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Non-communicable diseases are the leading cause of mortality in rural Birbhum, West Bengal, India: a sex-stratified analysis of verbal autopsies from a prospective cohort, 2012–2017

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ABSTRACT

Objectives There is a dearth of data on causes of death in rural India, which impedes identification of public health priorities to guide health interventions. This study aims to offer insights from verbal autopsies, to understand the pattern and distribution of causes of death in a rural area of Birbhum District, West Bengal, India.

Design Causes of death data were retrieved from a prospective vital event surveillance system.

Setting The Birbhum Population Project, a Health and Demographic Surveillance System, West Bengal, India.

Participants Between January 2012 and December 2017, all deaths were recorded.

Main outcome measures Trained Surveyors tracked all deaths prospectively and used a previously validated verbal autopsy (VA) tool to record causes of death. Experienced physicians reviewed completed VA forms, and assigned cause of death using the 10th version of International Classification of Diseases. In addition to cause-specific mortality fraction, cause-specific crude death rate (CDR) among males and females were estimated.

Results A total of 2320 deaths (1348 males and 972 females) were recorded. An estimated CDR was 708/100 000. Over half of all deaths (1176 deaths, 50.7%) were attributed to non-communicable diseases (NCDs), with nearly 30% of all deaths attributed to circulatory system disorders; whereas 24.2% and 3.9% deaths were due to cerebrovascular diseases and ischaemic heart disease, respectively. Equal percent (13%) of males died from external causes and from infectious and parasitic diseases, and 11% died from respiratory system-related diseases. Among females, 12% died from infectious and parasitic diseases. Among children aged 0–4 years, 50% of all male deaths and 45% of all female deaths were attributed to conditions in the perinatal period.

Conclusions NCDs are the leading cause of death among adults in a select population of rural Birbhum, India. Health programmes for rural India should prioritise plans to mitigate deaths due to NCDs.

Strengths and limitations of this study

► Given the lack of sufficient data on causes of death from rural India, cause-specific mortality data from a vital event surveillance system in rural West Bengal highlights emerging health priorities in a rural area.
► Cause of death data from 6 consecutive years (from January 2012 to December 2017) from a population-based prospective cohort provides stable estimates of mortality in a rural setting.
► Use of a prevalidated verbal autopsy tool helped reduces possible errors and bias in determining causes of death.
► This study does not include information on multiple causes of death which might have limited contribution of other conditions to a particular death.
► As this study setting is limited to a rural area of West Bengal, careful interpretation and cautious generalisability of study findings are needed.

INTRODUCTION

India is undergoing a rapid epidemiological transition and deaths due to non-communicable diseases (NCDs) have exceeded deaths from communicable, maternal, neonatal and nutritional diseases between 1990 and 2016.[1] The variation in the extent of epidemiological transition in India demonstrated by the Global Burden of Disease (GBD) study[1] suggests that tackling a specific disease burden requires robust evidence on the causes of death in order to facilitate a context-specific disease prevention strategy that varies between states. However, recording deaths and assigning cause to them has been a challenge in low-and-middle income countries where one in two deaths go unrecorded and India is no exception.[2,3] A majority of India's population live in rural

areas where access to healthcare is difficult. A significant proportion of deaths in rural areas occur outside formal medical facilities,[4] and information on cause of death at a population level is rare, hampering population-specific health strategies to address local disease burden. The government health system remains an important source of healthcare in rural and underdeveloped regions of India but it focuses predominantly on infectious diseases and maternal and child health given the prevalence of these conditions in rural areas. Given socioeconomic changes and ageing populations in rural areas, chronic diseases are likely to emerge as a health priority, thus estimates on cause-specific mortality from rural India is the need of the hour.

Against this backdrop, we used verbal autopsies to examine the pattern and distribution of causes of death among males and females during 2012–2017, as part of the Birbhum Population Project (BIRPOP), a health and demographic surveillance system (HDSS) operating under the ambit of the Society for Health and Demographic Surveillance (BIRPOP-SHDS) in the Birbhum district of the state of West Bengal, India. Although primarily rural, the study population is considered at a high risk for NCDs (cardiovascular disease, cancer, diabetes and chronic respiratory disease), where both metabolic risk factors and modifiable risk factors of NCDs—tobacco use, physical inactivity, unhealthy diet and the harmful use of alcohol have been observed.[5] Estimates of causes of deaths from this study complement existing literature on causes of death in rural India with a way forward to devise suitable interventions to avert preventable deaths.

METHODS
Study setting and population
The database used for this study is part of the vital events (fertility, mortality, migration and marriage) surveillance system within BIRPOP-SHDS.[6] BIRPOP-SHDS is located in Birbhum district in the state of West Bengal, India, covering four administrative blocks, namely Mohammad Bazar, Rajnagar, Sainthia and Suri-I (figure 1). Established in 2008, the population cohort consists of 59 395 individuals residing in 13 053 households spread across 351 villages.[6] These villages were selected using a simple stratified self-weighted random sampling method which used the total villages in the district as per the Indian National Census conducted in 2001 and the sampling was entrusted to a team of large-scale sample survey experts from reputed universities. By virtue of its sampling design, the cohort of population is representative of administrative blocks covered under BIRPOP-SHDS. BIRPOP-SHDS represents nearly 16% of the Birbhum district's population, which is listed as a rural and economically underdeveloped area by the State Government of West Bengal. Birbhum has also been included among the country's aspirational districts by the National Institution for Transforming India (NITI) *Aayog* (*Aayog* is synonymous with Commission), a policy think tank of the federal Indian
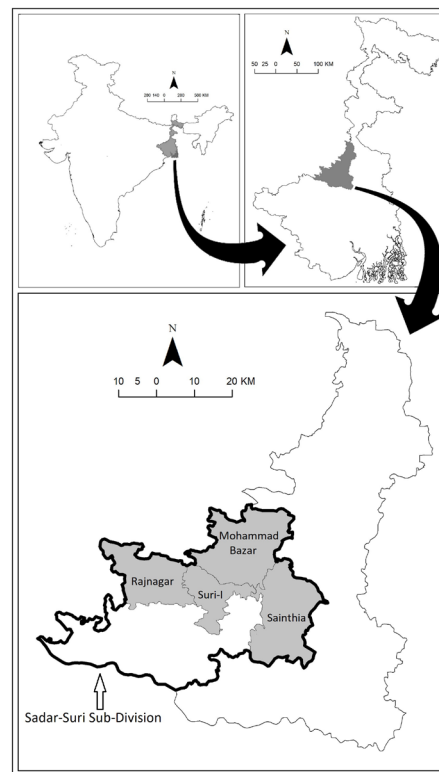

Figure 1 Study location of Birbhum Population Project, covering four administrative blocks (Mohammad Bazar, Rajnagar, Sainthia and Suri-I) of Birbhum District, West Bengal, India.

government. The socioeconomic and demographic statistics of BIRPOP-SHDS have earlier been published and are publicly available.[6]

BIRPOP-SHDS is solely financed by the West Bengal State Department of Health and Family Welfare, India and research findings of BIRPOP-SHDS have an important role in health policy decision making in the state. To date, BIRPOP has undertaken three rounds (2008–2009, 2012–2013 and 2017–2018) of cohort surveys on various health and demographic indicators. Collecting information on vital events is part of the regular survey activity, and depending on the information gathered on vital events, the database is updated continuously.

Data collection on causes of death
The information on causes of death is collected by a trained Surveyor who has at least an undergraduate degree and can speak a local language—Bengali or *Santhali*. BIRPOP-SHDS has 44 full-time salaried Surveyors who gather information from households on vital events. Following their recruitment, surveyors undergo stringent training for 7 working days on conducting a verbal autopsy (VA) and other vital events by experienced physicians who are also co-authors (AB, SM, KC and AC) of this paper. After the training, the surveyors underwent two rounds of written tests followed by a mock test on VA data recording, and they had to score over 95% marks in both types of tests to be eligible for VA data collection. Training for VA data collection given to surveyors of

BIRPOP-SHDS is comparable to community healthcare workers in India; however, surveyors of BIRPOP-SHDS are limited to data collection while community healthcare workers are expected to provide healthcare services to households. A study in Ballabgarh HDSS in northern India showed that health workers can be trained to use VA to ascertain the cause of death with precision.[7] Surveyors of BIRPOP-SHDS are recruited from communities being surveyed which helps to track the death of a person in the area. Once the death of a member is confirmed, a surveyor of BIRPOP-SHDS pays a visit to the deceased member's household within a day of the death to console. Surveyors attempt to locate a family member/neighbour(s)/caretaker who could be the best possible respondents for VA within a week. If the deceased is a child aged 0–15 years, 4–8 weeks are allowed to pass to give time for bereavement. This method helped reduce recall errors of respondents, and helped increase the rapport with community members. In addition, nearly 10% of all deaths were resurveyed independently by assigned physicians to confirm the accuracy of information collected by the surveyors.

Verbal autopsy (VA) and identification of causes of death

VA is a tool that can be used to collect and analyse data on causes of death. VA is defined by the WHO as 'a method used to ascertain the cause of a death based on an interview with next of kin or final caregivers' that can be applied for deaths without certification of medical causes. This VA tool is widely used in developing countries and validated for its accuracy in recording, and diagnosing cause-specific mortality.[8 9] To record the causes of death, a previously validated semistructured VA tool[8] with some structured questions and open narrative section were used. The VA method used in BIRPOP-SHDS consists of two distinct stages. First, information was collected via structured interviews with family members and caregivers of the deceased on signs, symptoms, medical history and circumstances around the time of death. Second, the information is reviewed by a panel of physicians to assign a cause of death. For this study, deaths between January 2012 and December 2017 (6 consecutive years) were analysed.

Separate VA questionnaires were developed and pilot-tested, one for each of three age groups: death in 0–28 days; death between 29 days and 14 years and death at age ≥15 years.[8] The questionnaires included questions on previously diagnosed medical conditions and a checklist of signs and symptoms occurring chronologically around the time of death. A narrative of the events leading to death was recorded as described by the respondent. When available, hospital records, medicine receipts, laboratory tests and death certificates were photocopied and included in the VA review process. Two experienced senior physicians working in a referral hospital and otherwise not involved in the surveillance study independently assessed the completed VA forms. They identified the cause of each death based on the information recorded on the form and available records. Each physician was unaware of the diagnosis assigned by the other physician. If these physicians' independent reviews of the underlying cause of death are discordant with each other, a third expert opinion from another physician is sought as an umpire reader. If all three physicians could not determine or agree on the cause of death, the death was recorded as having an unspecified cause. Of total deaths, 24 deaths were found to be discordant between two physicians, which required decision by an umpire physician through consensus opinion, hence there is no non-specified cause of death.

Guided by the algorithm of the Office of the Registrar General of India's Sample Registration System (SRS), Government of India, deaths are coded by the physicians according to the International Classification of Disease, version 10 (ICD-10).[10] ICD-10 is a globally accepted manual of codes for diseases, signs and symptoms, abnormal findings, disorder, social circumstances and external causes of injury or diseases. For ICD-10 coding, physicians used underlying cause of death. For this study, all physicians that participated in reviewing causes of death had a combined experience of over 25 years in reviewing causes of death, and are co-authors (AB, SM and KC) on this paper. Before data entry, data quality is checked and verified by the designated Field Monitor, followed by rechecking done by the Survey Manager.

Analytical approach

Year-wise causes of death were tabulated, and in addition to cause-specific mortality fraction, crude death rate (CDR) among males and females were calculated. CDR per year was calculated using the following formula:

$$\frac{Total\ number\ of\ deaths\ in\ six\ years,\ 2012-2017}{Total\ number\ of\ people\ exposed\ for\ six\ years,\ 2012-2017} \times 100,000$$

While calculating the rates, the exposed population was determined using the database, which was continuously updated and adjusted for any vital events, such as birth, death, marriage and migration. Descriptive statistics were calculated to note the proportion of deaths attributed by cause and stratified by age group. Combining all deaths for 2012–2017 helped to minimise the year-wise variation in the number of deaths. Analysis was conducted using statistical software Stata V.14.[11]

Patient and public involvement

This study used data from the vital event surveillance system of the BIRPOP-SHDS, an HDSS which recruited 59 395 members of 13 053 households in 2008. This cohort of participants is followed to understand the pattern of vital events. The socio-economic and demographic characteristics and public health profile of BIRPOP-SHDS are publicly available.[6] At its inception in 2008, participants were informed about the study design, purpose and how it would benefit the society at large. The study protocol does not include dissemination of the results to the individual study participant. Published findings are shared with the West Bengal State Department of Health and

Family Welfare, for their use in programme and policy making.

RESULTS

A total of 2320 deaths (1348 males and 972 females) were recorded during the period 2012–2017 (table 1). An overall CDR of 708/100 000 (95% CI: 680–738) was estimated. The lowest number of deaths (n=371, CDR: 785/100 000, CI: 712–864) was recorded in 2012 and the highest number of 414 deaths (CDR: 680/100 000, CI: 612–752) in 2017. Over half of all deaths (1176 deaths, 50.7%; CDR 359/100 000, CI: 339–380) were attributed to NCDs, with 30% of all deaths attributed to circulatory system disorders; whereas 24.2% and 3.9% deaths were due to cerebrovascular diseases and ischaemic heart disease, respectively.

Among males (table 2) and females (table 3), the leading cause of death was circulatory system disorders accounting for 27% (CI: 24–29) and 34% (CI: 31–37) deaths, respectively. Of deaths associated with the circulatory system, deaths from cerebrovascular diseases were 22% among males and 28% among females of total deaths in the respective category. Among diseases of the circulatory system, ischaemic heart disease was the second leading cause of death with 4% of death among males and females. The second-highest number of deaths among males was attributed to external causes of mortality: 13% (CI: 11–15) and death from infectious and parasitic diseases 13% (CI: 12–15), whereas among females, it was infectious and parasitic diseases 12% (CI: 10–14). The third leading cause of death among males was death related to the respiratory system—11% (CI: 10–13), whereas among females external causes of mortality and deaths from the respiratory system disorders accounted for 9% of deaths each. Almost equal percentages of deaths were from endocrine, nutritional and metabolic diseases among males (7%) and females (8%). Similarly, 7% and 8% of deaths due to neoplasms were recorded among males and females, respectively.

Distribution of deaths by age group (in years: 0–4, 5–14, 15–59 and ≥60) are presented for males (table 2) and females (table 3). The explanation for age-grouping is available elsewhere.[8] Most deaths among children aged 0–4 years were due to conditions in the perinatal period (male 50% and female 45%), whereas 21% and 31% of all deaths are attributed to deaths due to infectious and parasitic diseases among male and female children, respectively. Deaths attributable to intestinal infectious diseases among female children (29%) were relatively higher than males (17%). For the age group 5–14 years, nearly 50% of male deaths and 45% of female deaths were due to external causes, with accidental drowning being the top cause for both groups. Deaths due to infectious and parasitic diseases appeared prevalent among males and females in the same age group. Nearly 26% of female deaths in the age group 15–59 were attributed to the circulatory system as were 20% of male deaths, with cerebrovascular disease being the prime subcause. In the same age group, the highest proportion of deaths among males was from external causes (25%). Among females, external causes accounted for 17% of deaths. However, death due to self-harm among females was higher (11%) than males counterparts (9%). Among people aged ≥60 years, 36% of male deaths and 44% of female deaths were due to causes associated with the circulatory system and respiratory system deaths accounted for 18% of male deaths and 12% of female deaths; within this age group. Deaths due to infectious and parasitic diseases were prevalent among both males (13%) and females (12%) aged ≥60 years.

A sex-stratified CDR by disease group is presented in table 4. CDR among males was estimated to be higher (811, CI: 768–855) than females (603, CI: 566–642). Irrespective of sex, CDR was the highest for death related to the circulatory system, followed by death due to infectious and parasitic diseases and death due to external causes.

DISCUSSION

Using VA data collected between January 2012 and December 2017 from a Health and Demographic Surveillance System (HDSS) located in rural areas of Birbhum district of the state of West Bengal, India, we aimed to examine cause-specific mortality rate in addition to cause-specific mortality fraction. Overall, between 2012 and 2017, the crude death rate (CDR) was estimated to be higher (7.1/1000 with CI: 6.8–7.4 or 708/100 000, CI: 680–738) among the studied population, as compared with the CDR of the state of West Bengal in 2016—5.8/1000 (CI: 5.7–6.1).[12] The higher CDR in Birbhum is likely due to lower socioeconomic status and lack of healthcare access to the population. This study calls for improvement in the state's plan for overall mortality reduction in underserved areas. such as Birbhum, where this HDSS is located. The West Bengal State Department of Health and Family Welfare does not have any active roadmap or plan of action to reduce the overall mortality in the state, but the department complies with the 2017 National Health policy[13] which focuses on the reduction in specific causes of death nationally.

Of all deaths, over 50% deaths were attributed to NCDs. Apart from BIRPOP-SHDS, the authors are aware of over 10 functional HDSSs in India and many more are underway. Unfortunately, published data on causes of death are only available from three HDSS': Gadchiroli and Vadu in the state of Maharashtra and Ballabgarh in Haryana. Although detailed data from these HDSSs on causes of death for the time period of our study are not available publicly for comparison, a 2014 study reported 760 deaths in Vadu HDSS and 2553 deaths in Ballabgah HDSS during 2006–2012, with the burden of NCDs higher in Ballabgarh than Vadu.[14] A recent study from Gadchiroli HDSS also reported arising burden of NCDs in rural areas of India.[15] The SRS developed by the Office of the Registrar General and Census Commissioner,

Table 1 Year-wise number of deaths by cause, 2012–2017

Causes of death (ICD 10 code)	Total deaths	Year					
		2012	2013	2014	2015	2016	2017
Blood/blood forming organs (D50–D89)	**5**	**2**	**0**	**1**	**1**	**1**	**0**
Circulatory system (I00–I99)	**693**	**119**	**129**	**87**	**119**	**123**	**116**
Cerebrovascular disease	561	88	105	67	97	107	97
Ischaemic heart disease	91	23	19	14	15	10	10
Other	41	8	5	6	7	6	9
Conditions in the perinatal period (P00–P96)	**87**	**23**	**15**	**14**	**13**	**12**	**10**
Congenital malformations (Q00–Q99)	**7**	**0**	**2**	**1**	**1**	**2**	**1**
Digestive system (K00–K93)	**136**	**21**	**18**	**23**	**25**	**20**	**29**
Diseases of liver	103	19	18	21	15	13	17
Other	33	2	0	2	10	7	12
Endocrine, nutritional and metabolic diseases (E00–E90)	**173**	**23**	**25**	**32**	**33**	**26**	**34**
Diabetes mellitus	126	13	15	23	29	22	24
Other	47	10	10	9	4	4	10
External causes of mortality (S00–Y98)	**266**	**32**	**51**	**30**	**55**	**47**	**51**
Contact with venomous animals and plants	8	0	1	1	2	3	1
Exposure to smoke, fire and flame	32	2	11	1	6	5	7
Accidental drowning	24	2	4	3	5	5	5
Falls	16	1	3	3	3	5	1
Intentional self harm	94	11	20	10	25	12	16
Transport injuries	50	8	4	10	8	10	10
Other	42	8	8	2	6	7	11
Genitourinary system (N00–N99)	**95**	**18**	**9**	**10**	**16**	**20**	**22**
Infectious and parasitic diseases (A00–B99)	**294**	**57**	**41**	**54**	**37**	**46**	**59**
Diarrhoea	67	22	14	9	7	5	10
Intestinal infectious diseases	102	15	8	18	15	24	22
Tuberculosis	96	19	16	23	10	9	19
HIV	2	0	0	0	0	1	1
Other	27	1	3	4	5	7	7
Mental and behavioural disorder (F00–F99)	**1**	**0**	**1**	**0**	**0**	**0**	**0**
Neoplasm (C00–D48)	**178**	**31**	**31**	**26**	**39**	**29**	**22**
Lip, oral cavity and oropharynx	34	5	6	4	8	7	4
Digestive organs	61	9	11	13	15	5	8
Respiratory and intrathoracic organs	10	3	3	0	2	2	0
Male/female genital organs	12	1	1	1	2	4	3
Ill-defined and unspecific sites	1	0	0	0	0	0	1
Other	60	13	10	8	12	11	6
Nervous system (G00–G99)	**43**	**6**	**9**	**4**	**5**	**8**	**11**
Not elsewhere classifiable (R00–R99)	**84**	**5**	**12**	**14**	**22**	**25**	**6**
Ill-defined cause of death	4	1	1	0	1	1	0
Incomplete history	50	3	8	6	13	17	3
Sudden	24	1	3	7	7	5	1
Others	6	0	0	1	1	2	2

Causes of death (ICD 10 code)	Total deaths	Year					
		2012	2013	2014	2015	2016	2017
Pregnancy, childbirth and the puerperium (O00–O99)	**3**	**1**	**1**	**0**	**0**	**0**	**1**
Respiratory system (J00–J99)	**245**	**33**	**42**	**45**	**43**	**33**	**49**
Respiratory and intrathoracic organs	4	1	1	0	0	1	1
COPD/asthma	239	33	42	45	43	32	44
Other	2	0	0	0	0	1	1
Skin and subcutaneous tissue (L00–L99)	**8**	**0**	**0**	**2**	**1**	**2**	**3**
Diseases of the musculoskeletal system (M00–M99)	**2**	**0**	**0**	**0**	**0**	**2**	**0**
Total	2320	371	386	343	410	396	414

Table 1 title row: **Table 1** Continued

Bold values represent statistics for overall disease group, as per ICD 10.
COPD, chronic obstructive pulmonary disease; ICD 10, International Classification of Disease, version 10.

Ministry of Home Affairs, Government of India[16] provides information on state-wide causes of death for India. Besides, global research group such as the GBD Study[1] also provides model based estimates on causes of death in India at the national and subnational level. However, state level estimates often do not provide information on rural areas separately and may not be suitable to devise community-based interventions in rural settings. A handful of regional studies[8 14 15] in India have also made an effort to study causes of death. State level estimates are often not suitable indicators to devise community-based interventions and to bridge this gap, the work of HDSS' such as BIRPOP-SHDS, offer valuable insights for public health policy making to deliver effective and sustainable interventions, especially for rural India where most Indians reside.

Nearly 30% of overall deaths are attributed to the circulatory system in this studied population and cerebrovascular disease was the leading cause of death. This finding is in contrast with a study conducted in rural Andhra Pradesh[8] and the GBD study for West Bengal[1] where ischaemic heart disease was the leading cause of death and disability. Our findings concur with a study in Gadchiroli HDSS where cerebrovascular disease was the leading cause of death and accounted for 14% of all deaths.[4 15] In India, deaths due to ischaemic heart disease exceed those due to cerebrovascular diseases. However, in our study the reverse was seen. A recent nationally representative study[17] has found higher mortality due to cerebrovascular diseases in north-eastern states of India where West Bengal is located. The reasons for a higher risk of stroke will need further investigations. The deaths from cerebrovascular diseases in the BIRPOP-SHDS study area was higher among females than males which could be due to higher prevalence of overweight and obesity,[18] metabolic syndrome,[19] type 2 diabetes mellitus,[20] hypertension[21] and other cardiometabolic risk factors[22] among females. A population-based study from the city of Kolkata in the state of West Bengal had also reported higher incidence and case fatality due to stroke among females.[23]

External causes of mortality among both males and females appeared to be dominant in the age group 5–59 years. While drowning accounted for 1% of all deaths in the age group of 5–14 years, 20% of all deaths were due to accidental drowning which demands urgent attention and intervention. Drowning in West Bengal ranks 14th in causes of years of life lost in 2016.[1] A cross-sectional study in Andhra Pradesh also registered 1% of total deaths due to drowning during 2003–2004.[8] Potential reasons for higher accidental drowning among 5–14 years age group could be extensive use of home side ponds in this area for rearing fishes and limited supervision.[24]

Death due to intentional self-harm appeared to be another puzzle among adult deaths in rural India, and this finding concurs with the study conducted in rural Andhra Pradesh,[8] and the GBD study estimated that self-harm is the fourth leading cause (3.7%) of disability-adjusted life years (DALYs) in West Bengal in 2016.[1] Studies conducted in rural Haryana,[25] and Gadchiroli[15] also showed a high level of intentional self-harm such as death by suicide—3.5% and 2.5%, respectively. A study from BIRPOP-SHDS showed that this region has a high burden of probable psychiatric disorder (26%), which might be a contributing factor.[26] Deaths due to infectious and parasitic diseases among all age groups for both males and females was high with the highest percentage of deaths in the age group of 0–4 years. This is in contrast to a study conducted in rural Andhra Pradesh,[8] where deaths due to intestinal infectious diseases were recorded higher among age group 5–14.

Our finding that the third leading cause of overall death is the respiratory system associated with chronic obstructive pulmonary disease (COPD)/asthma. The GBD study also reported COPD as the third leading cause of DALYs in West Bengal.[1] An earlier study from BIRPOP-SHDS showed around half of the adult male population smoke,

Table 2 Causes of death among males, by age group

Causes of death (ICD 10 code)	Total N of deaths	Cause-specific mortality fraction (95% CI)*†	Mortality fraction by age group*			
			0–4 (n=101)	5–14 (n=20)	15–59 (n=523)	≥60 (n=704)
Blood/blood forming organs (D50–D89)	5	0.4	4	5	0.0	0.0
Circulatory system (I00–I99)	361	27 (24–29)	6	0.0	20	36
Cerebrovascular disease	291	22	1	0.0	16	29
Ischaemic heart disease	54	4	0.0	0.0	2	6
Other	16	1	5	0.0	2	0.4
Conditions in the perinatal period (P00–P96)	50	4 (3–5)	50	0.0	0.0	0.0
Congenital malformations (Q00–Q99)	4	0.3	4	0.0	0.0	0.0
Digestive system (K00–K93)	92	7 (6–8)	0.0	10	10	5
Diseases of liver	64	5	0.0	10	7	4
Other	28	2	0.0	0.0	3	2
Endocrine, nutritional and metabolic diseases (E00–E90)	94	7 (6–8)	2	0.0	7	8
Diabetes mellitus	81	6	2	0.0	7	6
Other	13	1	0.0	0.0	1	1
External causes of mortality (S00–Y98)	177	13 (11–15)	6	50	25	4
Contact with venomous animals and plants	2	0.1	0.0	0.0	0.2	0.1
Exposure to smoke, fire and flame	19	1	1	10	3	0.3
Accidental drowning	18	1	3	20	2	0.4
Falls	13	1	0.0	5	2	0.3
Intentional self harm	54	4	0.0	5	9	1
Transport injuries	42	3	0.0	10	7	0.6
Other	29	2	2	0.0	3	2
Genitourinary system (N00–N99)	59	4 (3–6)	0.0	5	6	4
Infectious and parasitic diseases (A00–B99)	181	13 (12–15)	21	10	13	13
Diarrhoea	33	2	2	0.0	2	3
Intestinal infectious diseases	52	4	17	5	1	4
Tuberculosis	76	6	1	5	7	5
HIV	2	0.1	0.0	0.0	0.4	0.0
Other	18	1	1	0.0	2	0.7
Mental and behavioural disorder (F00–F99)	1	0.1	0.0	0.0	0.2	0.0
Neoplasm (C00–D99)	99	7 (6–9)	0.0	5	9	8
Lip, oral cavity and oropharynx	29	2	0.0	0.0	2	2
Digestive organs	30	2	0.0	0.0	2	3
Respiratory and intrathoracic organs	8	0.6	0.0	0.0	0.4	0.9
Male genital organs	1	0.1	0.0	0.0	0.2	0.0
Ill-defined and unspecific sites	1	0.1	0.0	0.0	0.0	0.1
Other	30	2	0.0	5	3	2
Nervous system (G00–G99)	25	2	4	10	3	0.6

Continued

Table 2 Continued

Causes of death (ICD 10 code)	Total N of deaths	Cause-specific mortality fraction (95% CI)*†	Mortality fraction by age group*			
			0–4 (n=101)	5–14 (n=20)	15–59 (n=523)	≥60 (n=704)
Not elsewhere classifiable (R00–R99)	**42**	**3**	**4**	**5**	**2**	**4**
Ill defined cause of death	2	0.1	0.0	0.0	0.2	0.1
Incomplete history	25	2	0.0	5	1.1	3
Sudden	10	0.7	0.0	0.0	0.2	1
Other	5	0.4	4	0.0	0.0	0.1
Pregnancy, childbirth and the puerperium (O00–O99)	**0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Respiratory system (J00–J99)	**155**	**11 (10–13)**	**0.0**	**0.0**	**5**	**18**
Respiratory and intrathoracic organs	4	0.3	0.0	0.0	0.4	0.3
COPD/asthma	150	11	0.0	0.0	5	18
Other	1	0.1	0.0	0.0	0.2	0.0
Skin and subcutaneous tissue (L00–L99)	**3**	**0.2**	**0.0**	**0.0**	**0.2**	**0.3**
Diseases of the musculoskeletal system (M00–M99)	**0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Total	1348	100	100	100	100	100

Bold values represent statistics for overall disease group, as per ICD 10.
*Values above one rounded to nearest whole number and values less than one reported to one decimal place. Totals may not add precisely due to rounding.
†95% CIs have been provided where 50 or more deaths were reported.
COPD, chronic obstructive pulmonary disease; ICD 10, International Classification of Disease, version 10.

which is a risk factor for COPD.[27] Higher proportion of deaths due to endocrine, nutritional, metabolic diseases and neoplasms in our study is consistent with the estimates of the GBD study in West Bengal.[1] In-depth investigation by public health researchers and programme and policy makers is needed to respond to this challenge.

In spite of its usefulness in resource poor settings to assign broader causes of death, the VA method has several limitations. However, there is no single best-performing coding method for verbal autopsies, whether it is computer-coded verbal autopsy or physician-certified verbal autopsy (PCVA), and it is recommended to use a method that is simple and validated in various contexts, especially in rural settings.[28] Overall, if undertaken with strict protocol, the PCVA method (used in this study) for ascertaining and attributing causes of death could prove comparable and with all available methods. This study followed the authenticated guideline consistent with all available methods of causes of death review advised by the Government of India.[9] After sufficient brainstorming of various studies and metrics of VA, we could not arrive at any other method that would yield a different verdict on the death audits. Second, this study does not include information on multiple causes of death which might have limited understanding of the contribution of other conditions to a death.[29] Although VA works well for some diseases such as measles, whooping cough which are of

public health importance and bear specific symptoms, it might not be useful in cases of diseases of immense public health importance which have less specific symptoms such as HIV or malaria. Third, though we acknowledge the possibility of under-reporting of deaths attributable to tuberculosis (TB) or HIV as they are generally stigmatised, various government initiatives have already significantly curbed the prevalence of these diseases in the study area. In BIRPOP-SHDS survey area, Accredited Social Health Activists (village level health workers), with the supervision of the Senior Treatment Supervisor, undertake household visits for active TB case finding biannually. The routine sputum collection is around the stipulated target of 1200 samples per 100 000 population per year, indicating the robustness of the National TB Elimination Programme. The HIV surveillance programme in the BIRPOP-SHDS area ensured 100% HIV testing of antenatal mother's with less than 0.1% HIV prevalence. Thus the robustness of TB and HIV surveillance helped generate awareness among people covered under the BIRPOP-SHDS area. In addition, good rapport of the Surveyors with the community members helped reduce the underreporting of such occurrences. Fourth, the age-sex structure (figure 2) of the sampled population of BIRPOP-SHDS (as in 2017) was compared with the district representative data retrieved from the National Family Health Survey, 2015–2016,[30] to understand the

Table 3 Causes of death among females, by age group

Causes of death (ICD 10 code)	Total N of deaths	Cause-specific mortality fraction (95% CI)	Mortality fraction by age group			
			0–4 (n=83)	5–14 (n=22)	15–59 (n=301)	≥60 (n=566)
Blood/blood forming organs (D50–D89)	**0**	**0**	**0**	**0**	**0**	**0**
Circulatory system (I00–I99)	**332**	**34 (31–37)**	**7**	**5**	**26**	**44**
Cerebrovascular disease	270	28	0	0	18	38
Ischaemic heart disease	37	4	1	0	3	5
Other	25	3	6	5	5	0.7
Conditions in the perinatal period (P00–P96)	**37**	**4**	**45**	**0**	**0**	**0**
Congenital malformations (Q00–Q99)	**3**	**0.3**	**4**	**0**	**0**	**0**
Digestive system (K00–K93)	**44**	**5**	**0**	**0**	**9**	**3**
Diseases of liver	39	4	0	0	8	3
Other	5	0.5	0	0	0.7	0.5
Endocrine, nutritional and metabolic diseases (E00–E90)	**79**	**8 (7–10)**	**1**	**0**	**7**	**10**
Diabetes mellitus	45	5	0	0	5	5
Other	34	3	1	0	2	5
External causes of mortality (S00–Y98)	**89**	**9 (7–11)**	**8.4**	**45**	**17**	**4**
Contact with venomous animals and plants	6	0.6	4	9	0.3	0
Exposure to smoke, fire and flame	13	1	2	5	3	0.2
Accidental drowning	6	0.6	1	14	0.3	0.2
Falls	3	0.3	0	0	0.3	0.4
Intentional self harm	40	4	1	9	11	0.7
Transport injuries	8	0.8	0	9	1	0.4
Other	13	1	0	0	1	2
Genitourinary system (N00–N99)	**36**	**4**	**0**	**9**	**5**	**3**
Infectious and parasitic diseases (A00–B99)	**113**	**12 (10–14)**	**31**	**9**	**8**	**11**
Diarrhoea	34	3	2	5	1	5
Intestinal infectious diseases	50	5	29	5	0.7	4
Tuberculosis	20	2	0	0	5	0.9
HIV	0	0	0	0	0	0
Other	9	0.9	0	0	0.7	1
Mental and behavioral disorder (F00–F99)	**0**	**0**	**0**	**0**	**0**	**0**
Neoplasm (C00–D99)	**79**	**8 (7–10)**	**1**	**9**	**14**	**6**
Lip, oral cavity and oropharynx	5	0.5	0	0	0.3	0.7
Digestive organs	31	3	0	5	5	2
Respiratory and intrathoracic organs	2	0.2	0	0	0.7	0
Female genital organs	11	1	0	0	2	0.9
Ill-defined and unspecific sites	0	0	0	0	0	0
Other	30	3	1	5	6	2
Nervous system (G00–G99)	**18**	**2**	**2**	**23**	**3**	**0.2**
Not elsewhere classifiable (R00–R99)	**42**	**4**	**0**	**0**	**2**	**7**
Ill defined cause of death	2	0.2	0	0	0.7	0
Incomplete history	25	3	0	0	0.7	4
Sudden	14	1	0	0	0.3	2

Continued

Table 3 Continued

Causes of death (ICD 10 code)	Total N of deaths	Cause-specific mortality fraction (95% CI)	Mortality fraction by age group			
			0–4 (n=83)	5–14 (n=22)	15–59 (n=301)	≥60 (n=566)
Other	1	0.1	0	0	0	0.2
Pregnancy, childbirth and the puerperium (O00–O99)	**3**	**0.3**	**0**	**0**	**1**	**0**
Respiratory system (J00–J99)	**90**	**9 (8–11)**	**0**	**0**	**7**	**12**
Respiratory and intrathoracic organs	0	0	0	0	0	0
COPD/asthma	89	9	0	0	7	12
Other	1	0.1	0	0	0.3	0
Skin and subcutaneous tissue (L00–L99)	**5**	**0.5**	**0**	**0**	**0.3**	**0.7**
Diseases of the musculoskeletal system (M00–M99)	**2**	**0.2**	**0**	**0**	**0.3**	**0.2**
Total	972	100	100	100	100	100

Bold values represent statistics for overall disease group, as per ICD 10.
*Values above one rounded to nearest whole number and values less than one reported to one decimal place. Totals may not add precisely due to rounding.
†95% CIs have been provided where 50 or more deaths were reported.
COPD, chronic obstructive pulmonary disease; ICD 10, International Classification of Disease, version 10.

Table 4 CDR by causes of death, stratified by sex

Causes of death (ICD 10 code)	Male (number of exposed population: 166 284)		Female (number of exposed population: 161 226)	
	Number of death	CDR (95% CI) / 100 000	Number of death	CDR (95% CI)/100 000
Blood/blood forming organs (D50–D89)	5	3 (1–7)	0	nc
Circulatory system (I00–I99)	361	217 (195–241)	332	206 (184–229)
Conditions in the perinatal period (P00–P96)	50	30 (22–40)	37	23 (16–32)
Congenital malformations (Q00–Q99)	4	2 (1–6)	3	2 (0–5)
Digestive system (K00–K93)	92	55 (45–68)	44	27 (20–37)
Endocrine, nutritional and metabolic diseases (E00–E90)	94	57 (46–69)	79	49 (39–61)
External causes of mortality (S00–Y98)	177	106 (91–123)	89	55 (44–68)
Genitourinary system (N00–N99)	59	35 (27–46)	36	22 (16–31)
Infectious and parasitic diseases (A00–B99)	181	109 (94–126)	113	70 (58–84)
Mental and behavioural disorder (F00–F99)	1	1 (0–3)	0	nc
Neoplasm (C00–D99)	99	60 (48–72)	79	49 (39–61)
Nervous system (G00–G99)	25	15 (10–22)	18	11 (7–18)
Not elsewhere classifiable (R00–R99)	42	25 (18–34)	42	26 (19–35)
Pregnancy, childbirth and the puerperium (O00–O99)	0	nc	3	2 (0–5)
Respiratory system (J00–J99)	155	93 (79–109)	90	56 (45–69)
Skin and subcutaneous tissue (L00–L99)	3	2 (0–5)	5	3 (1–7)
Diseases of the musculoskeletal system (M00–M99)	0	nc	2	1 (0–4)
Total	1348	811 (768–855)	972	603 (566–642)

CDR, crude death rate; ICD 10, International Classification of Disease, version 10; nc, not calculated.

Figure 2 Age and sex distribution of the population. The shaded bars indicate the age and sex distribution for Birbhum District, West Bengal, India, National Family Health Survey, 2015–2016, and the clear outlined bars show the corresponding data for the Birbhum Population Project, 2017.

external validity of this study findings. As this study setting is limited to a rural region of Birbhum district of the state of West Bengal, a precaution on generalising the findings of this study to the other rural areas of India is needed. Fifth, a very low (24 of 2320 VA) level of discordance between physicians may not match with existing literature on India. For example, causes of under-five deaths had over 30% discordance[31] and auditing deaths from injury had over 20% discordance.[32] But low discordance in BIRPOP-SHDS, may be due to accessibility of all information available to audit VA. Since surveyors were recruited from the BIRPOP-SHDS area, this helped build strong relations with the community which helped a great deal to gather all relevant documents and information necessary for VA, which sometime required multiple visits or phone calls to the respondents. Finally, a very low proportion of deaths in the category of 'not elsewhere classifiable (R00–R99)' was recorded—84 of total 2320 deaths (3.6%). This could raise a doubt of misclassification as studies conducted elsewhere, such as studies in Andhra Pradesh[8] and Gadchiroli[15] classified over 18% and 26% of deaths in this category, respectively. One cannot rule out misclassification, however, given the adoption of strict guideline of VA audit coupled with availability of all supporting documents required for VA audit, reduced the probability of misclassification. Despite these limitations, determination of causes of death using data for 6 consecutive years from a prospective cohort in rural India is a significant strength of this study.

Findings of this study indicate a need for devising a state action plan of mortality reduction, coupled with testing various interventions to reduce risk factors for NCDs among adults. Although reducing the burden of NCDs should be the priority, investigating the rising burden of external causes of mortality among adults and interventions to reduce death from perinatal conditions are also an immediate need. India is a signatory of various global commitments to prevent NCDs. For example, the

Sustainable Development Goal target 3.4 recommends that India make every effort to reduce by one-third premature mortality from NCDs through prevention and treatment, and promote mental health and well-being, by 2030. In line with this commitment, the 2017 National Health Policy or the National Programme for prevention and control of Cancer, Diabetes, Cardiovascular disease and Stroke were devised.[33] However, further efforts are needed by the Ministry of Health and Family Welfare with the help of NITI *Aayog* to improve prevention of NCDs and will require the involvement of multiple stakeholders including an adaptive network governance structure where the centre coordinates with the state to ensure implementation is needed.[34] This study calls for the need for more community-based or locally embedded surveillance systems to track the changing patterns in public health needs and trends, as state-level measures are not necessarily indicative of a specific rural setting.

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