PLOS | NEGLECTED TROPICAL DISEASES

Snakebite Mortality in India: A Nationally Re Mortality Survey

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Abstract

Background

India has long been thought to have more snakebites than any other country. However, inadequate hospital- snakebite mortality ranging widely from about 1,300 to 50,000. We calculated direct estimates of snakebite r

Methods and Findings

We conducted a nationally representative study of 123,000 deaths from 6,671 randomly selected areas in 2(living respondents about all deaths. The underlying causes were independently coded by two of 130 trained reconciliation or, failing that, by adjudication.

A total of 562 deaths (0.47% of total deaths) were assigned to snakebites. Snakebite deaths occurred mostl than females (41%), and peaked at ages 15–29 years (25%) and during the monsoon months of June to Se snakebite deaths nationally (99% CI 40,900 to 50,900) or an annual age-standardised rate of 4.1/100,000 (9 (5.4/100,000; 99% CI 4.8–6.0), and with the highest state rate in Andhra Pradesh (6.2). Annual snakebite de Andhra Pradesh (5,200), and Bihar (4,500).

Conclusions

Snakebite remains an underestimated cause of accidental death in modern India. Because a large proportio snakebite totals might also be underestimated. Community education, appropriate training of medical staff a states with the highest prevalence, could reduce snakebite deaths in India.

Author Summary

Earlier hospital based reports estimate about 1,300 to 50,000 annual deaths from snakebites per year in Ind national mortality survey of 1.1 million homes in 2001–03. Full-time, non-medical field workers interviewed li were independently coded by two of 130 trained physicians. The study found 562 deaths (0.47% of total dea more commonly among males than females and peaking at ages 15–29. Snakebites also occurred more oft represents about 45,900 annual snakebite deaths nationally (99% CI 40,900 to 50,900) or an annual age-st rates in rural areas (5.4) and with the highest rate in the state of Andhra Pradesh (6.2). Annual snakebite de Andhra Pradesh (5,200), and Bihar (4,500). Thus, snakebite remains an underestimated cause of accidental two HIV-related deaths. Because a large proportion of global totals of snakebites arise from India, global sn interventions involving education and antivenom provision would reduce snakebite deaths in India.

Figures

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Introduction

Alexander the Great invaded India in 326 BC, and was greatly impressed by the skill of Indian physicians; es
has remained notorious for its venomous snakes and the effects of their bites. With its surrounding seas, Ind
snakes – some of which are abundant and can cause severe envenoming [2]. Spectacled cobra (*Naja naja*),
(Echis carinatus) and Russell's viper (*Daboia russelii*) have long been recognised as the most important, but
areas, such as the central Asian cobra (*Naja oxiana*) in the far north-west, monocellate cobra (*N. kaouthia*) i
-east, Wall's and Sind kraits (*B. walli* and *B. sindanus*) in the east and west and hump-nosed pit-viper (*Hypn*

Joseph Fayrer of the Indian Medical Service first quantified human snakebite deaths in 1869 for about half o
and Burma), finding that 11,416 people had died of snakebites [3]. Subsequent estimates of human deaths f
7,400 to 20,000 per year [4]–[6]. Government of India hospitals from all but six states reported only 1,364 sn
an under-report as many victims of snakebite choose village-based traditional therapists and most die outsid
some localities have shown much higher annual mortality rates, ranging widely from 16.4 deaths/100,000 in
Terai [9]. However, such focal data cannot be extrapolated to provide national or even state totals because c
uncertainties have resulted in indirect estimates of annual snakebite mortality in India that varied from appro

To fill this gap in knowledge, we estimated snakebite deaths directly from a large continuing study of mortalit

Methods

Ethics Statement

Ethics approval for the Million Deaths Study (MDS) was obtained from the Post Graduate Institute of Medica
Hospital, Toronto, Ontario, Canada [14]–[15].

Most deaths in rural India take place at home without prior attention by any qualified healthcare worker, so m approaches are therefore needed to help determine the probable causes of such deaths. The Registrar Gen System (SRS), which monitors all births and deaths in a nationally representative selection of 1.1 million hon India. India was divided into approximately one million areas for the 1991 census, each with about 1,000 inh areas to be represented in the SRS. Household characteristics were recorded and then enumerated twice ye the causes of death [16].

Since 2002, one of 800 non-medical field staff (trained by the RGI in appropriate fieldwork methods) visited e narrative (in the local language) for each death from families or other reliable informants. In addition to the na were also recorded in the field report. Fieldwork quality control methods were used routinely, including randc investigators [14], [15]. This survey is part of the MDS, which seeks to assign causes to all deaths in SRS ar

These field reports, or 'verbal autopsies', were emailed randomly (based on the language of the narrative) to disease coding. Physicians worked independently to assess the probable underlying cause of death, assigni of Diseases (ICD; 10th revision) code [20]. Any differences between the two coders were resolved by anonyr reconsider) or, for persisting differences, adjudication by a third physician (3% or 15/562 of snakebite deaths coders' training and their written guidelines (available online [21]) instructed them to use their best medical ju Field reports could not be collected on 12% of the identified deaths due to migration or change of residence. misclassification in cause of death was unlikely. We used logistic regression to quantify the odds of snakebit occupation, place of death and season. Risk is measured compared to the reference group of lowest risk for were obtained for each state from the India Meteorological Department [22]–[23].

The proportion of cause specific deaths in each age category was weighted by the inverse probability of hou each state, to account for the sampling design [16]. Using methods described earlier [14]–[15], [17]–[19], the applied to the United Nations (UN) population division estimates of deaths in India in 2005 [24] (9.8 million, u specific death totals and rates. The UN totals (which undergo independent demographic review [24]) were us by about 10% [25]–[26]. The UN totals are not affected by the 12% of the SRS-enumerated deaths that were were used because they: (i) were most complete; (ii) could be compared to the available Indian Census proj implementation of a new national health program in rural areas [27]. However, applying the 2001–03 proport since there was little change in the yearly distribution in snakebite deaths in our survey, or in the annual num hospital surveillance data between 2003 and 2008 [7].

Results

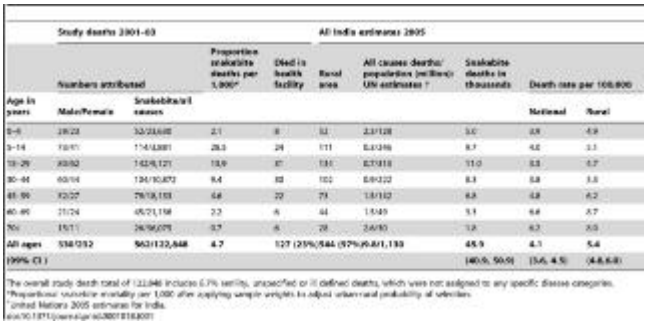
Snakebite deaths in study and nationally

Of the 643 deaths coded by physicians as ICD-10 codes X20–X29 (contact with venomous animals and plar review of these yielded no misclassified causes. Central re-examination of the symptoms and key words fou (uncertain) to be snakebite deaths. We excluded 75 deaths coded as X21–X25 (various arthropods), X26 (m

Among all 122,848 deaths, 2,179 of the deaths that were randomly chosen to be re-interviewed by independ and individuals of the MDS. Of the 2,179 re-sampled deaths, 9 were coded as snakebites, and 7 of these we the SRS field survey, assuming the re-sample deaths are the standard comparison, was 78% (7/9) and 100%

A total of 562 of the 122,848 deaths (0.47% weighted by sampling probability or 0.46% unweighted) were fro or 97%) were in rural areas. More men (330, 59%) than women (232, 41%) died from snakebites (overall rat was highest at ages 5–14 years. Only 23% (127/562) of the deaths occurred in a hospital or other healthcare

Table 1. Snakebite deaths in the present study, 2001–03 and estimated national totals, by age.
doi:10.1371/journal.pntd.0001018.t001



Expressed as national totals, snakebites caus
50,900). The age-standardised death rate pe
nationally and was 5.4 (99% CI 4.8–6.0) in ru

Risk factors and seasonality

Figure 1 shows the odds ratios for snakebite
for high prevalence states (13 states with age
100,000) versus other states. The risks of sna
and farmers/labourers, deaths occurring outs
September (Figures 1 and 2). In contrast, ge
risk of snakebite death. About 5,000–7,000 snakebite deaths per month occurred during the monsoon period
Monthly numbers of snakebite deaths correlated with rainfall (R = 0.93, p<.0001) and mean minimum tempe
temperature (R = 0.35, p = 0.2585; Figure 2).

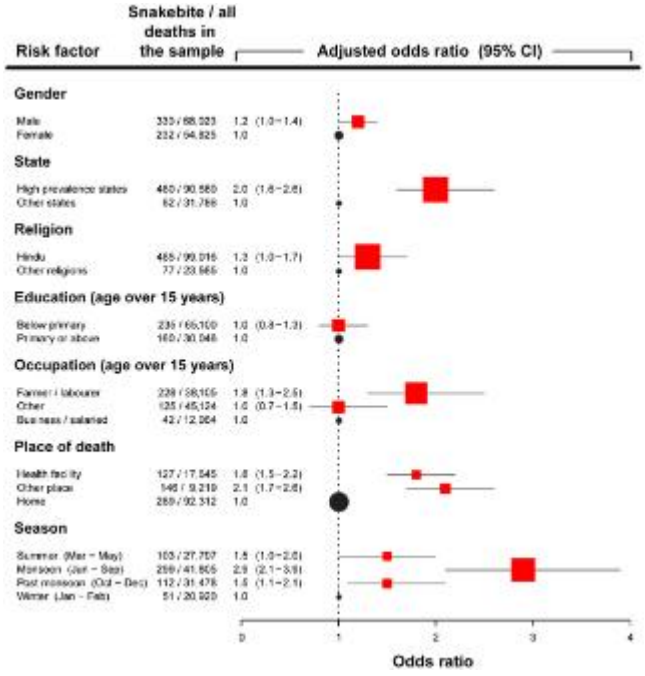
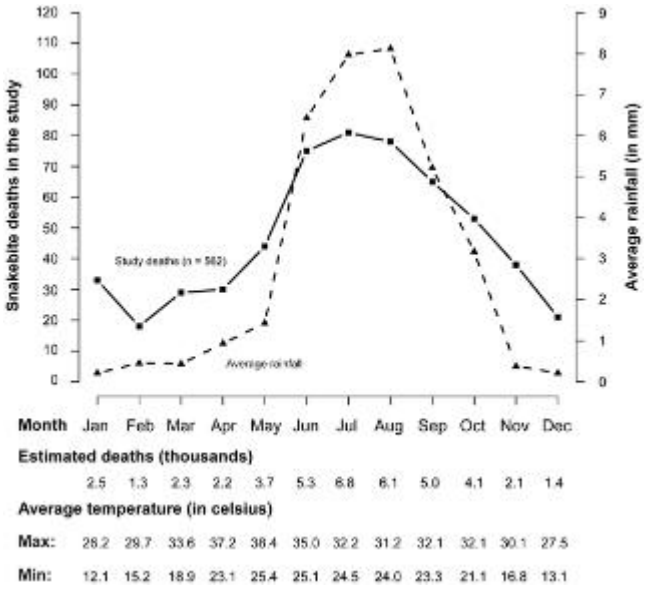


Figure 1. Selected risk factors for snakebite mortality in India (study deaths 2001–03).
Odds ratio after adjusting for age, gender and states with a high prevalence of snakebite deaths (see def
and house wives.
doi:10.1371/journal.pntd.0001018.g001

Figure 2. Seasonality pattern of snakebite mortality and rainfall in states with high prevalence of s
Rainfall amount (mm) is cumulative daily rainfall for the past 24 hours measured by the India Meteorologi
temperatures are also measured daily and presented as monthly averages across the 13 snakebite high
between snakebite mortality and weather were: (i) rainfall; 0.93 (p<0.0001); (ii) minimum temperature: 0.8
0.2585).
doi:10.1371/journal.pntd.0001018.g002

State mortality patterns

Annual age-standardised mortality rates per 100,000 from snakebite varied between states, from 3.0 (Mahar
highest prevalence (average 4.5) compared to 1.8 in the rest of the country (Table 2; Figure 3). Total deaths



(5,200), and Bihar (4,500). The age and genc
these differences were not significant due to
Deaths at ages 5–14 years were prominent ir
older ages were prominent in Andhra Prades
shown). In Bihar, Madhya Pradesh, Maharas
deaths (Table 2).

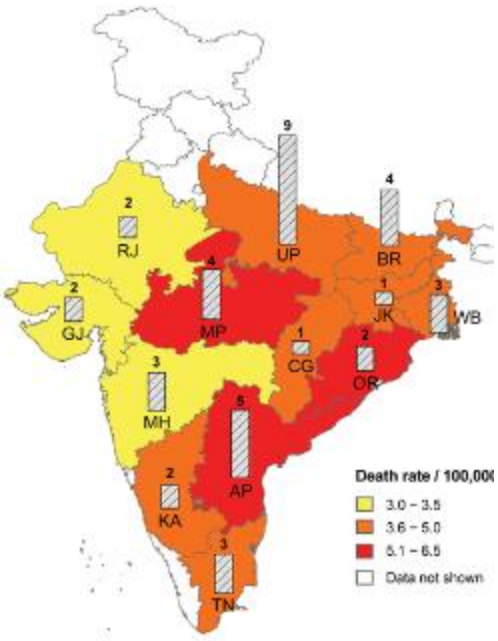


Figure 3. Estimated deaths and standardized death rates in states with high prevalence of snakeb
Death rates are standardised to 2005 UN population estimates for India [24]. The vertical bars represent
snakebite deaths for the 13 states with high-prevalence of snakebite death are 42,800 or 93% of the nati
estimated population of India). States where the snakebite death rate was below 3/100,000 or where pop
states with high-prevalence of snakebite deaths are: AP-Andhra Pradesh, BR-Bihar, CG-Chhattisgarh, G
Pradesh, MH-Maharashtra, OR-Orissa, RJ- Rajasthan, TN-Tamil Nadu, UP-Uttar Pradesh, WB-West Be
doi:10.1371/journal.pntd.0001018.g003

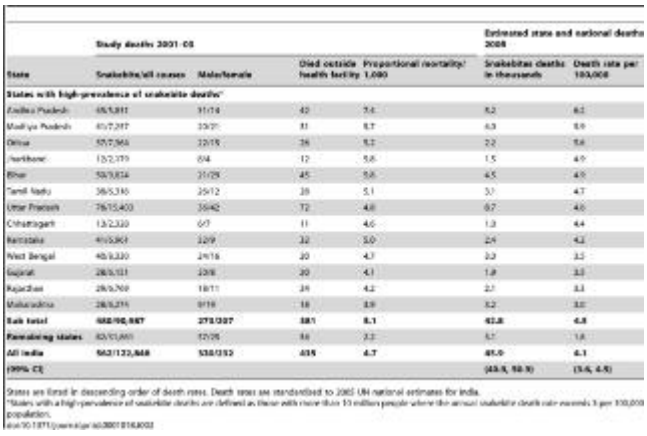


Table 2. Estimated snakebite deaths in the Indian states with a high prevalence of snakebite deatl
doi:10.1371/journal.pntd.0001018.t002

Discussion

Snakebite remains an important cause of accidental death in modern India, and its public health importance
total of 45,900 (95% CI 40,900–50,900) national snakebite deaths in 2005 constitutes about 5% of all injury
30-fold higher than the number declared from official hospital returns [7]. The underreporting of snake bite de
is well known that many patients are treated and die outside health facilities – especially in rural areas. Thus
and other infections [19] or bites from snakes or mammals (rabies; [28]), are underestimated by routine hosp
not reported as official government returns vary in their reliability, as shown from a study of snakebites in Sri
revealed by our study is similar in magnitude to that of some higher profile infectious diseases; for example,
India [18]. Consequently, snakebite control programmes should be prioritised to a level commensurate with t

Our data suggest underestimation in recent global estimates of mortality from snakebite deaths [10]: the upp
globally and 15,000 deaths in India. This total for India is only about one-third of the snake bite deaths detec
100,000 population per year in a recent community-based study in Bangladesh was similar to ours [30], sugg
more snakebite deaths than is currently assumed. Considering the widely accepted gross underestimation o
that well over 100,000 people die of snakebite in the world each year.

A minimal number of non-fatal snakebites in India may be estimated with far less certainty. Indian data from
of deaths (recording only 1 in 5 of the deaths we estimated to have occurred in hospital). Nonetheless, the ra
2,200) in these hospital data from 2003–08 (about 64:1) is informative of the relative burden of bites to death
to 32, this would suggest at least 1.4 million non-fatal bites corresponding to the 45,000 fatal bites. The actua
as the community-based study in Bangladesh found about 100 non-fatal bites for each death [30].

Our study has limitations; notably the misclassification of snakebite deaths. However, snakebites are dramat
and neighbours, making them more easily recognizable by verbal autopsy. We observed a reasonably high s
deaths. Confusion with arthropod bites and stings is unlikely because of the different circumstances, size an
envenoming. For example, most deaths from hymenoptera stings result from rapidly evolving anaphylaxis. K
may unobtrusively envenom sleeping victims, who may die after developing severe abdominal pain, descend
deaths might not be associated with snakebite at all. These examples suggest possible underestimation of d

Since the numbers of deaths observed in each state were small, the estimated totals for each state are unce
with that reported by the RGI survey of deaths in selected rural areas in the 1990s [32]. The marked geograp
country-wide survey conducted during the period 1941–45, which identified Bengal, Bihar, Tamil Nadu, Uttar
having the highest death rates from snakebite [6]. Moreover, despite the obvious underestimates in hospitali
deaths were similar to what we observed from household reports of deaths. The marked differences in snake
variations in human, snake and prey populations, and in local attitudes [8] and health services. The 13 states
four most common deadly venomous snakes: *Naja naja*, *Bungarus caeruleus*, *Echis carinatus* and *Daboia ru*
open wasteland, these are widely distributed species of the plains and low hills where most Indians live. Whi
[2], this is exceptional and higher mountainous regions have considerably lower death rates.

As found in an earlier study [33], the peak age group of snakebite deaths is 15–29 years (25% or 142/562). I
another cause was greater at ages 5–14 years. The peak age range and gender associated with snakebite r
differences in the relative numbers of children and women involved in agricultural work [34]–[35]. The slight e
and greater use of traditional treatments [2]. Snakebites and snakebite fatalities peak during the monsoon se
reflecting agricultural activity, flooding, increased snake activity, and abundance of their natural prey.

Only 23% of the snakebite deaths identified in our survey occurred in hospital, consistent with an earlier stud
hospital-based data reflect poorly the national burden of fatal snakebites; (ii) inadequacy of current treatmen
victims outside hospital. Practicable solutions include strengthening surveillance to allow a more accurate pe
community education to reduce the incidence of snakebites and speed up the transfer of bitten patients to m
levels of the health service (including implementation of the new WHO guidelines [12]), and deployment of a
they are needed in rural health facilities to decrease case fatality [36]–[38]. In addition, phylogenetic and ven
antivenoms to cover the species responsible for serious envenoming.

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The Registrar General of India has managed the SRS since they established the survey in 1971, and is colla Death Study. All study materials are available at www.cghr.org. The opinions expressed here are those of th Government of India. We thank Ansely Wong for comments and Brendon Pezzack for graphics.

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Author Contributions

Conceived and designed the experiments: PJ DAW BM. Performed the experiments: PJ DAW. Analyzed the Analysis planning: PB BM WS DAW PJ. Statistical analysis: WS PJ. Data interpretation, critical revision of th ND RMJ PSR KM RW PJ.

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