 (9)

Figure 3: Reported injuries from 1124 verbal autopsy narratives (49% of all 2299 RTI deaths). Percentages refer to those in each row with given injury (columns). *Values in bold denote two by two chi square tests with p<0.05 (excluding unknowns). Abdominal and spinal injuries were also reported but not shown due to small numbers (61 and 25 cases, respectively).
141x191mm (300 x 300 DPI)

	Narrative section			Timing of Death			Place of Death			Deceased Mode of Transportation			Injury Reported		
	Missing n (%)	Not missing n (%)	p	Missing n (%)	Not missing n (%)	p	Missing n (%)	Not missing n (%)	p	Missing n (%)	Not missing n (%)	p	Missing n (%)	Not missing n (%)	p
all RTI (n=2299)	142 (6.2)	2157 (93.8)		703 (30.6)	1596 (69.4)		566 (24.6)	1733 (75.4)		194 (8.4)	2105 (91.6)		1175 (51.1)	1124 (48.9)	
age															
<20 years	12 (2.9)	402 (97.1)	0.002	106 (25.6)	308 (74.4)	0.015	90 (21.7)	324 (78.0)	0.133	37 (8.9)	377 (91.1)	0.687	199 (48.1)	215 (51.9)	0.172
≥20 years	130 (6.9)	1755 (93.1)		597 (31.7)	1288 (68.3)		476 (25.3)	1409 (75.0)		157 (8.3)	1728 (91.7)		976 (51.8)	909 (48.2)	
sex															
male	118 (6.2)	1785 (93.8)	0.916	582 (30.6)	1321 (69.4)	0.991	461 (24.2)	1442 (75.8)	0.336	161 (8.5)	1742 (91.5)	0.934	972 (51.1)	931 (48.9)	0.946
female	24 (6.1)	372 (93.9)		121 (30.6)	275 (69.4)		105 (26.5)	291 (73.5)		33 (8.3)	363 (91.7)		203 (51.3)	193 (48.7)	
location															
rural	125 (7.2)	1623 (92.9)	0.001	559 (32.0)	1189 (68.0)	0.009	456 (26.1)	1292 (73.9)	0.004	143 (8.2)	1605 (91.8)	0.429	896 (51.3)	852 (48.7)	0.799
urban	17 (3.1)	534 (96.9)		144 (26.1)	407 (73.9)		110 (20.0)	441 (80.0)		51 (9.3)	500 (90.7)		279 (50.6)	272 (49.4)	
neighbourhood asset															
low	126 (7.5)	1548 (92.5)	0.001	552 (33.0)	1122 (67.0)	0.000	451 (26.9)	1223 (73.1)	0.001	136 (8.1)	1538 (91.9)	0.468	883 (52.8)	791 (47.3)	0.057
high	16 (3.2)	487 (96.8)		121 (24.1)	382 (75.9)		97 (19.3)	406 (80.7)		46 (9.2)	457 (90.9)		241 (47.9)	262 (52.1)	
missing	0 (0.0)	122 (100.0)		30 (24.6)	92 (75.4)		18 (14.8)	104 (85.3)		12 (9.8)	110 (90.2)		51 (41.8)	71 (58.2)	
education															
below primary	38 (4.0)	916 (96)	0.000	289 (30.3)	665 (69.7)	0.894	230 (24.1)	724 (75.9)	0.719	80 (8.4)	874 (91.6)	0.757	468 (49.1)	486 (50.9)	0.094
primary and above	100 (7.7)	1196 (92.3)		396 (30.6)	900 (69.4)		321 (24.8)	975 (75.2)		104 (8.0)	1192 (92.0)		682 (52.6)	614 (47.4)	
missing	4 (8.2)	45 (91.8)		18 (36.7)	31 (63.3)		15 (30.6)	34 (69.4)		10 (20.4)	39 (79.6)		25 (51.0)	24 (49.0)	
occupation															
non-worker	60 (8.1)	679 (91.9)	0.006	243 (32.9)	496 (67.1)	0.094	205 (27.7)	534 (72.3)	0.016	60 (8.1)	679 (91.9)	0.701	381 (51.6)	358 (48.4)	0.757
worker	81 (5.2)	1478 (94.8)		459 (29.4)	1100 (70.6)		360 (23.1)	1199 (76.9)		134 (8.6)	1425 (91.4)		793 (50.9)	766 (49.1)	
missing	1 (100.0)	0 (0.0)		1 (100.0)	0 (0.0)		1 (100.0)	0 (0.0)		0 (0.0)	1 (100.0)		1 (100.0)	0 (0.0)	

Supplementary Table 1: Summary of missing data. There are no missing values for age, sex, and location in the study population. The chi square test was used to determine the p values and excluded deaths with missing neighbourhood asset, education, or occupation.

Deceased Mode of Transportation	Timing of Death was Instant n (%)	Adjusted OR	99% CI	Place of Death was Prehospital n (%)	Adjusted OR	99% CI	Head Injury was Reported n (%)	Adjusted OR	99% CI
non-vulnerable road users	170 (58.6)	ref	--	223 (69.5)	ref	--	125 (31.5)	ref	--
vulnerable road users:									
pedestrian	338 (58.5)	1.1	0.7-1.7	425 (69.1)	1.1	0.7-1.7	192 (24.9)	0.8	0.5-1.1
bicyclist & motorcyclist	245 (52.0)	0.8	0.5-1.1	306 (59.2)	0.6	0.4-1.0	256 (43.5)	**1.7***	**1.2-2.5***
three wheelers & animal riders	93 (56.4)	0.9	0.5-1.6	117 (67.6)	0.9	0.5-1.7	72 (33.0)	1.2	0.7-1.9
unknown	37 (40.2)	0.5	0.3-1.0	55 (51.4)	0.5	0.3-1.0	46 (25.1)	0.8	0.5-1.4

Supplementary Table 2: Association between deceased mode of transportation and the timing of death, place of death, and head injuries reported. Odds ratios are adjusted for deceased's age, sex, rural/urban, neighbourhood asset, and education. *Value in bold denote statistically significant difference between comparison groups.

	2005 UN population estimates (in '000)	Number of RTI deaths in 2005*		Crude RTI Death Rate in 2005 (per 100,000)*		% Under-reporting of Crude RTI Death Rate
		MDS	NCRB	MDS	NCRB	
Northeast States	13211	3610	724	27.3	5.5	79.9
Punjab	26455	7380	1622	27.9	6.1	78.0
Bihar + Jharkhand	122181	13172	3430	10.8	2.8	74.0
Uttar Pradesh	186591	33287	9860	17.8	5.3	70.4
Jammu & Kashmir	11120	2335	857	21.0	7.7	63.3
Other States	14121	4037	1589	28.6	11.3	60.6
Assam	29150	3277	1456	11.2	5.0	55.6
West Bengal	86499	9363	4364	10.8	5.0	53.4
Madhya Pradesh + CDH	90568	15726	7686	17.4	8.5	51.1
Haryana	23688	6128	3282	25.9	13.9	46.4
Orissa	39485	5083	2895	12.9	7.3	43.0
Kerala	33785	5051	3161	15.0	9.4	37.4
Maharashtra	106386	16638	10613	15.6	10.0	36.2
Rajasthan	63375	9237	6793	14.6	10.7	26.5
Gujarat	55926	6987	5264	12.5	9.4	24.7
Himachal Pradesh	6559	1077	854	16.4	13.0	20.7
Karnataka	57141	8172	6876	14.3	12.0	15.9
Delhi	16289	2161	2023	13.3	12.4	6.4
Tamil Nadu	66154	14808	13961	22.4	21.1	5.7
Andhra Pradesh	81934	10991	10944	13.4	13.4	0.4
Total	1130618	178520	98254	15.8	8.7	45.0

Supplementary Table 3: Comparison between present study (MDS) estimates and National Crime Records Bureau (NCRB) police reports of the number of RTI deaths and crude death rate, by state. *Excludes railroad deaths since NCRB does not publish state-level railroad death figures. Northeast States include Sikkim, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura, and Meghalaya. Other States include Pondicherry, Chandigarh, Uttaranchal, Dadra & Nagar Haveli, A & N Islands, Daman & Diu, Lakshadweep, and Goa. CDH = Chhatisgarh. % under reporting = (MDS death rate - NCRB death rate) / MDS death rate *100%.

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Road traffic injury mortality and its mechanisms in India: nationally representative mortality survey of 1.1 million homes

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Keywords: Road traffic injury; verbal autopsy; India; low- and middle-income countries

Word count: Text: 3361~~3440~~

ABSTRACT:

Objectives: To quantify and describe the mechanism of road traffic injury (RTI) deaths in India.

Design: We conducted a nationally representative mortality survey where at least two physicians coded each non-medical field staff's verbal autopsy reports. RTI mechanism data were extracted from the narrative section of these reports.

Setting: 1.1 million homes in India.

Participants: Over 122 000 deaths at all ages from 2001-2003.

Primary and secondary outcome measures: Age- and sex-specific mortality rates, place and timing of death, modes of transportation, and injuries sustained.

Results: The 2299 RTI deaths in the survey correspond to an estimated 183 600 RTI deaths or about 2% of all deaths in 2005 nationally, of which 65% occurred in males between the ages of 15-59 years. The age-adjusted mortality rate was greater in males than in females, in urban than in rural areas, and was notably higher than that estimated from national police records. Pedestrians (68 000), motorcyclists (36 000), and other vulnerable road users (20 000) constituted 68% of RTI deaths (124 000) nationally. Among the study sample, the majority of all RTI deaths occurred at the scene of collision (1005/1733, 58%), within minutes of collision (883/1596, 55%), and/or involved a head injury (691/1124, 62%). Compared to non-pedestrian RTI deaths, about 55 000 (81%) of pedestrian deaths were associated with less education and living in poorer neighbourhoods.

Conclusions: In India, RTI cause a substantial number of deaths, particularly among pedestrians and other vulnerable road users. Interventions to prevent collisions and reduce injuries might address over half of the RTI deaths. Improved pre-hospital transport and hospital trauma care might address just over a third of the RTI deaths.

ARTICLE SUMMARY

Article focus

- To directly estimate the age- and sex-specific mortality rates and describe the place and timing of death, modes of transportation, and injuries sustained for road traffic injury (RTI) deaths in India using a nationally representative mortality survey of 1.1 million homes.

Key messages

- Road traffic injuries cause a substantial number of avertable deaths, particularly in males of productive working age and among pedestrians and other vulnerable road users.
- Preventative interventions should be emphasized as the majority of all RTI deaths occurred at the scene of collision, within minutes of collision, and/or involved a head injury.
- Properly designed mortality survey with verbal autopsy narratives can provide much-needed data to assist RTI prevention efforts.

Strengths and limitations of this study

- This study is the first nationally representative survey of the causes of death in India and overcomes limitations of existing data sources including regional injury surveys, hospital series, and national police reports.
- Limitations of the study include potential misclassification of deaths by physician coders, the use of layperson narratives with a potential for recall bias and inaccuracies, and limited ability to forward project study results given the rapid changes in motorization in India.

INTRODUCTION

Road traffic injuries (RTI) area large and growing public health burden, especially in low-and middle-income countries (LMIC) where 90% of the world's deaths due to RTI are estimated to occur.[1] There are few high-quality epidemiologic data on RTI to guide the development, implementation, and surveillance of evidence-based policy and programs in LMICs.[2-4]

The number of deaths due to RTI in India is projected to rise with increasing motorization.[1,5] Aside from a few regional injury surveys,[6-11] the current data on the numbers and mechanisms of RTI deaths in India rely on police or hospital records, both of which can substantially underestimate death rates in the poor, rural, and uneducated people who still constitute large proportions of the Indian population.[2-4,12,13]

The World Health Organization (WHO), using indirect modeling methods, estimated about 202 000 RTI deaths in India in 2004.[14,15] No study has validated this estimate with direct measurement nor documented detailed RTI mechanism for India nationally. Here, we estimate the regional, age- and sex-specific mortality rate and risk of RTI death in India using data from the Million Death Study (MDS). We also report the modes of transportation, place and timing of death, and injuries sustained in RTI deaths.

METHODS

Study Design: The MDS is an on-going nationally representative survey designed to determine the causes and risk factors of death in India, organized by the Registrar General of India (RGI). The design, methodology, and preliminary findings of the MDS have been described elsewhere.[16-19] In brief, the MDS used an enhanced version of verbal autopsy (known as the routine, reliable, representative, re-sampled household investigation of mortality with medical evaluation or RHIME) to monitor a nationally representative sample of 1.1 million households in the Sample Registration System (SRS). Within six months of every death occurring in these households from 2001-3, a trained, nonmedical RGI surveyor interviewed a relative or close-acquaintance of the deceased to obtain the symptoms and events around the death using structured questions and a local language narrative guided by a specific symptom list. These records were converted into electronic records and emailed to two of 140 trained physicians who, independently and anonymously, assigned an underlying cause of death (with allocation determined randomly based only on the physician’s ability to read the local language), using guidelines for the major causes of death.[20] Records were assigned cause of death in three-digit International Statistical Classification of Diseases and Related Health Problems, 10th revision (ICD-10).[21] Records where coders disagreed on the cause of death underwent anonymous reconciliation. Continuing disagreements were adjudicated by a third senior physician. Five percent of households were randomly resurveyed and the results were consistent within families of ICD-10 codes.[16] Participation in the SRS is on a voluntary basis and oral consent was obtained under the confidentiality and consent procedures of the Registration of Births and Deaths Act, 1969.

Road Traffic Injury Deaths: The RTI deaths in this study were of people who died between 2001 and 2003 with a final assigned ICD-10 code within V01-V89. We translated the open-ended narratives into English from 14 local languages, and systematically extracted the modes

of transportation, place and timing of death, and injuries sustained from 2157 of the 2299 RTI deaths using a standardized data extraction tool and procedure (the remaining 142 deaths, 6%, had missing or illegible narratives). For these four data elements, there were substantial inter-rater agreement between two investigators and two research assistants who were trained and independently extracted data from the narratives of a random 10% of RTI deaths (lowest kappa statistic was greater than 0.69 for all pair-wise comparisons between the four data extractors; data not shown). The two research assistants then independently extracted data from all narratives. Adjudication was done by an investigator (MH) for discrepancies in extracted data.

Analysis: The age and sex-specific proportion of RTI deaths within the 2001-2003 survey was applied to the 2005 United Nations (UN) estimates of the number of deaths from all causes in India, after weighting for sampling probability for each rural or urban stratum per state (although such weighting made little difference because the study was nationally representative).[18,22] The 2005 UN death estimates were used so as to correct for the slight undercounts reported in the total death rates in the SRS [23,24] and to account for the 12% of enumerated deaths without completed field visits (mostly due to out-migration of the family or from incomplete field records). The proportion of these missed deaths was similarly dispersed across sex, age, and states. Use of 2003 or 2004 UN death totals yielded nearly identical results (data not shown). The 99% confidence intervals (99%CI) for mortality rate were calculated based on the weighted number of study deaths. State- and rural/urban-specific estimates of the number, mortality rate, and lifetime risk of RTI death were calculated by partitioning the UN national death totals according to relative SRS death rates as previously described.[18,25,26] Urban and rural status was defined according to the Census of India. Logistic regression was used to compare the socio-demographic traits of pedestrian and non-pedestrian RTI deaths. Household fuel type was used as a measure of community wealth, based on earlier principal component analyses [18]: high asset neighbourhoods had >50% of households that used gas, electricity, or kerosene; low asset or poor neighbourhoods used primarily coal, firewood, or other. Attributable proportion was calculated for traits of pedestrian deaths compared to non-pedestrian RTI deaths.

The MDS received ethics approval from the review boards of the Post-Graduate Institute of Medical Education and Research in Chandigarh, India; St Michael's Hospital in Toronto, Canada; and the Indian Council of Medical Research's Health Ministry's Screening Committee.

RESULTS

The 2299 RTI deaths in the 2001-2003 survey correspond to an estimated 183 600 (99%CI 173 800-193 400) RTI deaths in India in 2005. The majority of these RTI deaths occurred in males (152 100 deaths, 82.8%; table 1). The age-standardized RTI mortality rate for males (26.2 per 100 000, 24.6-27.7) was higher than for females (5.7 per 100 000, 5.0-6.4). While the RTI mortality rate increased with age in both genders, the largest number of RTI deaths occurred in males between 15-59 years of age (118 900, 64.8%).

At these death rates and in the theoretical absence of other causes of death, males in India had a 2.1% (2.0-2.3) risk of dying from RTI before age 70, with the highest risks at ages 30-59 years; females had a 0.5% (0.4-0.5) risk of dying from RTI before age 70. Males in Haryana, Punjab, Tamil Nadu, and Uttar Pradesh had significantly higher risks (3.0-4.1%) than the national risk (figure 1). In contrast, males in Bihar, Jharkhand, Andhra Pradesh, Orissa, Gujarat, and West Bengal had significantly lower risks (1.3-1.6%) than the national risk of RTI deaths. Males living in urban areas had slightly higher age-standardized mortality rates and risks of RTI deaths (27.6 per 100 000; 2.4%, 2.1-2.6) compared to males living in rural areas (24.9 per 100 000; 2.0%, 1.8-2.1). By contrast, female RTI mortality rates and risks before age 70 varied much less across states and were similar in rural and urban areas (data not shown).

	Study deaths, 2001-2003				All India, 2005			
	Number of RTI deaths / all coded deaths	Proportion RTI*	Rural (%**)	Two coders immediately agree	All deaths / population (millions, 2005 UN estimates)	Estimated RTI deaths§, thousands	RTI death rateΨ per 100 000 (99% CI)	Period risk for RTI death†
Male - age in years								
0-4	44 / 11719	0.4%	37 (76.7)	44	1.2 / 67	4.9	7.4 (6.5-8.4)¶	0.04%
5-14	97 / 1926	5.2%	86 (84.1)	87	0.2 / 129	8.5	6.6 (4.9-8.3)	0.1%
15-29	605 / 4727	13.0%	462 (68.9)	558	0.4 / 163	47.1	28.9 (25.9-31.9)	0.4%
30-44	529 / 6817	7.7%	385 (67.0)	477	0.6 / 115	43.8	37.9 (33.7-42.1)	0.6%
45-59	356 / 11731	3.0%	249 (60.9)	312	0.9 / 73	28.0	38.4 (33.2-43.6)	0.6%
60-69	149 / 12120	1.2%	117 (71.8)	133	0.9 / 24	10.6	44.0 (34.6-53.4)	0.5%
>70	123 / 18732	0.6%	106 (81.2)	98	1.3 / 14	9.1	64.5 (49.1-80.0)	--
All ages	1903 / 67772	2.8%	1442 (68.9)	1709	5.3 / 585	152.1	26.2	2.1%†
(% or 99% CI)				(89.8%)		(143.2-161.0)	(24.6-27.7)	(2.0-2.3)
Female - age in years								
0-4	50 / 11492	0.4%	46 (93.4)	45	1.2 / 61	5.0	8.1 (7.1-9.1)¶	0.04%
5-14	44 / 1955	2.3%	38 (80.1)	43	0.2 / 118	3.8	3.2 (2.0-4.4)	0.03%
15-29	72 / 4394	1.5%	53 (60.5)	63	0.3 / 150	5.3	3.5 (2.4-4.6)	0.1%
30-44	59 / 4055	1.4%	39 (59.0)	50	0.3 / 106	4.4	4.1 (2.7-5.5)	0.1%
45-59	70 / 6402	1.1%	55 (70.9)	61	0.5 / 69	6.0	8.6 (5.9-11.3)	0.1%
60-69	54 / 9016	0.6%	42 (68.6)	52	0.6 / 25	3.7	14.8 (9.8-19.9)	0.2%
>70	47 / 17343	0.3%	33 (61.8)	35	1.3 / 16	3.5	21.6 (13.4-29.9)	--
All ages	396 / 54657	0.7%	306 (69.8)	349	4.5 / 546	31.5	5.7	0.5%†
(% or 99% CI)				(88.1%)		(27.5-35.6)	(5.0-6.4)	(0.4-0.5)
Total male and female, <70 years	2129 / 86354	2.4%	1609 (68.5)	1925	7.2 / 1100	171.0	15.5	1.3%†
(% or 99% CI)				(90.4%)		(161.5-180.4)	(14.7-16.4)	(1.3-1.4)
Total male and female, all ages	2299 / 122429	1.8%	1748 (69.0)	2058	9.8 / 1131	183.6	16.2	1.3%†
(% or 99% CI)				(89.5%)		(173.8-193.4)	(15.4-17.1)	(1.3-1.4)

Table 1: Road traffic injury deaths in the present study and estimated national totals for 2005, by age and gender. *Proportion of RTI deaths compared to all deaths, weighted by state and residence (rural/urban). **Percentage rural is weighted by state and residence (rural/urban). §Obtained by multiplying the United Nations estimated total deaths in 2005 by the weighted proportions. ΨAge standardized to the 2005 United Nations estimated Indian population; 99% CI shown are calculated based on weighted number of study deaths, which result in wider CI than those based on physician agreement. †Annual RTI death rate multiplied by the duration of age range, except for the lifetime risk which is calculated between 0-69 years by summation of the age specific period risks. ¶Crude death rate.

The deceased mode of transportation was described in the narratives of 2105 (92%) of the RTI deaths. National estimates for the deceased mode of transportation were calculated, as those with unknown and known modes of transportation did not appear to differ with respect to the major socio-demographic traits (Supplementary Table 1). Vulnerable road users are those without a rigid barrier protecting against traumatic forces and include pedestrians, motorcyclists, bicyclists, and three-wheelers. They constituted a majority (68%; n=124 000, 99%CI 115 000-131 000) of RTI deaths, led by pedestrians (37%; n=68 000, 62 000-73 000) and motorcyclists (20%; n=36 000, 31 000-40 000) (figure 2). Drivers and passengers of motorized four-wheelers comprised 16% (n=31 000, 27 000-35 000) of RTI deaths. By contrast, the 2005 police reports, which use a different but compatible classification system to ICD-10, recorded only 33000 vulnerable road user deaths and only 9000 pedestrian deaths.[27] The most common types of vehicle to collide into the decedents were heavy transport vehicles and buses (37%; n=68 000, 61 000-74 000), followed by cars and vans (15%; n=28 000, 24 000-32 000). Single-vehicle incidents comprised 9% of deaths (n=17 000, 14 000-20 000). The most frequent combinations, resulting in 23% (n=42 000, 37 000-47 000) of RTI deaths, were collisions of heavy transport vehicles or buses with pedestrians and motorcyclists (data not shown).

The place and timing of death were described in the narratives of 1733 (75%) and 1596 (69%) of the RTI deaths respectively (figure 2; see supplementary table 1 for a summary of missing data from the narratives with respect to deceased characteristics). For these narratives, only the study proportion and not national estimates were made. Most RTI deaths occurred at the scene of collision (58%, 1005/1733) or instantly, defined as within 5 minutes (55%, 883/1596). Only 3% (45/1733) were labeled as potentially avertable with better pre-hospital transport as they occurred on scene but not instantly. Another 35% of deaths occurred en route (7%, 124/1733) or in hospital (28%, 481/1733).

Injuries sustained by the deceased were reported from1124 narratives (49%). Head injuries were the most commonly reported (62%, 691/1124), of which 76% (524/691) were reported as isolated head injuries (figure 3). A greater percentage of motorcyclists (78%, 188/241) had head injuries reported compared to non-motorcyclists (57%, 457/807). After adjusting for age, sex, rural/urban, neighbourhood asset, and education, bicyclists and motorcyclists were more likely to have head injuries reported compared to non-vulnerable road users (adjusted OR 1.7, 1.2-2.5) (supplementary table 2).

Compared to non-pedestrian RTI deaths, pedestrian deaths occurred to those who had less education (or in the case of children age <15 years, have less educated parents) (adjusted OR 2.9, 99%CI 2.0-4.2), lived in poorer neighbourhoods (1.7, 1.1-2.5), were children or elderly adults (<15 years: 2.9, 1.8-4.5; >59 years: 1.7, 1.2-2.4), were female (1.5, 1.2-2.2), and lived in urban areas (1.5, 1.1-2.2) (table 2). If pedestrian deaths had the same proportion of secondary or higher education as non-pedestrian RTI deaths, there would be 406/825 (49%) fewer pedestrian deaths, corresponding to approximately 33 000 deaths nationally in 2005. The corresponding attributable proportion for living in richer versus poorer neighbourhoods would be 265/825 (32%) or approximately 22 000 deaths nationally. Within the narratives we could code, there were no differences between pedestrians and non-pedestrian RTI deaths in timing of death, place of death, reported injuries, or reported routine use of alcohol or smoking (data not shown).

	Pedestrian / Non-Pedestrian Total=825/1280	Adjusted OR^ (99% CI)	Attributable Pedestrian Deaths (% of all 825 pedestrian deaths)	
Education*				
Secondary or higher	112/382	ref		
Primary or middle	248/450	1.8 (1.3-2.6)	110	406 (49%)
Below primary	451/423	2.9 (2.0-4.2)	296	
Unknown	14/25	1.6 (0.6-4.2)	N/A	
Neighbourhood Asset				
High	137/320	ref		
Low	643/895	1.7 (1.1-2.5)	265 (32%)	
Unknown	45/65	1.5 (0.8-2.8)	N/A	
Age in years				
15-59 (driving ages)	497/1046	ref		
<15 (children)	144/74	2.9 (1.8-4.5)	94	170 (21%)
>59 (elderly adults)	184/160	1.7 (1.2-2.4)	76	
Sex				
Male	621/1121	ref		
Female	204/159	1.5 (1.1-2.2)	68 (8%)	
Location				
Rural	643/962	ref		
Urban	182/318	1.5 (1.1-2.2)	61 (7%)	
Occupation				
Salaried / Wage Earner / Professional	229/517	ref		
Cultivator / Agricultural labour / Other	162/300	0.9 (0.6-1.3)	N/A	
Non-worker / Children <15 years	433/463	1.2 (0.9-1.6)	N/A	
Unknown	1/0	N/A	N/A	
Routine Alcohol Use**				
No	494/877	ref		
Yes	145/260	1.1 (0.7-1.5)	N/A	
Unknown	42/69	1.0 (0.5-1.9)	N/A	

Table 2: Characteristics of pedestrian RTI deaths and attributable proportions. *Education of deceased adults or, in cases of deceased children <15 years, education of respondent. **Excludes 218 children. ^Odds ratios are adjusted for all other variables in this table except for alcohol use; the odds ratios for alcohol use are adjusted for all other variables in this table.

DISCUSSION

RTI is an important cause of death in India, causing 183 600 deaths in 2005, or about 2% of all deaths.[22] Much of the deceased were men between ages 15-59 years. Males had a four-fold higher cumulative risk of RTI death compared to females before the age of 70. Among the major states, there was approximately 3-fold variation in the age-standardized RTI death rate and cumulative risk for males.

Our estimated number of RTI deaths is more than 50% greater than the 118 265 deaths reported in the official police statistics of the National Crime Records Bureau (NCRB) in 2005.[27] Compared to our estimates, the extent of under-reporting of the crude death rate in major states by NCRB ranged from <1% to about 80% (supplementary table 3). Existing regional population-based injury surveys in India support our findings and also report higher crude RTI death rates than NCRB statistics.[8,11] Under-reporting of RTI deaths in police statistics has been reported in India and other LMIC.[28-30] A study in urban India comparing both hospital- and community-based RTI data to police records identified factors contributing to under-reporting that included the deceased believed to be at fault, collision resulting from hit-and-runs, limited police resources, and the lack of a standard police reporting protocol by hospitals.[28] The factors contributing to police under-reporting, especially in rural India, require further examination. Our estimated number of RTI deaths in 2005 was consistent with the WHO estimate for 2004.[14] However, we observed a slightly higher male proportion (83% MDS vs. 77% WHO, all ages) and a higher proportion of male deaths between 15-59 years (65% MDS vs. 61% WHO).

Almost three-quarters of all RTI deaths in India were of pedestrians and other vulnerable road users. In contrast, a much lower proportion (27%) was reported by the NCRB (figure 2). This difference equated to 59 000 pedestrian and 32 000 other vulnerable road user deaths that were not included in the 2005 NCRB records. Existing RTI studies based on regional surveys and hospital series also reported a high proportion (>60%) of vulnerable road user deaths similar to our findings.[11,12,30-32] Since the majority of vulnerable road users were pedestrians, our findings suggested that RTI deaths in individuals who were less educated, poor, female or live in urban areas may have been disproportionally excluded from the NCRB records. While poverty and education are not likely to be in the direct causal pathway of pedestrian deaths, they nonetheless point to other associated risk factors. Indeed, 55 000 pedestrian deaths in 2005 (81%) was associated with lower education or living in poorer neighbourhoods compared to non-pedestrian RTI deaths. While the less educated and the poor likely travelled more often by foot, they might also be exposed to undetermined environmental (neighbourhoods with unsafe roads), biological (poor vision or decreased mobility due to poor health), and behavioral (alcohol or other substance use) risk factors for pedestrian death.[12, 33, 34] Further studies are needed to better understand pedestrian deaths in LMIC.

Over half of RTI deaths occurred instantly at the scene of collision and/or had head injury reported. These findings, together with existing RTI hospital series and regional surveys in India, make a strong argument that investments in primary and secondary prevention could potentially avert the greatest proportion of RTI deaths. To address the high proportion of instant deaths and head injuries among RTI deaths in India, specific interventions that are effective and based on studies in LMIC should be emphasized; these may include speed bumps, motorcycle helmets, and increasing fines and license suspensions for rule infractions.[33] In contrast, improving pre-hospital transport and hospital trauma care, could only potentially affect the 38%who died on scene with delayed hospital transport (3%), en route to hospital (7%), or in hospital (28%).

Our study is the first nationally representative survey of the causes of death in India. The simple descriptive statistics provide clear evidence on the large and avertable burden from RTI, particularly among productive age adults and pedestrians. To the best of our knowledge, only one recent study in Vietnam has used similar methods to analyze RTI deaths and policy implications on a national scale.[35]

Our study faced certain limitations. First, we might have misclassified certain causes of death including suicide as RTI deaths. However, the extent of misclassification should be minimal since the RHIME verbal autopsy method was shown to be robust in discerning between types of injury deaths[36] and since the immediate two-physician agreement was high for RTI deaths(89.5%, table 1). Furthermore, suicides cause about 200 000 deaths in India annually but few are due to RTI.[19] Second, since the modes of transportation, place and timing of death, and injuries sustained were extracted from layperson open-ended narratives, the data accuracy may be in question. For example with the deceased mode of transportation, the extent of misclassification (by our study) or misreporting (by NCRB) that contributed to the differences between the two sources is uncertain. With reported injuries, our findings from these narratives most likely undercounted less visible injuries (chest, abdomen, and spine) compared to highly visible injuries such as bleeding and deformity for head and extremity injuries. Nevertheless, our findings are consistent with available Indian regional surveys and hospital series on the mode of transportation[11,12,30-32,37] place and timing of death,[1,37-41] and injuries sustained.[12,37,42,43] Third, since the narrative was not designed specifically to capture RTI death characteristics, over 25% of deaths had missing data for mode of transportation, place of death, timing of death, or reported injuries (supplementary table 1). Thus, our findings for these elements extracted from the narratives may be less representative of the decedents who lived in rural or poor areas. Finally, reliable forward projection of the number of RTI deaths beyond 2005 was not possible since the increase in the NCRB reported number of RTI deaths of 140% from 2005 to 2011 appeared to outpace the rate of population growth.[44] As the proportion of vulnerable road user deaths remained stable during this period in the NCRB reports, we postulated that this increase represented an actual increase in RTI death totals rather than more accurate reporting. Furthermore, given the rapid economic expansion and concurrent changes in motorization including the types of vehicle sharing the road and road infrastructure,[45,46] our results on deceased mode of transportation, place and timing of death, and injuries sustained may not reflect the current Indian scenario. An analysis of the trend from 2001-2014 is planned pending ongoing data collection in the MDS.

In India, RTI is a significant cause of preventable death, particularly in males of productive working age and among pedestrians, bicyclists, and motorcyclist. We have shown that properly designed simple verbal autopsy narratives can document the much needed surveillance data on the numbers, rates, risks, and basic RTI mechanism such as modes of transportation, timing of death, place of death, and injuries sustained. Our findings suggested that investment in primary and secondary prevention could address a large proportion of avoidable RTI deaths.

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COMPETING INTERESTS

We declare that we have no competing interests.

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collection, analysis, interpretation; writing of the manuscript; or decision to submit for publication. The senior author had full access to all the data in the study and had final responsibility for the decision to submit this study for publication.

AUTHOR'S CONTRIBUTION

PJ and the MDS Collaborators (appendix) designed, planned, the executed the MDS in close collaboration with the Office of the Registrar General of India (RGI). MH and PJ performed the data analysis. All authors contributed to data interpretation, revisions of the manuscript, and provided final approval. PJ is the guarantor for this report.

DATA SHARING STATEMENT

Data used in this study are the property of the Registrar General of India and the overall mortality results have been published in 2009.[47] This specific analyses is produced under an agreement with CGHR.

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FIGURE LEGENDS

Figure 1: Road traffic injury deaths, age-standardized death rate, and cumulative risk (age 0-69 years) across states and regions of India, by gender.

Death rates are standardized to the 2005 United Nations estimated Indian population. Symbol size is proportional to sample size. Northeast states include Sikkim, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura, and Meghalaya. Total estimates include the 80 male and 19 female deaths from Pondicherry, Chandigarh, Uttarakhand, Dadra & Nagar Haveli, A&N Islands, Daman & Diu, Lakshadweep, and Goa. CHT=Chhatisgarh.

Figure 2: Deceased mode of transportation, place of death, and timing of death.

(A) Deceased mode of transportation in present study compared to National Crime Records Bureau 2005 Report. Shaded line represents vulnerable road users (defined as road users without a rigid barrier protecting against traumatic forces, i.e. pedestrian, bicyclist, motorcyclist, and three wheelers). Percentages from present study are weighted by state and rural/urban residence. T=estimated/reported number of deaths in 2005 (in thousands). (B) Place of death and (C) timing of death based on verbal autopsy narratives. Shaded lines represent deaths that are reported as occurring at the scene of collision or occurring instantly (defined as within 5 minutes).

Figure 3: Reported injuries from 1124 verbal autopsy narratives (49% of all 2299 RTI deaths).

Percentages refer to those in each row with given injury (columns). *Values in bold denote two by two chi square tests with p<0.05 (excluding unknowns). Abdominal and spinal injuries were also reported but not shown due to small numbers (61 and 25 cases, respectively).

LIST OF ACRONYMS

CI	Confidence interval
ICD-10	International Statistical Classification of Diseases and Related Health Problems, 10th Revision
LMIC	Low- and middle-income countries
MDS	Million Death Study
NCRB	National Crime Records Bureau
RGI	Registrar General of India
RTI	Road traffic injury
SRS	Sample registration system
UN	United Nations
WHO	World Health Organization