Child, maternal, and adult mortality in rural Ethiopia in 2019: a cross-sectional mortality survey using electronic verbal autopsies

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Summary

Background Ethiopia, with about 10% of Africa's population, has little direct information on causes of death, particularly in rural areas where 80% of Ethiopians live. In 2019–2020, we conducted electronic verbal autopsies (e-VA) to examine causes of death and quantify cause-specific mortality rates in rural Ethiopia.

Methods We examined deaths under 70 years in the three years prior to the survey dates (November 25, 2019–February 29, 2020) among 2% of East Gojjam Zone (Amhara Region) using registered deaths and adding random sampling in this cross-sectional study. Trained surveyors interviewed relatives of the deceased with central dual-physician assignment of causes as the main outcome. We documented details on age, sex and location of death, and derived overall rural death rates using 2007 Census data and the United Nations national estimates for 2019. To these, we applied our sample-weighted causes to derive cause-specific mortality rates. We calculated death risks for the leading causes for major age groups.

Findings We studied 3516 deaths: 55% male, 97% rural, and 68% occurring at home. At ages 5 and older, injuries were notable, accounting for over a third of deaths at 5–14 years, half of the deaths at ages 15–29 years, and a quarter of deaths at ages 30–69 years. Neonatal mortality was high, mostly from prematurity/low birthweight and infections. Among children under 5 (excluding neonates), infections caused nearly two-thirds of deaths. Most maternal deaths (84%) arose from direct causes. After injuries, especially suicide, assaults, and road traffic accidents, vascular disease (15%) and cancer (13%) were the leading causes among adults at 30–69 years. HIV/AIDS and tuberculosis deaths were also important causes among adults.

Interpretation Rural Ethiopia has a high burden of avoidable mortality, particularly injury, including suicide, assaults, and road traffic accidents.

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Keywords: Ethiopia; Rural; Mortality; Causes of death; Electronic verbal autopsies

Introduction

Over the last two decades, Ethiopia, home to about ten percent of Africa's 1.4 billion people, has realized substantial improvements in death rates.[1] Since 2000, under-five mortality rates decreased annually by an average of 5%.[1,2] Despite this remarkable progress, premature mortality remains high, including high maternal,[3,4] neonatal, and under-five mortality,[5] especially in rural areas where over 80% of Ethiopians live. Access to medical care[3,6] and public health services is

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Research in context

Evidence before this study

We searched PubMed and Google Scholar for articles on causes of death in Ethiopia using search terms "mortality", "cause of death", and "Ethiopia" published from inception up to May 1, 2023 with no language restrictions. Most studies were model- or health facility-based studies at the national and subnational levels with age group or a focus on specific causes. Others reported burial system data or data from the seven health and demographic surveillance systems sites. No study used data from a vital event registration system with a verbal autopsy component at the national or regional level.

Added value of this study

The Statistical Alliance for Vital Events in Ethiopia study provides insights into the causes of deaths below age 70 years in rural populations, revealing tangible evidence on the high levels of avoidable deaths in 2019. It expands understanding of the leading causes of death with injuries emerging as a major contributor to premature mortality and males particularly affected by assault. Our results suggest the need for direct evidence to complement model-based national estimates in Africa. The study methods provide a feasible method for larger national mortality surveys.

Implications of all the available evidence

The study provides catalytic evidence to support the need and feasibility of a cost-effective, large-scale national mortality survey based on the forthcoming census in Ethiopia. Direct cause of death data may guide national programs for resource-limited countries like Ethiopia, including for rural areas where most deaths occur. We identified key priorities for action by the government to reduce premature mortality for all age groups in Ethiopia, most notably for injuries.

particularly low in rural areas.[3,7,8] Most deaths occur outside health facilities.[8,9]

In 2016, the Ethiopian government strengthened its civil registration and vital statistics (CRVS) system to capture births and deaths through the Vital Events Registration Agency (VERA).[6] Although VERA geographic coverage exceeds 90%, delayed registration and other constraints lead to low effective coverage. Reliable estimates of coverage of death registration do not yet exist, but demographic surveys find birth registration (which usually exceeds death registration) of only 3%.[10] Moreover, VERA captures only the fact of death, but not the causes.

Electronic verbal autopsies (e-VA) are an established and well-tested alternative to obtain cause-specific data in settings like Ethiopia where medical attention at the time of death remains uncommon.[8,9,11,12] The Statistical Alliance for Vital Events (SAVE) in Ethiopia implemented e-VA on a sample of deaths below age 70 years in East Gojjam Zone of Amhara, a predominantly rural and populous region in north-western Ethiopia,[7] from 2019 to 2020. The original objective was to conduct an in-depth study on the causes of rural deaths to establish procedures for a post-census mortality survey on a nationally representative random sample of deaths enumerated during the 2020 census.[9] However, that census has been postponed due to the COVID pandemic and ongoing civil strife. Given the paucity of data on causes of death in Ethiopia, we release the results of this study to provide preliminary estimates of cause-specific mortality in rural areas, and to serve as a catalyst for larger verbal autopsy studies that are required for the diverse populations of Ethiopia.

Methods

Sampling frame

The School of Public Health, Addis Ababa University, and the Ethiopian Public Health Association led SAVE in East Gojjam, supported by the Centre for Global Health Research, University of Toronto. According to the 2007 Ethiopia census, East Gojjam had approximately 2.1 million people in 21 districts, with 90% of its population being rural.[13]

SAVE covered about 2% of the East Gojjam population, enrolling VERA-recorded deaths. Trained field staff used VERA identifiers to locate households with a death, stratified by residence (urban/rural), villages, and ecological zones using the probability-proportional-to-size method. We also captured additional deaths (hereafter defined as "SAVE-captured" deaths) through household enumeration. For the latter, we surveyed 10 adjacent households for each VERA-recorded death (11,591 households overall; 40,895 household members). The use of 10 sampled households used proportion to population methods to capture an overall number of about 3500 deaths (VERA-recorded and SAVE-captured) for our study sample, which was the upper limit permitted by the project budget. We included deaths below 70 years and examined these at ages when they are largely avoidable: neonatal (0–28 days), childhood (29 days–14 years), maternal, and adult (15–69 years) age groups in a cross-sectional study. We excluded deaths over 70 years, even though they constitute 22% of Ethiopian national totals,[1] as deaths at older ages are less avoidable, and their causes are subject to greater misclassification.[9]

Ethics

Research Ethics Board approvals were provided by the Ethiopian Public Health Institute (#613-417) and Unity

Health Toronto (#15-231). All participants (relatives of the deceased) gave informed consent.

Enumeration, baseline survey, and e-VA

Between November 25, 2019 and February 29, 2020, we enumerated deaths for the three years prior to the survey dates and conducted e-VA on both VERA-recorded and unreported deaths in the index households and in randomly selected adjacent households. We used an adapted e-VA data collection tool (neonates, children, and adults), based on the World Health Organization (WHO) 2016 version,[14] in both English and Amharic. This tool is functional offline with an integral database that permits real-time data validation, audio recording, random resampling (review of records for quality control and consistency) and surveyor feedback. Twenty-five specially trained surveyors, in teams of six to eight, implemented the fieldwork by interviewing consenting adult respondents on cause of death information and demographic details, risk factors and treatments among the deceased. Surveyors initiated the e-VA interview process by explaining the study, and obtained inform consent with digital signature, and implemented the interview which lasted approximately 40 min. Two coordinators supervised data collection and provided quality assurance. Each day, the e-VA data were uploaded to a cloud server where, after further data checks, they became available for central online physician coding.

Central cause of death determination

The cause of death determination process was nearly identical to that in the Indian Million Death Study[15] and Healthy Sierra Leone (HEAL-SL).[12] We assigned International Classification of Diseases (tenth edition, ICD-10) three-digit codes to each death following independent e-VA reviews online by two of 15 physicians, each randomly assigned records. Physicians were specially trained in death certification and verbal autopsy coding (www.cghr.org/training). Differences underwent anonymous reconciliation, with a senior physician adjudicating persistent disagreements. For maternal deaths (occurring during pregnancy or within 6 weeks of delivery among females aged 15–49 years), we followed the WHO–ICD maternal death coding guidelines.[16] We grouped the 344 unique ICD-10 codes in this study into 45 distinct cause categories following the WHO Global Health Estimates[17] death classification system (Appendix Table 1).

Statistics

We derived sex-specific mortality rates for children 5–14 years old, and adults aged 15–29 years and 30–69 years. We applied sample-weighted proportions of death to mortality estimates generated for rural Ethiopia in 2019. We derived the rural estimates in turn by partitioning the United Nations (UN) World Population Prospects (2022)[1] data for Ethiopia in 2019 into rural and urban age- and sex-specific deaths based on the last Census conducted in 2007 (Appendix Tables 2 and 3). This enabled us to create a rural lifetable[18] that we used to calculate overall age-period specific probabilities of death (Appendix Table 4). Census data for neonates (0–28 days) and stillbirths are not available. Hence, we applied the 2019 UNICEF neonatal Ethiopian mortality rate[19] (27.8/1000 live births) and stillbirth rates (24.6/1000 births) to WPP-derived rural livebirths to obtain rural death estimates. The rural/urban distributions by age and sex and the resulting sampling weights appear in Appendix Table 5.

We subtracted neonatal deaths from under-five deaths (estimated using UNICEF 2019 under-five mortality rate; 50.8/1000 live births) to derive rural estimates for 1–59 month deaths. To estimate maternal deaths, we applied the sample-weighted proportion to the UN death total for females 15–49 years of age for rural Ethiopia. We calculated risks of death for each cause based on[18] calculated lifetables.

We computed 95% CIs for the risks using the delta method for age- and cause-specific rates.[20] We examined VERA-recorded and SAVE-captured (identified during household enumeration) deaths to assess differences in cause of death distributions overall and by age groups. We used Stata version 16 software for analyses.

Role of the funding source

The project sponsors had no role in the design, implementation, data collection, or manuscript preparation.

Results

We captured the deaths of 3516 individuals from the 21 districts of East Gojjam Zone (Fig. 1), for which physicians assigned ICD-10 codes; initial concordance was 71%. Conflicting diagnoses were resolved at reconciliation (15%) or adjudication (14%). Nearly all deaths (97%) occurred in rural areas and 68% took place at home, with slightly more male (55%) than female deaths.

Among the 241 neonatal deaths in our study, 63% occurred by day six of life, including 38% of deaths on the day of birth. About 71% of neonatal deaths occurred at home and 66% were male. Infections caused about 35% of neonatal deaths, led by pneumonia (18%) and sepsis (17%). Birth asphyxia and trauma and prematurity/low birthweight each accounted for 25%. The overall neontal mortality rate per 1000 livebirths was 27.8 (95% CI 27.6-28.0), equating to a 3.0% risk of death.

About 43% of stillbirths occurred at home and 63% were male. Stillbirths constituted about 11% of the combined total of stillbirths and neonatal deaths, with the sample-weighted count of one stillbirth for every

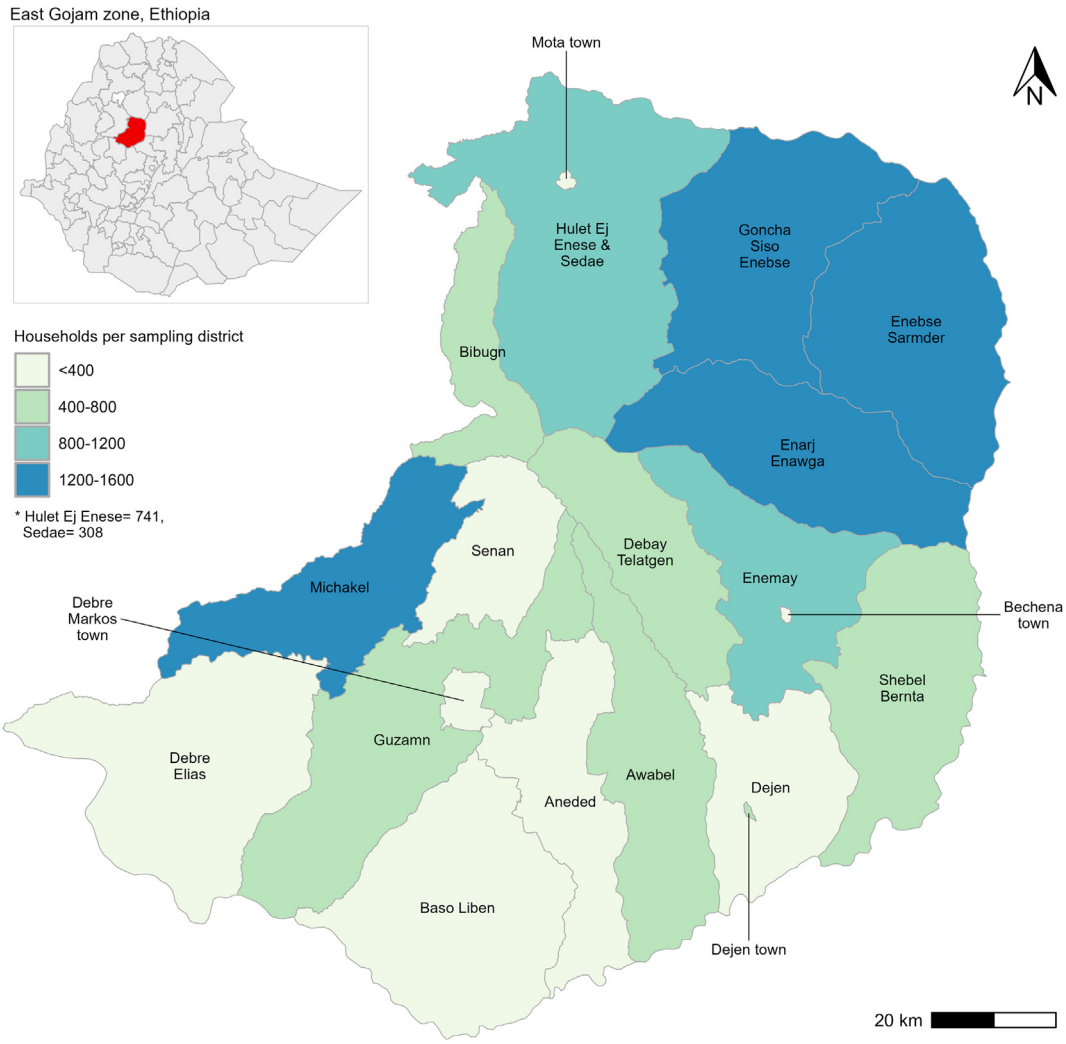

***Fig. 1:* Map of East Gojjam Zone, Ethiopia, showing enumeration areas and district**. Map of East Gojjam Zone, Ethiopia, with the corresponding number range of households per sampling unit.

eight neonatal deaths. Applying the denominators (livebirths and stillbirths for stillbirths and livebirths for neonatal deaths), yielded ratio of 0.21 or approximately 1 to 5 between the stillbirth and neonatal mortality rates.

Most (81%) of the 344 study deaths in children under 5 years (excluding neonates) occurred at home and 55% were male. Sixty-four percent were due to infections, with pneumonia causing 33%, followed by diarrhoea (14%) and meningitis/encephalitis (8%). Injuries (drowning, road traffic accidents, and falls) caused an additional 15% of deaths. The rural mortality rate at these ages was 21.1 (20.9–21.3) per 1000 livebirths who survived to 28 days and the overall risk of dying between 1 month and 5 years was 2.2%.

We documented 112 maternal deaths, half of which occurred at home. Direct causes dominated by 84%, including 47% due to obstetric haemorrhage. Other direct maternal causes (maternal sepsis, miscarriage, abortion, and hypertensive disorders of pregnancy) accounted for 12% of maternal deaths. The maternal mortality ratio was 326 (320–332) deaths per 100,000 livebirths, with a 1.7% lifetime risk of dying from maternal causes (Table 1). About 18% of deaths among females aged 15–49 years were from maternal causes.

Death rates were lowest among children aged 5–14 years compared to other age groups, with 206 deaths captured in the study. About 61% of these children died at home and 61% were male. Infections (41%) and injuries (36%) were leading causes of death. Infections were primarily diarrhoea (10%), tuberculosis (7%), and meningitis/encephalitis (7%). Injuries comprised, in

Cause of death	Study deaths (male/female)	Percentage of total[a]	Risk of death, %	Annual rural mortality rate (per 1000 livebirths)	Lifetime death risk %	Maternal mortality ratio, per 100,000 livebirths
Stillbirths	30 (19/11)	11%	Not applicable			
Neonatal deaths						
Birth asphyxia/birth trauma	62 (43/19)	25%	0.8	7.0 (6.9–7.1)		
Prematurity/low birthweight	59 (41/18)	25%	0.8	7.0 (6.9–7.1)		
Pneumonia	43 (21/22)	18%	0.5	4.9 (4.8–5.0)		
Sepsis	43 (31/12)	17%	0.5	4.6 (4.5–4.7)		
Other non-communicable	22 (13/9)	8%	0.2	2.1 (2.1–2.2)		
Ill-defined/unknown	12 (9/3)	8%	0.2	2.2 (2.2–2.3)		
All neonatal deaths	**241 (158/83)**	**100%**	**3.0**	**27.8 (27.6–28.0)**		
+1–59 months deaths						
Pneumonia	117 (56/61)	33%	0.7	6.9 (6.8–7.0)		
Diarrhoea	49 (27/22)	14%	0.3	2.9 (2.8–3)		
Injuries	48 (26/22)	15%	0.3	3.1 (3–3.2)		
Other non-communicable	39 (25/14)	13%	0.3	2.7 (2.6–2.8)		
Meningitis/encephalitis	22 (14/8)	8%	0.2	1.7 (1.7–1.7)		
Other infectious and parasitic	23 (13/10)	6%	0.1	1.3 (1.3–1.3)		
Tuberculosis	14 (10/4)	4%	0.1	0.8 (0.8–0.8)		
Nutritional diseases	12 (5/7)	4%	0.1	0.8 (0.8–0.8)		
Ill-defined/unknown	20 (12/8)	4%	0.1	0.9 (0.9–0.9)		
All 1–59 months deaths	**344 (188/156)**	**100%**	**2.2**	**21.1 (20.9–21.3)**		
Maternal deaths						
Direct causes	88	84%			1.5	274
Obstetric haemorrhage	49	47%			0.8	152
Other maternal	25	25%			0.4	83
Other direct causes[a]	14	12%			0.2	40
Indirect causes	24	16%			0.3	52
All maternal deaths	**112**	**100%**			**1.7**	**326 (320–332)**

Weighted estimates calculated at the area level using population numbers from the 2007 census. UNICEF neonatal mortality rate for 2019 (27.8 per 1000 LB) used to calculate denominator for estimating rural total of neonatal deaths. Livebirths for 2019 were estimated from the UN World Population Prospects (2022). Denominator for estimating national total of 1–59 month deaths calculated by subtracting neonatal deaths from under-five deaths for 2019 (estimated from UNICEF 2019 under five years mortality rate). Maternal deaths and ratios calculated using 2019 female (age 15–49 years) deaths, multiplied by proportion of study maternal deaths, and then divided by the UN (2022) live births estimate. Rural denominators: Livebirths (3,372,088). Deaths–neonates (93,717) and 1–59 months (69,307). The percentages of home deaths were 43% for stillbirths (13/30), 71% for neonatal (172/241), 81% for 1–59 months (278/344), and 50% for maternal (56/112). [a]Other direct causes of maternal deaths: maternal sepsis (8), abortion or miscarriage (4), and hypertensive disorders of pregnancy (2). Other indirect causes: non-communicable diseases (5), co-incidental (8), and communicable diseases (11). +1–59 months: mortality rate per 1000 livebirths who reached age 29 days.

Table 1: **Neonatal (0–28 days of age), child (1–59 months), and maternal (15–49 years) causes of deaths in rural Ethiopia, 2019.**

descending order by proportion, falls, drowning, road traffic accidents, and suicide. The rural mortality rate for this age group was 189.8 deaths (188.1–191.5) per 100,000 population (Table 2).

Of the 591 study deaths among young adults aged 15–29 years, 51% occurred at home and 59% were male (Table 2). Fifty percent of deaths resulted from injuries, including suicides (20%), assaults (11%), and road traffic accidents (7%). Infections accounted for 22% of deaths, including 7% from tuberculosis (Fig. 2). The rural mortality rate of 307.9 (305.8–310.0) per 100,000 population yielded an overall risk of death of 4.6% during this age group.

We recorded 2104 deaths among adults aged 30–69 years old. About 71% occurred at home, and 53% were male (Table 2). Injuries accounted for 24% of deaths, led by suicides (7%) and assaults (6%; Fig. 2). Other leading causes were vascular diseases and cancers contributing 15% and 13% of deaths, respectively. Tuberculosis and HIV together accounted for 19% of deaths. The rural mortality rate for this age group was 784.1 deaths (780.7–787.5) per 100,000 population, yielding an overall risk of death of 36.0% during these ages.

Overall, tuberculosis and HIV caused 12% of deaths under age 70 years. Tuberculosis was a notable cause of death for children (1 month–14 years) and adults (15–69 years). HIV predominated among adults aged 15–69 years, accounting for 93% of all HIV-related deaths, with the rest below age 15 years. Age-specific mortality rates for tuberculosis and HIV display nearly J-shaped curves, higher in younger and older age groups (Fig. 3). For tuberculosis, the mortality rates were similar for males

Cause of death	Study deaths (male/female)	Percentage of sample weighted total	Rural mortality rate per 100,000 population	Risk of death (%)
5–14 years deaths				
Injuries	75 (49/26)	36%	67.4 (66.4–68.4)	0.7
Other non-communicable	46 (23/23)	21%	40 (39.2–40.8)	0.4
Diarrhoea	21 (11/10)	10%	19.6 (19.1–20.1)	0.2
Meningitis/encephalitis	12 (7/5)	7%	12.9 (12.5–13.3)	0.1
Tuberculosis	12 (6/6)	7%	13.6 (13.2–14.1)	0.1
Pneumonia	12 (10/2)	5%	9.9 (9.5–10.3)	0.1
Other infectious and parasitic	12 (10/2)	5%	9.9 (9.5–10.3)	0.1
HIV/AIDS	10 (5/5)	6%	12 (11.6–12.4)	0.1
Ill-defined/unknown	6 (4/2)	2%	4.6 (4.3–4.9)	0.1
All 5–14 years deaths	**206 (125/81)**	**100%**	**189.8 (188.1–191.5)**	**1.9**
15–29 years deaths				
Suicide	119 (68/51)	20%	61.4 (60.5–62.4)	0.9
Other unintentional injuries	79 (66/13)	12%	37.4 (36.7–38.2)	0.6
Assaults	56 (47/9)	11%	32.9 (32.2–33.6)	0.5
Other infections	56 (31/25)	10%	31.9 (31.2–32.6)	0.5
Road traffic accidents	45 (34/11)	7%	21 (20.5–21.6)	0.3
Tuberculosis	40 (19/21)	7%	20.6 (20.1–21.2)	0.3
All vascular	38 (19/19)	6%	18.1 (17.6–18.6)	0.3
Maternal	36 (0/36)	6%	19.7 (19.2–20.2)	0.3
All cancers	30 (16/14)	5%	15.3 (14.8–15.8)	0.2
Other non-communicable	30 (20/10)	5%	14.1 (13.7–14.6)	0.2
HIV/AIDS	29 (10/19)	5%	15 (14.5–15.5)	0.2
Epilepsy	17 (9/8)	3%	10.6 (10.2–11)	0.2
Ill-defined/unknown	16 (7/9)	3%	9.9 (9.5–10.3)	0.1
All 15–29 years deaths	**591 (346/245)**	**100%**	**307.9 (305.8–310)**	**4.6**
30–69 years deaths				
All vascular	325 (152/173)	15%	117.7 (116.4–119)	5.4
All cancers	296 (140/156)	13%	100.9 (99.7–102.1)	4.6
Tuberculosis	234 (106/128)	11%	88.4 (87.3–89.5)	4.1
HIV/AIDS	179 (91/88)	8%	63 (62.1–64)	2.9
Suicide	137 (77/60)	7%	53.3 (52.4–54.2)	2.4
Assaults	120 (107/13)	6%	50 (49.2–50.9)	2.3
Kidney failure	109 (49/60)	5%	41.6 (40.8–42.4)	1.9
Diarrhoea	82 (43/39)	4%	32.6 (31.9–33.3)	1.5
Other unintentional injuries	81 (57/24)	4%	33.1 (32.4–33.8)	1.5
Road traffic accidents	78 (53/25)	3%	24.5 (23.9–25.1)	1.1
Falls	65 (43/22)	3%	24.3 (23.7–24.9)	1.1
Maternal	62 (0/62)	4%	27.9 (27.3–28.5)	1.3
Pneumonia	55 (22/33)	3%	20.7 (20.2–21.3)	1.0
Meningitis/encephalitis	50 (30/20)	2%	18.9 (18.4–19.4)	0.9
Other infections	45 (28/17)	2%	16.8 (16.3–17.3)	0.8
Liver and alcohol related	37 (22/15)	2%	13.1 (12.7–13.5)	0.6
Other digestive	36 (22/14)	2%	13 (12.6–13.4)	0.6
Other non-communicable	33 (21/12)	2%	14.3 (13.9–14.8)	0.7
Asthma and chronic respiratory	31 (18/13)	2%	11.9 (11.5–12.3)	0.5
Epilepsy	23 (12/11)	1%	7.9 (7.6–8.2)	0.4
Other Ill-defined/unknown	26 (14/12)	1%	9.8 (9.4–10.2)	0.4
All 30–69 years deaths	**2104 (1107/997)**	**100%**	**784.1 (780.7–787.5)**	**36.0**

Weighted estimates calculated at the area level using population numbers from the 2007 census. Denominator for estimating national rural total deaths for 2019 obtained from UN (2022). Rural denominators: Deaths—5–14 years (49,297), 15–29 years (80,172), 30–69 years (207,777); population—5–14 years (25,971,053), 15–29 years (26,034,553), 30–69 years (26,499,201). The percentages of home deaths were 61% for children aged 5–14 years (126/206), 51% for adults aged 15–29 years (300/591), and 71% for adults aged 30–69 years (1501/2104). Risk of death estimates were derived from life tables for rural Ethiopia.

Table 2: **Causes of death among children (5–14 years) and adults (15–29 and 30–69) in rural Ethiopia, 2019.**

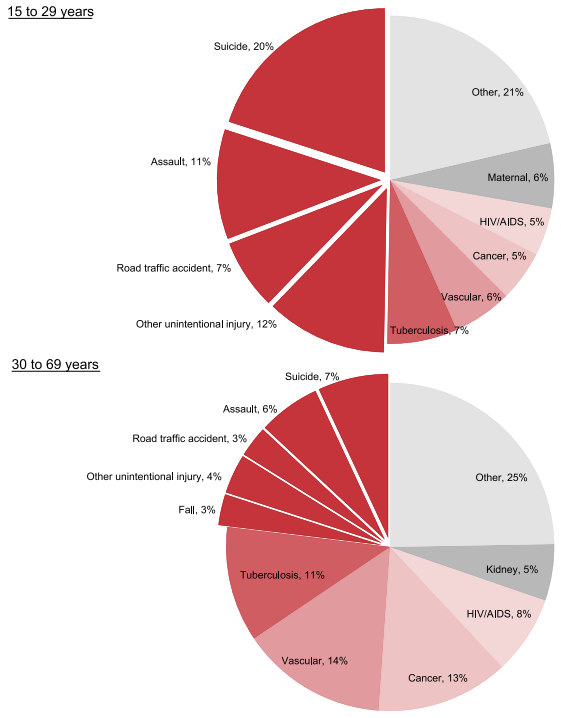

Fig. 2: **Leading causes of death among adults at ages 15–29 years and 30–69 years in rural Ethiopia**.

and females across all age groups, with a sharp increase in adults aged 60–69 years, for whom the risk of dying from tuberculosis alone was 2.8%. We observed a similar pattern for HIV, except for females aged 45–59 years, where the rate plateaued compared to males.

Age-specific mortality rates at 15–69 years were higher for males than for females for all three injury causes, except for road traffic accidents at 60–69 years (Fig. 4). The modes of suicide deaths at 15–59 years were 48% from pesticide ingestion and 27% by hanging. The pattern of suicide mortality rates was similar for males and females, with elevated rates at 15–29 years, a decrease for the 30–44 years age group, and a steady increase for adults aged 45–59 and 60–69 years. Compared to females, males had higher and rising assault mortality rates with age. Most assaults were caused by firearms (49%) and sharp/blunt force objects (41%).

Neonatal deaths and stillbirths were a lower proportion of VERA-recorded versus SAVE-captured deaths (Appendix Tables 6–8), but there were otherwise few differences in the location, age, and cause of death patterns. Injuries, including assault, were reported equally in each sampling frame.

Discussion

In rural Ethiopia, premature mortality from mostly preventable and treatable conditions is high. Residents face a 43% risk of mortality before reaching 70 years of age, among the highest avoidable mortality rates in the world. Infections and injuries ranked among the top contributors to overall death, while non-communicable diseases, including all vascular diseases and cancers, were major causes among adults aged 30–69 years.[7,8,21,22] This evidence is critical for framing effective strategies to reduce premature mortality and strengthening existing disease control programs.

Our most surprising finding involves injury, which caused over a third of deaths at ages 5–14 years, about half of deaths at ages 15–29, and nearly a quarter of deaths at ages 30–69 years. Injury-related deaths were predominantly due to suicides, road traffic accidents, assaults, and falls, with drownings also important at the younger age groups. These are consistent with focal studies suggesting injuries to be a major burden in Ethiopia.[8,21,23,24]

Suicide remained high among older adults, in contrast to other Ethiopian reports of the high rates mainly among younger adults.[23] About 8% of deaths were attributable to suicides in rural Ethiopia. Deaths from suicide may have been underreported or misclassified as "undetermined" or "accidental"[25] in other data sources. Effective interventions for suicide may include reducing access to agricultural pesticides, as done in Sri Lanka[26] to decrease fatality of suicide attempts. Parallel efforts to reduce suicidal ideation include improving community-based mental health services, and reducing alcohol abuse, especially among males, who accounted for 60% of these deaths.

Recurrent conflicts in the country are reflected in males comprising nearly nine in ten deaths from assaults. Outside of efforts to curtail road traffic accidents in Ethiopia, other forms of injury have not received serious attention[24] and timely information about them is limited. Our reference period of deaths and the survey dates were both prior to the most recent civil unrest. Thus, assault death totals in more recent years, particularly in Amhara and other regions affected by the unrest, may well be substantially higher.

Mortality rates for tuberculosis and HIV increased in tandem with age for both sexes. This underscores the higher risk of tuberculosis mortality among people co-infected with HIV,[27] who are further weakened by advancing age. WHO has deemed Ethiopia as a high tuberculosis burden country which achieved its 2020 goal of reducing the incidence rate by 20% compared to its 2015 baseline.[3,27] However, the COVID pandemic impacted reporting of incident cases,[27] potentially reversing gains. Hence, intensified case finding for tuberculosis may be needed.

Prior focal studies also showed that birth asphyxia and trauma, respiratory infections, sepsis, and prematurity to be the dominant causes of death among neonates, while pneumonia and diarrhoea were the top causes for children under 5 years.[21,28] We report a somewhat lower maternal mortality ratio (332/100,000

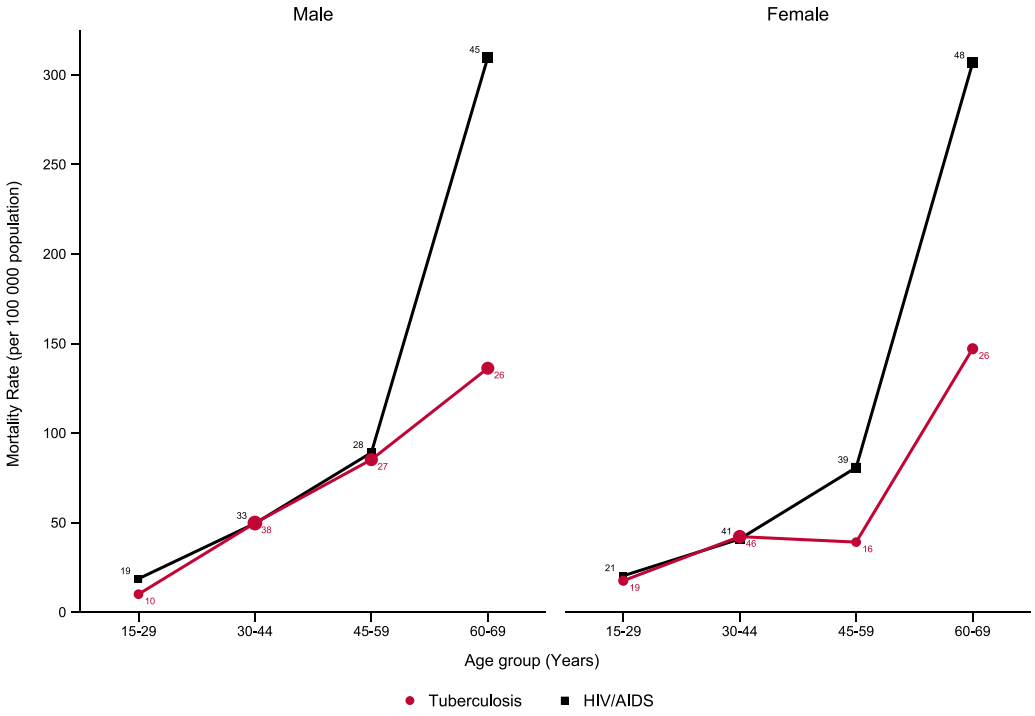

***Fig. 3:* Annual tuberculosis and HIV mortality rates by age group and sex for adults in rural Ethiopia**. Labels on weighted markers represent the number of study deaths.

livebirths) than the Ministry of Health and WHO (401).[3,4] The most recent WHO estimate for 2020 suggests further declines (267 [80% CI 189–427]).[29] Obstetric haemorrhage was the leading cause of maternal death, consistent with previous findings.[30,31] Additional results highlighted the prominence of other direct maternal causes.[32]

SAVE documented fewer stillbirths than expected, yielding a ratio of stillbirth to neonatal death rates of about 1 to 5, which is well below UNICEF/WHO's model-based estimates for the world and for Ethiopia that suggest a ratio of 1 to 1. However, the global ratio estimate is based mostly on high income countries with more complete registration.[33,34] SAVE, as a one-

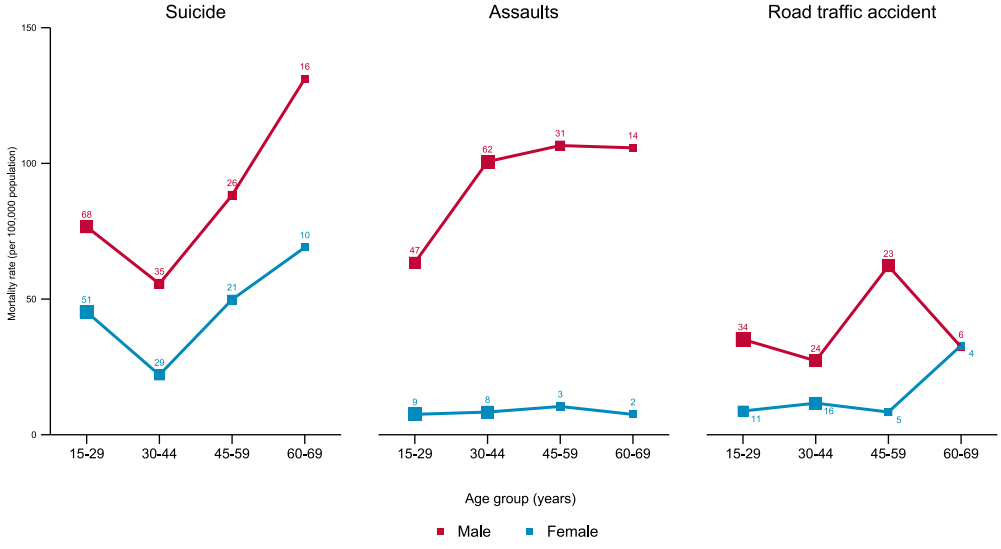

***Fig. 4:* Annual suicide, assault, and road traffic accident mortality rates by age group and sex for adults in rural Ethiopia**. Labels on weighted markers represent the number of study deaths.

time survey, may well have missed stillbirths. Indeed, pregnancy outcomes are not commonly tracked in many low-income countries. However, even the Healthy Sierra Leone study, which had more complete and continuous capture of stillbirths and neonatal deaths, showed a ratio of stillbirth to neonatal death rates to be 1 to 2[12] and similarly low ratios have been documented in India.[34] Additional studies in low and middle-income countries are needed to confirm if the model-based estimates relating stillbirths to neonatal death totals may be over reporting stillbirths.

Absent a comprehensive national system to capture and identify causes of death, model-based evidence derived from a combination of small and often out-of-date studies continues to inform health priorities, policies, and program interventions in Ethiopia (Panel: research in context). Except for estimates from a few subnational health and demographic surveillance systems and a mortality surveillance program using cemetery data,[21] national demographic surveys lack cause of death information. Careful assembly of all focal studies to estimate rural cause-specific mortality fractions for the key causes of death is an obvious follow-up to our study.[35]

The recently created VERA is a step forward but cause of death determination within this system is limited to some health facilities.[3,6] While registration efforts expand, a complementary approach for Ethiopia would be to conduct a post-census mortality survey after the (delayed) 2024 census. This relatively inexpensive option would add e-VA to a random sample of census-recorded deaths.[9] Such a survey could change the census reference period for recorded deaths from January 2020 onwards to also document all-cause excess mortality during the COVID pandemic.[36] More generally, many countries in Africa require direct nationwide mortality studies to decrease reliance on modelling. For example, the Sierra Leone HEAL-SL studies showing lower maternal mortality than earlier WHO model estimates have led to a revision in the WHO 2020 estimate[12] and are showing lower COVID deaths than those based on models.

Our results provide information of direct relevance for health programs in Ethiopia and similar countries, and have several strengths, including use of a robust e-VA instrument, independent dual-physician coding of causes, and high coverage of the target survey area. Nonetheless, we face some limitations. Misclassification occurs in cause of death data,[9] including from verbal autopsy. This may be minimal, as the proportion of ill-defined deaths at all ages studied was small. Second, while East Gojjam Zone is predominantly rural, it has a demographic make-up similar to the national profile and is likely to be representative of rural Ethiopia (Appendix Table 9; Fig. 1). It is, however, likely that the cause of death distribution varies across regions, as already documented in the variation in child mortality rates between urban and rural areas and specific regions.[10,37] Therefore, our application of results from one region to the national rural population should be taken only as approximate. Indeed, our study should spur larger, nationwide mortality surveys. Similarly, our use of the 2007 census to partition current UN mortality estimates into rural areas is crude but was necessary, given that demographic surveys have limited information on adult mortality. This further emphasises the urgency to implement a complete census in Ethiopia. Future surveys should also consider all ages including above age 70 years, given that demographic transitions to older age distributions are occurring already, and to provide a more complete accounting of the non-communicable diseases that account for most of adult mortality in many parts of Africa.[38]

Notwithstanding these limitations, the SAVE study has documented remarkably high avoidable mortality, notably from injury, and forms the basis for future public health and clinical interventions, as well as the basis for expanded efforts to count the dead and describe causes reliably.

Contributors

Conceived and developed the study and design: WM, PJ. Data analysis: PJ, WM, DH, HA, CM, AAi. Field implementation: WM, PJ, DH, BY, HA, WA, SA, AA. Literature review: WM, PJ, DH, BY, HA, WA, SA, CM. CM, WM, and PJ wrote the initial draft, and all authors were involved in revisions. WM and PJ had full access to all relevant data in the study and had final responsibility for the decision to submit for publication. All authors read and approved the final version of this manuscript.

Data sharing statement

The fully anonymised dataset is available upon request through writing to Dr. Mekonnen, and will be posted soon to www.openmortality.org.

Declaration of interests

We declare no competing interests.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.eclinm.2024.102573.

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