Monitoring excess mortality during epidemics in African countries

Stéphane Helleringer
Division of Social Science, NYU-Abu Dhabi

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Abstract

Monitoring excess mortality resulting from epidemics of infectious diseases requires extensive epidemiological surveillance systems and/or continuously-updated data from civil registration systems. However, in many African countries, the coverage of such systems is limited. Estimates of the death toll from epidemics are thus obtained from complex statistical models and projections, informed by (very) partial data. In this paper, I review how global institutions produced estimates of excess mortality associated with the 2013-2016 Ebola outbreak in West Africa. I highlight several limitations of these estimates, and I make recommendations for strengthening the monitoring of excess mortality associated with the COVID-19 pandemic in African countries. In the long term, achieving universal death registration should be a key objective of epidemic preparedness plans in African countries.

Keywords: Excess mortality, COVID-19, Epidemics, Civil registration, Surveys, Censuses, West Africa

1 Introduction

At the end of April 2021, more than 3 million COVID deaths have been recorded worldwide. Among those, $\approx 120,000$ (3.9%) have occurred in Africa, even though the continent comprises 16% of the global population (Maeda & Nkengasong 2021). This comparatively low burden of COVID-19 in Africa has been linked to early action by local governments (Celum et al. 2020), climatic differences with other world regions where SARS-CoV-2 has spread more broadly (Njenga et al. 2020), extensive experience stemming large-scale epidemics (Maeda & Nkengasong 2021), prior exposures to other viruses and vaccines (Curtis et al. 2020), youthful age structures (Dowd et al. 2020, Nepomuceno et al. 2020, Sudharsanan et al. 2020, Diop et al. 2020) and more limited integration into global exchange networks (Gilbert et al. 2020).

There are also concerns that the burden of COVID-19 might be higher than recorded in many African countries (Maeda & Nkengasong 2021). Epidemiological surveillance systems that rely on antigen or PCR testing underestimate the magnitude of the spread of SARS-CoV-2 in many settings. The extent of testing for SARS-CoV-2 is however much lower throughout the African continent than in other world regions. For example, whereas more than 2,000 tests per 1,000 people have been performed in the United Kingdom since the beginning of the pandemic, only 9 tests have been carried out in Nigeria per 1,000 people during the same time-frame (Hasell et al. 2020). In several serosurveys, the prevalence of antibodies to SARS-CoV-2 was much higher than expected based on reported COVID-19 cases (Uyoga et al. 2021, Majiya et al. 2020, Olayanju et al. 2020, Chibwana et al. 2020). In Malawi, among participants in a panel study, fewer than 10% of those who reported developing new respiratory symptoms during the first 6 months of the pandemic were tested for SARS-CoV-2 (Banda et al. 2021). In Lusaka (Zambia), close to 20% of the deaths that transited through the morgue of the main referral hospital were positive for SARS-CoV-2 according to post-mortem PCR tests. Among those, only 8% had been tested for SARS-CoV-2 prior to death (Mwananyanda et al. 2021).

COVID-19 surveillance systems also do not count deaths from non–COVID-19 causes. They thus cannot detect the indirect effects of the pandemic on mortality from non-COVID causes (e.g., Malaria, HIV, non-communicable diseases). Indeed, during the course of the

pandemic, healthcare services might have been disrupted due to high levels of mortality and morbidity among healthcare workers, higher than usual caseloads, or interruption of non-COVID services (Siedner et al. 2020, Ogunkola et al. 2021). Potential patients might also have refrained from attending health facilities for non-COVID conditions due to fear of infection or stigma. Economic activity frequently declined precipitously since the start of the COVID-19 pandemic, thus raising concerns that deaths related to malnutrition and mental health conditions might have increased. On the other hand, deaths from accidents and other external causes might have declined due to reductions in mobility associated with lockdowns, border closures and other strategies to prevent the geographical spread of COVID-19 (Carlitz & Makhura 2021).

In many settings, civil registration and vital statistics (CRVS) systems help remedy these limitations of epidemiological surveillance systems, after short delays. CRVS systems register all deaths, regardless of their cause(s). This allows calculating "excess mortality", i.e., how many more deaths are currently occurring, compared to a recent pre–COVID-19 past (Vandoros 2020, Krieger et al. 2020). This measure is not affected by coverage of testing for SARS-CoV-2. It also includes the (net) indirect effects of COVID-19 on deaths from other non-COVID-19 causes. It is thus well-suited for comparing the impact of the pandemic on mortality over time, and between regions or countries. For example, in south Africa, more than 150,000 excess deaths have been estimated since the start of the pandemic, even though only $\approx 54,000$ COVID deaths have been reported.

Unfortunately, in many other African countries, the coverage of CRVS remains limited in many settings (AbouZahr et al. 2015, Mikkelsen et al. 2015). Few deaths are registered, and among registered deaths, delays and misclassifications of causes of deaths are frequent (Fisker et al. 2019; @ Tobin et al. 2013). As a result, excess mortality associated with the COVID-19 pandemic cannot be measured in near real-time using standard time-series methods, as in high-income countries. Instead, this calculation requires triangulating data from multiple partial sources (e.g., surveys, censuses). In this paper, I review how estimates of excess mortality were obtained following the 2013-2016 Ebola outbreak in West Africa, a major epidemic that has affected Guinea, Liberia and Sierra Leone for more than 2 years. I highlight several limitations of these estimates, and I make recommendations for

the measurement of excess mortality associated with the COVID-19 pandemic in African countries with limited civil registration.

2 Case study: the 2013-2016 Ebola outbreak in West Africa

2.1 Background

The 2013-2016 outbreak of Ebola virus disease (EVD) that occurred predominantly in West Africa, is the largest recorded EVD outbreak in history by orders of magnitude. It originated in the forest region of Guinea, before spreading to neighboring Sierra Leone and Liberia. Cases were also recorded in X other countries, including Senegal, Mali and Nigeria, as well as in several European countries and in the US. The outbreak was declared a Public Health Emergency of International Concern (PHEIC) by the World Health Organization (WHO) on 8 August 2014. It was declared over in June 2016, 42 days after the last patient infected with EVD recovered in Monrovia, Liberia. According to figures reported by the WHO, the outbreak was responsible for 28,616 EVD cases and 11,310 recorded deaths.

2.2 Ebola surveillance systems

Case recording: During the course of the EVD outbreak, surveillance systems were established in each affected country to track the course of the epidemic (McNamara 2016). Suspected cases initially were identified through contact tracing; case-finding; or additional surveillance mechanisms, such as walk-ins to dedicated Ebola treatment units (ETUs), calls to emergency phone lines and visits to hospitals. The definition of "suspected" cases varied during the course of outbreak, and across countries, depending on the number of symptoms required to establish suspicion. Once a possible case was suspected, surveillance staff gathered additional information about the possible case and his or her contacts (e.g., age, gender, symptoms, date of onset). Case data were then compiled at local levels (e.g., prefecture, county, or districts) in a local database or line list and transmitted to ministry of health staff working at the national level. Meanwhile, local staff initiated contact tracing

to observe each contact's health for 21 days after exposure. Ultimately, cases were thus classified as either "suspected", "probable" or "confirmed". In all countries, confirmation of EVD required a positive PCR test or detection of IgM antibodies against EVD.

Under-reporting of cases: Similar to the COVID-19 pandemic, there were strong concerns that the data generated by EVD surveillance systems under-estimated the spread of EVD in the 3 most-affected countries, for several reasons (Scarpino et al. 2015, Meltzer et al. 2014). Some communities were reluctant to engage with health workers, contact tracing or safe burial teams. EVD response teams might not have been adequately trained in data collection and management. They might also been overwhelmed at various points during the outbreak. Situation reports from ministries of health and from the WHO thus repeatedly pointed out the "deterioration in the ability of overwhelmed responders to record accurate epidemiological data" during the early stages of the outbreak, when cases were increasing exponentially in Liberia and Sierra Leone, in particular. As a result, the WHO and the US CDC incorporated adjustment factors into their forecasts of epidemic trajectories. For example, a CDC model considered that there might have been up to 2.5 times cases of EVD than reported by epidemiological surveillance systems (Meltzer et al. 2014).

Missing data: Data from EVD surveillance systems also included significant amounts of missing data. For example, the gender of the case patient was missing in large numbers of records in Sierra Leone (Figure 1). Missing data were especially common on survival outcomes, i.e., whether the case patient recovered or died from EVD (Forna et al. 2020). Such data were missing in 44% of all the records compiled by Ministries of Health and WHO, with the problem being particularly severe in Sierra Leone and Liberia, where 48% and 57% of the cases recorded had a missing survival outcome, respectively. This was due to several factors. On the one hand, some patients might have been turned away from health facilities and ETUs, and were thus frequently lost to follow-up. On the other hand, overwhelmed health workers might have failed to record and/or transmit data on disease outcomes. In addition, some cases might only have been detected after death, for example following post-mortem testing ordered by safe burial teams. In this context, the lethality of EVD might be misrepresented. Estimates of the case-fatality ratio might significantly

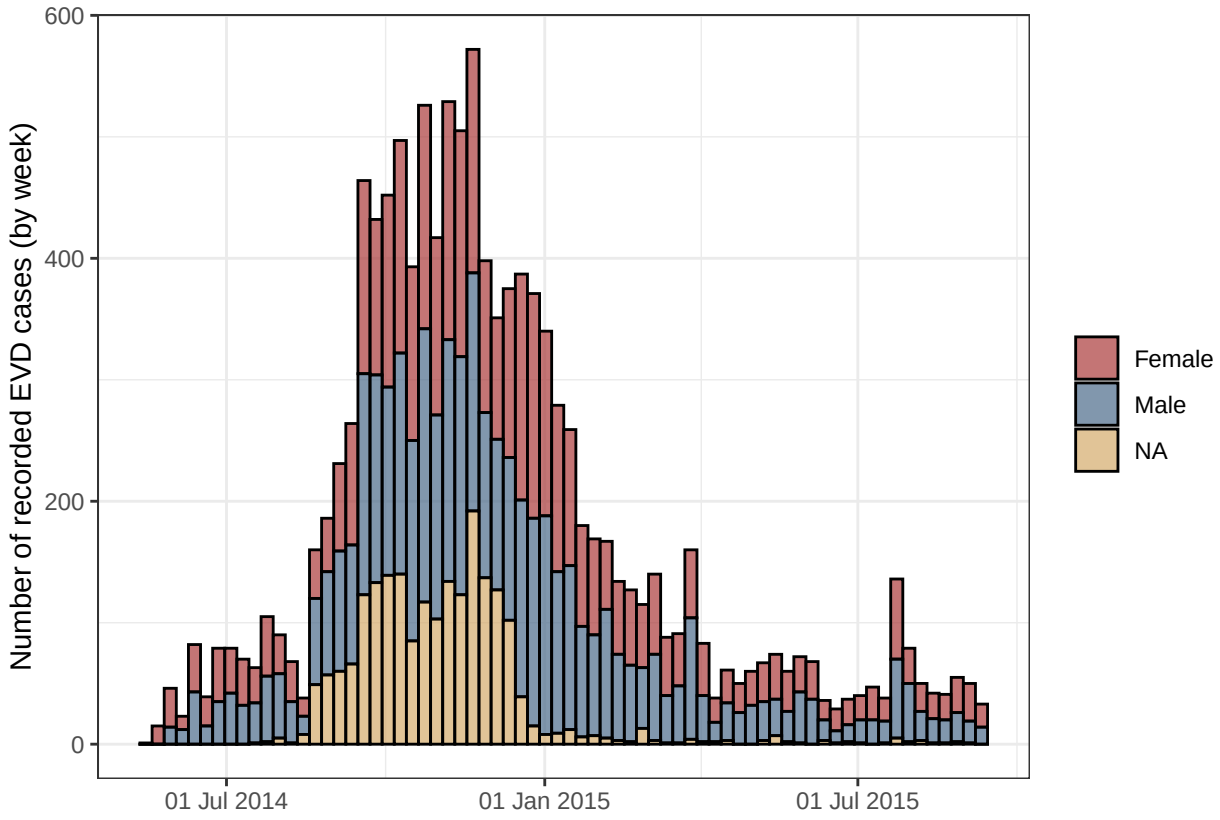

Figure 1: EVD Cases recorded in Sierra Leone, by gender. Data analyzed in this figure were obtained from the Outbreaks package in R

differ from the "naive" estimates obtained by divided reported deaths and cases. For example, whereas Liberia recorded 4,810 EVD deaths and 10,678 cases (45% deceased), CFR estimates among cases with available survival outcomes were much higher (71.7% deceased).

2.3 Potential indirect effects of the EVD outbreak

EVD surveillance systems do not monitor potential indirect effects of the EVD outbreak on mortality, even though such effects might have been large in the 3 most-affected countries. Several studies have thus documented large reductions in the use of non-EVD healthcare services during the course of the outbreak, because resources of the health system were diverted to respond to the ongoing epidemic (Iyengar et al. 2015) . Results from a systematic review suggested that healthcare utilization declined by 18 percentage points on average across the 3 most-affected countries, with larger declines observed during periods and in localities with high EVD incidence (Wilhelm & Helleringer n.d.). Similarly, the number of HIV tests conducted in health facilities declined in several areas, as did the number of patients diagnosed with tuberculosis or newly enrolled in HIV care (Leuenberger et al. 2015). The incidence of vaccine-preventable diseases and Malaria might have risen significantly during the course of the EVD outbreak due to reduced vaccination rates and more limited access to anti-malarial treatments (Walker et al. 2015, Parpia et al. 2016, Takahashi et al. 2015). Several models and projections thus indicated that the indirect effects of EVD might be at least as large its direct effects in the most-affected settings (Ngo et al. 2021).

2.4 Data sources on excess mortality

Death registration: In high-income countries, and in some middle-income countries, CRVS systems have universal coverage. The data they generate allow measuring how the direct and indirect effects of an epidemic combine to cause varying levels of excess mortality. Unfortunately, CRVS systems have limited coverage in each of the 3 countries most affected by the 2013-2016 West African EVD outbreak. The Ministry of Health of Liberia thus reported that <5% of all deaths were registered in the country. Statistical agencies in these 3 countries seldom process death registration records. They do not report annual

series of vital statistics (i.e., estimates of births and deaths) based on such data. This is due to a broad array of factors, related to the legislation related to civil registration, the adminsitrative systems overseeing the registration process, and the demand for registration and certification emanating from families. In Guinea, the process of death registration is thus organized by the Civil Code adopted in 1998. It stipulates that deaths must be registered within 3 days of occurrence of the event, and it establishes a fee for registration that is fixed by local municipalities. In Liberia, death registration is regulated by the 1976 Public Health Law, and the ministry of Health is in charge of overseeing the death registration process. Deaths must be registered within 24 hours of the event. Registration also requires the payment of a fee, and there are penalties associated with late registration but those are seldom enforced. Sierra Leone has adopted a new National Civil Registration Act in 2016. Prior to this, the process of death registration was organized by the Births and Deaths act of 1983. Registration of deaths is required by law, within 14 days of the event. Penalties are then assessed if the event is not registered within that timeframe. The CRVS systems of these 3 countries largely relied on paper-based forms and processes at the time of the EVD outbreak. They were thus subject to delays in transmission, stock-outs of forms, and loss of documents. Since then, various digitization pilots have been launched in each country. in neighboring countries (e.g., Guine-Bissau), limited knowledge about death registration or about the benefits it entails was a main barrier to registration among mothers of recently deceased infants.

Surveys and Censuses: Instead of relying on data from CRVS systems, the 3 countries most affected by the 2013-2016 EVD outbreak primarily use survey and census data to monitor trends in mortality. Censuses are ideally conducted every 10 years. They collect data on mortality in two ways: 1) by recording the number of children ever born and children surviving to each woman of reproductive age, and 2) by listing the deaths of the last 12 months in each household. Surveys are conducted every 3-5 years, as part of large cross-national programs such as the Multiple Indicators Cluster Survey (MICS) supported by UNICEF, or the Demographic and Health Surveys (DHS), funded primarily by USAID. Such surveys collect mortality data retrospectively, by asking respondents to list (some of) their relatives, and to report their vital status, age and/or age at death and time since the

death. Several instruments included in the MICS or DHS thus allow measuring mortality in various age groups: birth histories, for example, allow measuring under-5 mortality, and possibly mortality up to age 14; whereas siblings' survival histories allow measuring mortality at ages 15-59 years old ("adult mortality"). Given the typical size of DHS and MICS samples (i.e., 5,000 to 20,000 households), the retrospective questionnaires included in these surveys only allow estimating mortality for long reference periods stretching 3-5 years (birth histories) or 6-8 years (siblings' survival histories) before the survey. In a few surveys, DHS and MICS have also occasionally included questionnaires about the deaths that have occurred in respondents' households in the 12 months prior to the survey, similar to the questionnaires used in censuses.

Data on mortality generated by surveys and censuses primarily allow estimating all-cause mortality. They also frequently include questions about the circumstances of reported deaths, for example whether a death occurred while the woman was pregnant and whether the death was due to an accident or to violence. Such data allow estimating mortality rates by broad group causes at adult ages. Additional questions to assess, for example, HIV-related mortality have been tested in small trials but have not yet been incorporated into the MICS or DHS questionnaires. In some cases, surveys and censuses also include a verbal autopsy (VA) component, i.e., a follow-up questionnaire during which interviewers seek to determine the symptoms and exposures that might have preceded each reported death. Coupled with statistical algorithms, VA data allow classifying the cause of a death reported during the survey or census, using the international classification of diseases (ICD).

In Guinea and Sierra Leone, censuses were conducted during the course of the EVD outbreak, in July 2014 and December 2015, respectively. In Liberia, on the other hand, the most recent census dates back to 2008. All these censuses have collected a summary of the birth history of women of reproductive age, as well as a list of recent household deaths. Guinea, Liberia and Sierra Leone have all been participating in the MICS and DHS programs since the 1980's or 1990's (figure 2). Each country has thus conducted a mortality-related survey within 2 years of the start of the EVD outbreak, but no DHS or MICS were conducted during the course of the outbreak. Instead, surveys resumed shortly after the end of the outbreak in 2016. In Guinea, a MICS survey was launched in July 2016,

whereas in Liberia and Sierra Leone, Malaria Indicator Surveys (MIS, a shorter version of the DHS) were initiated at approximately the same time. The surveys conducted in these three countries since the 1990's have overwhelmingly focused on under-5 mortality, with all surveys including either a summary or a complete birth history. By contrast, the surveys conducted in Guinea, Liberia and Sierra Leone have not systematically collected data on adult mortality. Eight out of 15 pre-outbreak surveys and 4 out of 7 post-outbreak surveys have thus collected SSH data. In particular, the MIS program has never collected SSH data in any of these 3 countries, whereas MICS only collected SSH data during their post-EVD outbreak round, in 2016 and 2017. In all countries, the sample size of mortality-related surveys has increased since the 1990s. Exceptions include primarily the MIS surveys, whose objectives focus on measuring the coverage of preventive interventions against Malaria and/or the prevalence of Malaria in children under age 5.

2.5 How were estimates of excess mortality obtained?

In this context of limited data availability, few estimates of the extent of excess mortality generated by the EVD outbreak are available. Several studies have attempted to measure excess mortality at the local level, e.g., in the Western Area of Sierra Leone or in Monrovia, the capital of Liberia. These studies were however based on small samples, which generated data on <100 deaths at all ages. They also compared mortality rates to an "emergency threshold", rather than against a pre-outbreak baseline. As a result, they do not provide an assessment of excess mortality, even for small areas. Instead, estimates of excess mortality currently available at the country level have been computed by international groups engaged in the global assessment of health metrics (e.g., IHME, UN IGME). In the rest of this paragraph, I focus on the methods used by IHME researchers to produce estimates of excess mortality associated with the EVD outbreak. To do so, I use documentation available for the 2016 and 2019 revisions of the Global Burden of Disease (GBD) Study (Vos et al. 2020, Wang et al. 2017).

The GBD aims to provide estimates of mortality rates by gender, age, cause, year and risk factors for every country in the world. To do so, it combines available data sources on mortality (e.g., vital registration, surveys, censuses) with a multi-stage estimation process.

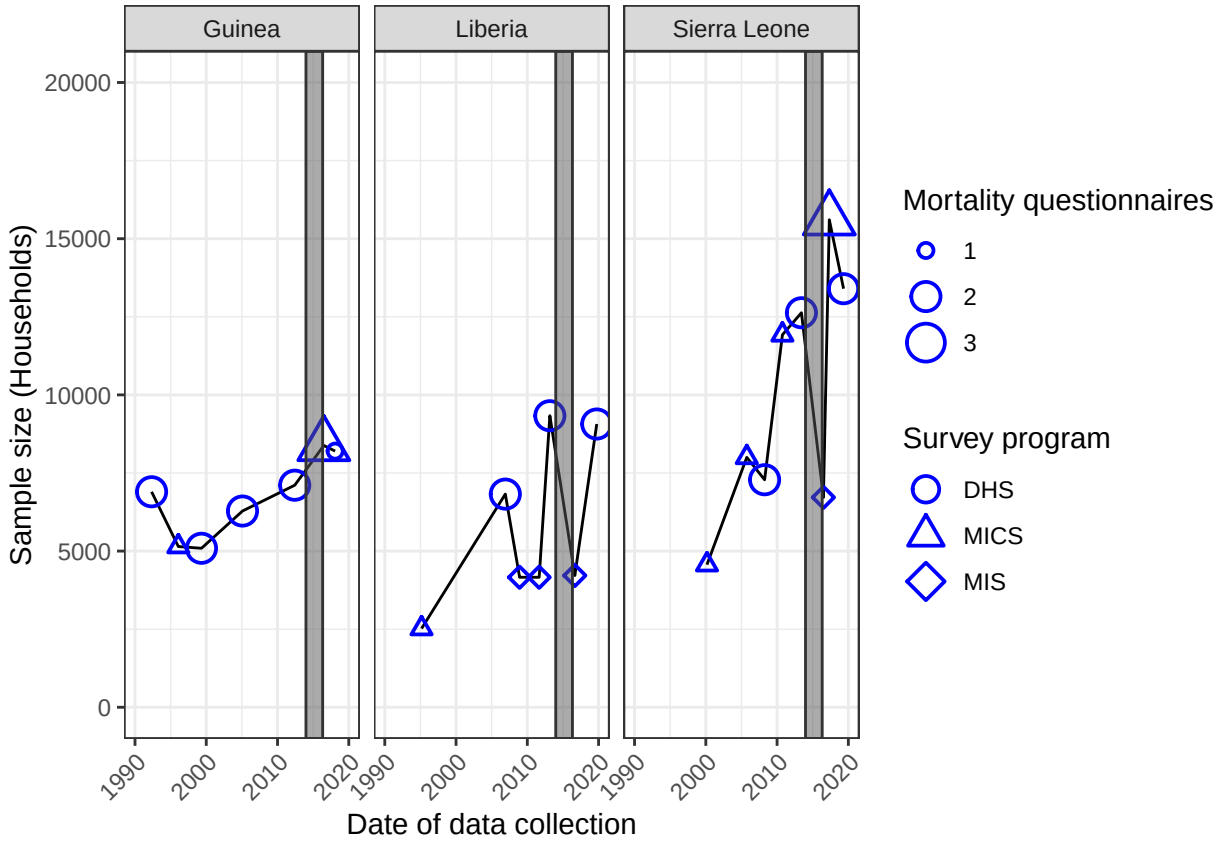

Figure 2: **Mortality-related surveys conducted in EVD-affected countries, 2005-2020.**, MIS = Malaria Impact Survey; DHS = Demographic and Health Survey; MICS = Multiple Indicator Cluster Survey

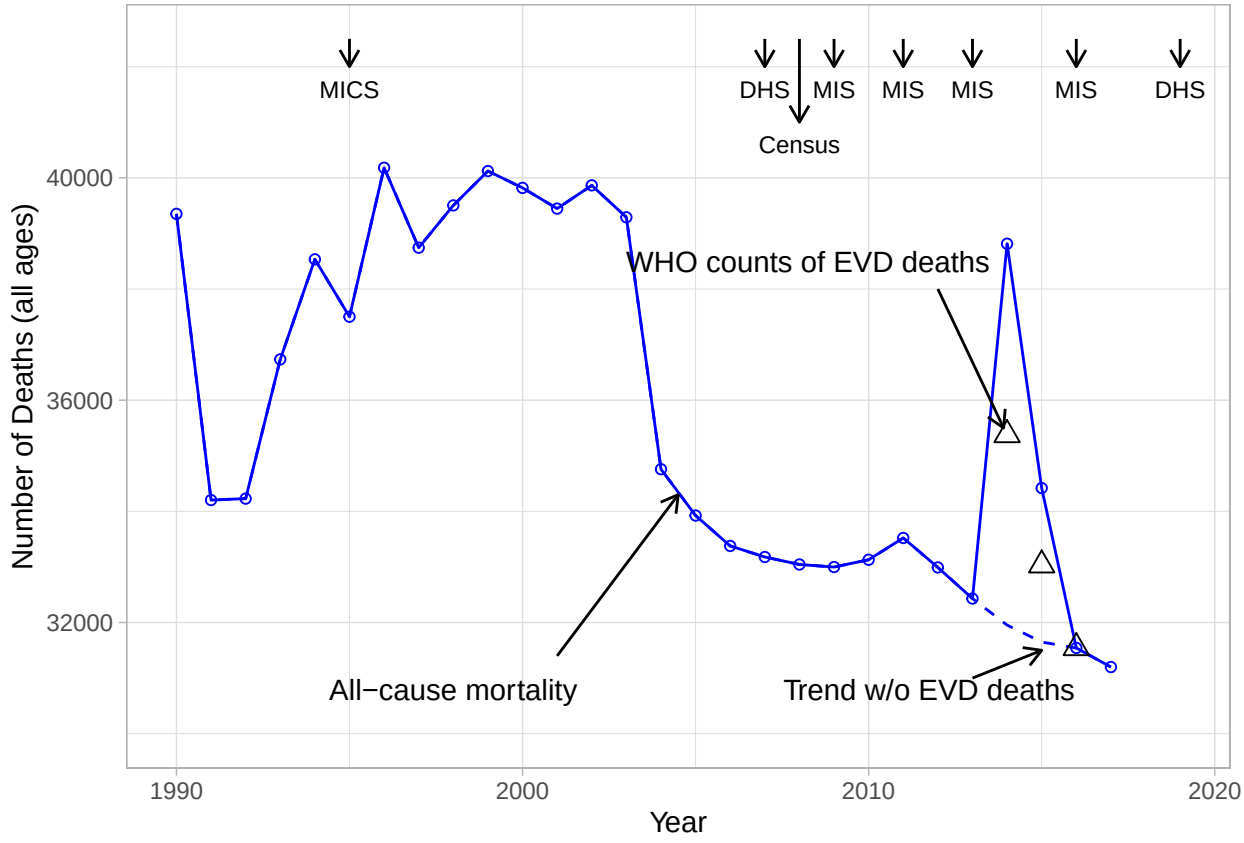

Figure 3: GBD estimates of excess mortality associated with EVD in Liberia, 1990-2017

Specifically, the GBD process for the estimation of mortality rates entails estimating under-5 (${}_5q_0$) and adult (${}_{45}q_{15}$) mortality separately, before using these estimates as inputs in a model life table systems that generates a complete set of age-specific mortality rates (i.e., from 0 to 110+ years). The GBD mortality estimation process also includes adjustments for HIV prevalence, as well as multiple smoothing procedures. This system allows predicting mortality rates in country-years for which no data sources are available.

The recent revisions of the GBD consider the EVD outbreak in West Africa in 2013-2016 as one of several potential "fatal discontinuities" (REF GBD). These are "events that are stochastic in nature, and that cannot be modeled because they do not have a predictable time trend". Fatal discontinuities include primarily natural disasters and conflicts, as well as a few infectious diseases that are prone to epidemics (e.g., meningitis, Cholera). In countries with limited data on causes of deaths (e.g., EVD-affected countries), data that pertain to country-years in which fatal discontinuities occurred are initially excluded

from the GBD mortality estimation process. This is deemed necessary because such crises might confound estimates of the long-term trends in mortality rates ("mortality envelope"). Instead, the number of deaths that occur in a year with a fatal discontinuity is estimated in two steps. First, deaths from other causes are predicted from life tables describing the underlying mortality risks in a given country-year; second, deaths due to the fatal discontinuity are added back to the mortality envelope.

In the case of the EVD outbreak in West Africa, deaths due to the fatal discontinuity are estimated from WHO records of cases and deaths. These counts are then adjusted for the potential under-reporting of cases in EVD surveillance systems. To obtain adjustment factors, the GBD teams reviewed and summarized all empirical studies and mathematical models that estimated the extent of under-reporting in linelists compiled by the local ministries of Health and the WHO. The studies included in this meta-analysis included, for example, capture-recapture studies comparing multiple lists of EVD cases, genomic studies of EVD clusters, as well as input parameters in epidemic models of EVD spread. Adjustment factors ranged from ≈ 1.5 to ≈ 2.5, with a mean of 2. Following these adjustments, GBD estimates of excess deaths were 6,861 deaths in 2014, and 2,770 deaths in 2015. GBD estimates thus suggest that, in 2014, the EVD outbreak precipitated levels of mortality that were last seen during the civil war (i.e., prior to 2003) in Liberia (see figure 3). Corresponding figures for Guinea and Sierra Leone are shown in the appendix.

2.6 Limitations of excess mortality estimates

Estimates of the excess mortality caused by the EVD outbreak that occurred in West Africa in 2013-2016 were thus obtained using limited data and complex, multi-stage statistical models and projections. They suffer from two major limitations.

Lack of indirect effects: Existing estimates are derived from models that do not allow for the possibility of indirect effects of the EVD outbreak on mortality from non-EVD causes (e.g., HIV, non-communicable diseases). This is so because, in countries with limited CRVS data on causes of deaths, GBD estimates simply add deaths resulting from a fatal discontinuity (e.g., an EVD outbreak) to deaths resulting from underlying mortality risks.

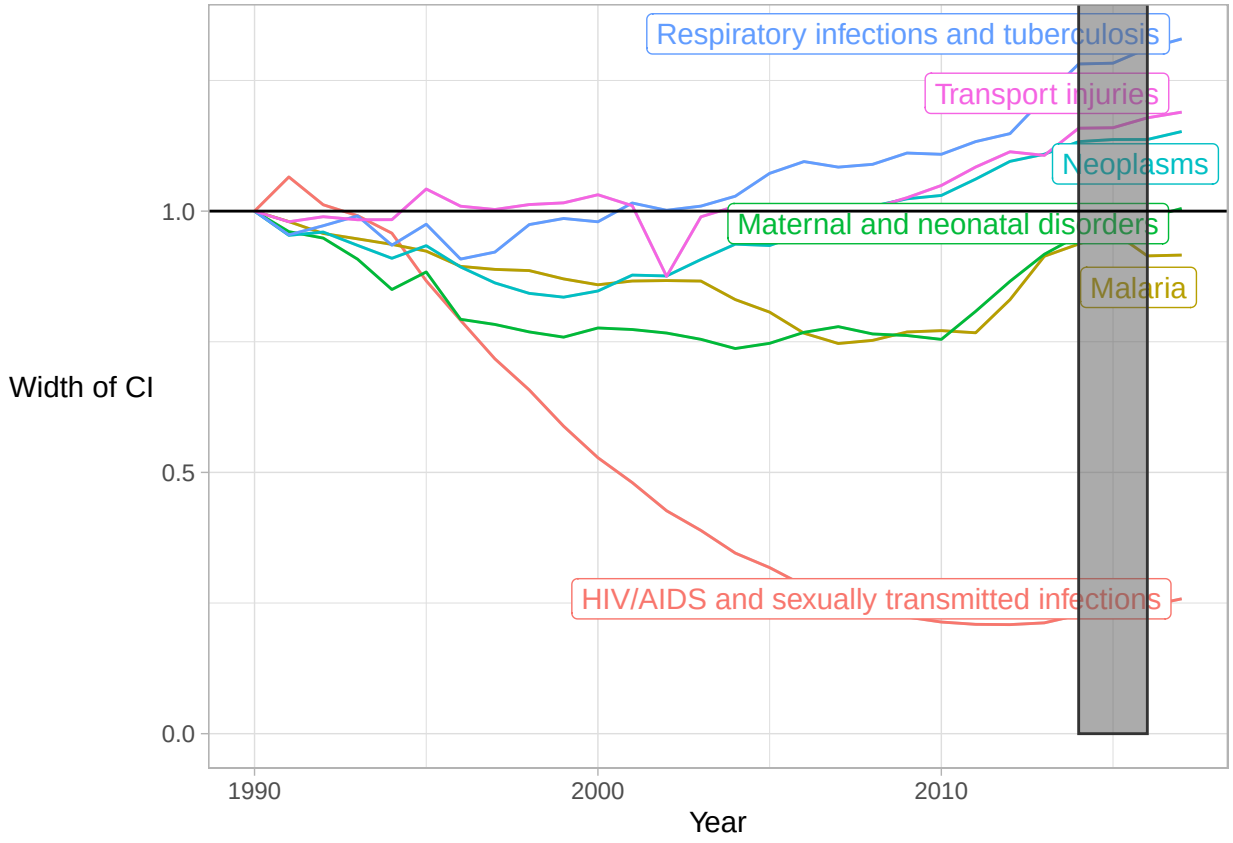

Figure 4: Trends in uncertainty of GBD estimates, Liberia (1990-2017)

As a result, all the excess deaths shown in figure 3 are deaths due to EVD. There are no excess deaths that are linked to concomitant changes in the risk of dying from non-EVD causes. Furthermore, the level of uncertainty about mortality from non-EVD causes is not heightened during the EVD outbreak in GBD estimates (figure 4), even several models have projected that deaths from these causes might have spiked during the course of the EVD outbreak. This lack of attention to potential indirect effects is highly problematic since there are several causal pathways through which the EVD outbreak might have affected non-EVD mortality, including through reduced health care utilization or increased economic hardship.

Constant adjustment factors: In measuring the completeness of EVD surveillance systems (section 2.5), GBD estimates focused on a set of studies that were conducted in the early phases of the outbreak (e.g., June to August 2014). These coincided with periods of

exponential growth in the number of EVD cases in several settings (e.g., Monrovia), during which health care workers might have been overwhelmed by rapidly rising case loads. At that time, some potential EVD cases might have been turned away at ETUs and other health care facilities, whereas contact tracing teams and emergency services might not have been able to respond to all calls received during those early months. In addition, surveillance systems were still being established during those early months, possibly resulting in delays or gaps in recording and transmission of EVD records. Consequently, surveillance systems might have become more complete, following digitization and other improvement processes. The proportion of EVD cases that were not included in surveillance data might thus have declined over time, during the course of the outbreak. In that context, using time-invariant adjustment factors for under-reporting might over-estimate the number of deaths due to EVD that occurred during the outbreak.

3 Recommendations for measuring excess mortality due to the COVID-19 pandemic

The 2013-2016 EVD outbreak unfolded primarily in countries with limited death registration. As a result, estimates of excess mortality were only obtained after the completion of the outbreak. They also suffered from key limitations: they did not allow for the possibility of indirect effects of the outbreak on non-EVD causes, and they did not consider the possibility that the completeness of EVD surveillance systems might have improved over the course of the outbreak. SARS-CoV-2 presents epidemiological features that differ significantly from Ebola virus in several ways, e.g., its modes of transmission or the possibility of asymptomatic transmission. It has also already spread much more widely throughout the African continent than any EVD outreak in history. However, because most African countries also have limited CRVS coverage, there are lessons from the EVD outbreak that can be drawn to improve excess mortality measurement during the COVID-19 pandemic.

Adopt new models that allow for indirect effects: The COVID-19 pandemic, similar to the EVD outbreak in West Africa, has prompted significant declines in health care

utilization. Several models and projections have thus suggested that non-COVID deaths might exceed the number of COVID deaths occurring in African countries. Such indirect deaths might occur at all ages, including age groups less affected by COVID-19. It is thus essential to ensure that excess mortality measurement methods allow for variations in the underlying risks of non-COVID deaths during the course of the pandemic. Using the "fatal discontinuity" approach adopted by the GBD study, analysts thus might consider that several causes of deaths (e.g., COVID and non-COVID) undergo such discontinuities in a given country-year. This might require determining which non-COVID causes might be affected by indirect effects, e.g., using health system data on health care utilization. The GBD includes the possibility of such a framework, since some causes of deaths (e.g., Malaria) are modeled as part of the mortality envelope, but might also exhibit rapid increases during epidemic peaks. This approach was however not used to model excess mortality due to the EVD outbreak in West Africa.

CMeasure the causes and circumstances of deaths: The limitations associated with the "fatal discontinuity" approach to measuring excess mortality stem from the lack of data on causes of deaths in country with limited CRVS. Indeed, in countries with complete death records, the fatal discontinuities can simply be subtracted out of the CRVS data to assess how other causes of deaths might have varied during the course of a discontinuity (e.g., an epidemic). In countries with limited CRVS, on the other hand, such data are not routinely available. They are only generated every few years when surveys (or censuses) are conducted. Unfortunately, most surveys and censuses are limited to assessing all-cause mortality, as well as a small number of circumstances (e.g., pregnancy-related deaths, accidential deaths). To remedy this issue, mortality-related surveys should seek to investigate additional causes or circumstances of reported deaths. This might include adding short series of questions to SSH or CBH questionnaires, to ascertain whether symptoms associated with COVID-19 were present prior to death (e.g., anosmia, cough) or to determine whether deaths might have been prompted by other diseases such as HIV. Collecting more detailed mortality data might also entail planning follow-up visits to conduct verbal autopsies, i.e., longer instruments aimed at classifying the cause(s) of reported deaths using ICD codes.

Conduct larger and/or more frequent mortality-related surveys: Improving the measurement of excess mortality associated with epidemics in countries with limited CRVS will also require increasing the sample size of mortality-related surveys. Indeed, at the present, such surveys have sample sizes large enough to produce estimates of ${}_5q_0$ or ${}_45q_15$ that cover a reference period of 3-5 years or 6-8 years prior to the survey, respectively. On the other hand, in measuring excess mortality, analysts seek to detect whether mortality departed from an expected trend over an often shorter period of time. This narrower focus requires sample sizes that are larger than current practice in MICS or DHS by orders of magnitude. However, several surveys conducted after the EVD outbreak in Liberia, Sierra Leone or Guinea, for example, did not have sample sizes that were much larger than those adopted in pre-outbreak surveys (figure 2). Surveys of the MIS program, in particular, did not exhibit any increase in sample size after the outbreak. Sample size requirements are further increased due to the need to measure the causes and circumstances of deaths, as described above (section 3).

One potential approach to increasing the sample sizes available for mortality measurement might entail conducting more frequent surveys via mobile phones. Owing to the penetration of mobile phones in all regions of the world, mobile phone surveys have become highly popularin African countries. They can be conducted without in-person contact with respondents, which makes them particularly suitable for settings affected by epidemics or humanitarian crises. Few mobile phone surveys, however, have measured mortality in LLMICs. Exceptions include, for example, a small survey of all-cause mortality during the EVD outbreak in Monrovia.

Implement frequent record linkages between data sources: During the EVD outbreak, verifications of the completeness of surveillance data were primarily conducted at times when the health system was overwhelmed and several features of surveillance systems were not yet in place. Subsequently, the completeness of surveillance data might have improved. To improve estimates of excess mortality, record linkages between independent data sources on COVID deaths should be repeated frequently during the course of the pandemic. This would help guide quality improvement strategies, but also develop time-varying adjustment factors. Record linkages could be conducted with post-mortem testing

studies, population surveys or partial death records, for example. This is particularly important since initial estimates of the completeness of COVID-19 surveillance systems in African settings appear much lower than those obtained during the EVD outbreak in West Africa.

4 Conclusion

In this paper, I have reviewed how global institutions have produced estimates of excess mortality associated with the 2013-2016 Ebola outbreak in West Africa. I have highlighted several limitations of these estimates, and I have made recommendations for strengthening the monitoring of excess mortality associated with the COVID-19 pandemic in African countries. In the long term, achieving universal death registration should be a key objective of epidemic preparedness plans in African countries.

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