Estimation of crisis-attributable mortality in Yemen: Evidence from several studies

Summative briefing note

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Core study team: Francesco Checchi[1] (principal investigator), Mervat Alhaffar[1], Emilie S. Koum Besson[1], Catherine R. McGowan[1]

Contributors:

Aden and Yemen-wide satellite imagery analysis of burials: Andy Norris[2], Terri Freemantle[2], Yolanda Vazquez[2], Chris Reeve[2], Abdulla S. Bin Ghouth[3], Patrick J. Curran[4], Ola Ali[1], Odai Al-Masni[5], Naji Saeed[5], Timothy Lingard[6], Colin Scott[6]

Key informant and capture-recapture study: Huda BaSaleem[7], Fouad Othman[8], Khaled Alsakkaf[7], Sena Mohammed Mohsen Naji[9], Hussein Kolaise[10], Abdullah K. Babattah[11], Yaseen Abdulmalik Mahyoub Salem[9], Hannah Brindle[1], Najwa Yahya[12], Pasquale Pepe[13]

Web survey of the Yemeni diaspora: Promise Ekoriko[1], Sawsan Al-Refai[13], Jamal Badr[14], Lucy Bell[1]

[1] Department of Infectious Disease Epidemiology, Faculty of Epidemiology and Population Health, London School of Hygiene and Tropical Medicine, London, UK

[2] Satellite Applications Catapult, Electron Building, Didcot, United Kingdom

[3] Department of Community Medicine, Hadhramout University, Hadhramout, Yemen

[4] Department of Psychology, University of North Carolina, Chapel Hill, NC, United States of America

[5] Independent consultant

[6] 1715 Labs, London, UK

[7] Department of Community Medicine and Public Health, Faculty of Medicine and Health Science, University of Aden, Aden, Yemen

[8] Faculty of Medicine and Health Science, Ta'iz University, Ta'iz, Yemen

[9] Epidemiology Surveillance Office,Ta'iz Governorate Health Office, Ta'iz, Yemen

[10] Department of Internal Medicine, Faculty of Medicine and Health Science, University of Aden, Aden, Yemen

[11] Primary Health Care Program, Health Sector, HUMAN ACCESS for Partnership and Development, Aden, Yemen

[12] Yemen Public Health Network, Aden, Yemen

[13] Independent expert

[14] Het Grote Midden Oosten Platform [The Greater Middle East Platform], The Hague, Netherlands

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Background to the project

Yemen has been affected by **armed conflict** since late 2014. The conflict has resulted in > 100,000 reported deaths due to war-attributable injuries, the internal **displacement** of millions of Yemenis, epidemics and serious disruptions to public services and infrastructure. **Food insecurity** has also been a prominent feature of the crisis, exacerbated by the **COVID-19** pandemic and global price rises.

Despite the above observations, quantitative evidence on the full **health impacts of the crisis** in Yemen is surprisingly scarce given the widespread perception of its severity, and the large investment by multiple actors in the resulting humanitarian response. This briefing note summarises a set of studies conducted under a **project to estimate mortality** before and during the crisis in Yemen. The premise of the project is that the death rate and resulting death toll are arguably the most fundamental and downstream indicators of a population's health status, and a key metric of the unmet need of a humanitarian response.

Who carried out the project, and how was this funded?

The United Kingdom government's Foreign, Commonwealth and Development Office funded the project as part of its humanitarian assistance activities. However, the UK government had no role in designing, implementing or analysing the study. The researchers acted independently.

The project was coordinated by the **London School of Hygiene and Tropical Medicine** (LSHTM), a public university in the United Kingdom that carries out research and teaches students around the world on diseases and the health of populations. For different studies falling under the project, the LSHTM partnered with other academic groups, including the **University of Aden** and the **University of Ta'iz** in Yemen, geospatial analysis companies including **Satellite Applications Catapult** and **1715 Labs**, and several other specialists. All studies received ethics approval (available on request).

What did the project consist of?

Between 2020 and 2023, we implemented **several studies, utilising different methods** but all attempting to go back in time to examine **mortality trends over the crisis period and, if possible, even prior**.

In addition to mortality estimation, we also combined existing datasets on population, displacement and other variables to reconstruct the **evolution of Yemen's population**, including the number of internally displaced persons (IDPs).

With the exception of a study that collected data from key informants, we relied on **existing or remotely collectable primary data**: this was to circumvent the lack of access or authorisations to do large-scale ground data collection.

Our original intent was to produce country-wide estimates based on a random sample of the population in Yemen. However, **bureaucratic and security challenges**, as well as problems with the availability of data (e.g. sufficient-quality satellite imagery) from different parts of the country, ultimately meant that the different studies have only partial overlap in terms of their analysis period and the locations in Yemen for which data were collected (see **Table 1**).

Furthermore, two of the mortality studies resulted in a considerably **smaller sample than planned**: (i) a country-wide study to analyse burial trends over time based on satellite imagery yielded data from only 35 cemeteries in 10 subdistricts (17% of all sites classed as likely to be cemeteries across the 24 sampled subdistricts); (ii) a survey of the Yemeni diaspora, designed to support respondent-driven chain referral of ever-larger waves of participants, had limited penetration, achieving 15% of the target sample size.

Lastly, the key informant and diaspora survey studies yielded **insufficient data on children** to allow us to estimate child mortality specifically.

On balance, this means that **each study paints a partial picture** in terms of the populations covered by data collection: across the project, these tended to be **disproportionately urban and higher-income**.

Table 1. Overview of studies conducted.

Study title (link to paper if published)	Locations covered (population as of September 2021)	Period covered: Pre-conflict 2008	2009	2010	2011	2012	2013	Armed conflict 2014	2015	2016	2017	2018	2019	C-19 2020	2021	2022
Excess mortality during the COVID-19 pandemic: a geospatial and statistical analysis in Aden governorate, Yemen (Koum Besson et al.)	All cemeteries in Aden governorate (940,000)															
Reconstructing subdistrict-level population denominators in Yemen after six years of armed conflict and forced displacement (Checchi et al.)	All of Yemen, by subdistrict and month (31.1M)															
Adult mortality before and during the first wave of COVID-19 pandemic in nine communities of Yemen: a key informant study (Alhaffar et al.)	9 urban and rural sites in Aden and Ta'iz governorates (≈ 130,000)															
Adult mortality patterns in Yemen before and during armed conflict and the COVID-19 pandemic: Evidence from a web survey of the global diaspora (McGowan et al., McGowan et al.)	84 respondents from multiple countries with family in 9/22 governorates															
Population mortality before and during armed conflict in Yemen: geospatial and statistical analysis of cemetery data (to be published)	35 cemeteries in 10 subdistricts out of 24 randomly sampled (2M)															

What were the findings?

Mortality over time

Our studies looked at **different indicators of mortality**: (i) burials in cemeteries (we believe nearly all Yemenis are buried in recognised cemeteries); (ii) survival among adults aged ≥ 50 years; and (iii) the death rate (i.e. how many people die, out of a given unit of population and per unit of time) among persons aged ≥ 15 years.

Figure 1 summarises the best estimates we came up with of **the extent to which mortality increased** during the conflict period (Jun 2014 to Feb 2020), the conflict + pandemic period (Mar 2020 onwards) or both periods combined, relative to before the conflict. The estimates are very **divergent**, as may be expected given that the samples were not representative of Yemen as a whole. In particular, sites for the informant study were **selected purposively** to reflect a range from low to high exposure to active conflict: the very high estimates from this study likely reflect some of these more extreme conditions.

Despite differences, a **pattern of considerably elevated mortality**, compared to the 'baseline', appears to emerge from this evidence.

Figure 1. Best estimates of the relative increase in mortality, based on different studies we conducted (for example, 2.0 = mortality twice the expected non-crisis level). M1, M2 = alternative statistical models. A1-A4, T1-5 = sites in Aden and Ta'iz governorates.

What about COVID-19?

Our studies mainly covered the **first wave of COVID-19**. Satellite imagery analysis in Aden corroborated available data from civil registration in indicating a **spike in burials** during May-August 2020; this same increase was picked up by our key informant study (**Figure 2**). In Aden, we estimated that ≈ 2100 excess deaths had occurred up to mid-September 2020, consistent with increases seen in European cities.

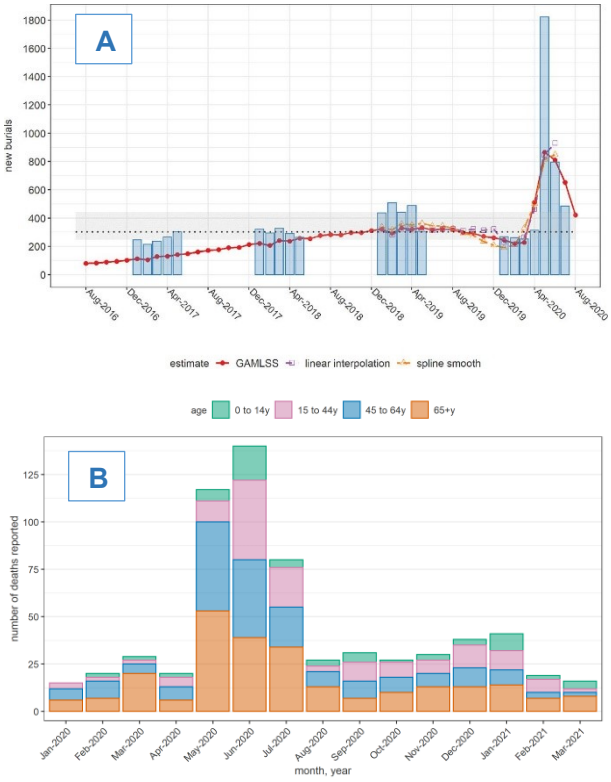

Figure 2. Number of cemetery burials in Aden (panel A) and deaths reported by key informants in 9 sites of Aden and Ta'iz governorates (panel B), by year and month. Note the different time scales.

Elderly mortality, as estimated through the **diaspora survey**, was also higher during the pandemic period than the preceding conflict period, though the difference was not statistically significant. By contrast, in sites included in the **key informant study** there was no obvious pattern of increasing death rate during the pandemic: it is possible that in some of these highly crisis-affected sites, intense armed conflict and resulting public health risk factors in the pre-pandemic period may have obscured any added effect of COVID-19.

Other notable findings

- While we only collected limited data on **causes of death**, in at least two sites in Aden and Ta'iz governorates the younger age of adult decedents, combined with the high percentage reported to have died of war injuries, suggests very elevated mortality directly due to the conflict, at least in selected sites.
- Our **population reconstruction** analysis suggested that during the early phase of the conflict, up to 6M Yemenis may have been displaced at any time, far more than UN figures. At a minimum, our analysis shows that a different approach to analysing the data yields very different IDP estimates both locally and country-wide.
- While the **intensity of armed conflict** was linearly associated with increasing burial rate, we saw the opposite trend for increasing price of staple cereal: this may however reflect the mostly urban make-up of our limited sample of cemeteries.

What are the implications?

Yemen humanitarian response

At the outset of the project, despite extensive circumstantial evidence there remained **uncertainty among response actors about the true severity of Yemen's crisis**, both in absolute terms and if compared to other high-priority humanitarian responses.

Our project partly fills this evidence gap through a set of studies that, while individually limited, appear to **consistently point to a substantially increased risk of dying** during the crisis, and more so during the first phase of the COVID-19 pandemic. Set against the pre-crisis / non-crisis baseline, the ***relative*** **increases** we saw are broadly comparable to those observed in large crisis-affected populations over the past two decades, including in Iraq post-2003, the Democratic Republic of Congo after the outbreak of large-scale insecurity in 1999 and South Sudan after 2013.

As illustrated in **Figure 3**, over 8.5 years of crisis and across a population of about 30M, even a moderate relative increase from the UN-projected pre-crisis death rate would have resulted in a large **death toll**. For example, a 25% increase in mortality would have resulted in some 400,000 excess deaths, while a doubling (100% increase) would translate to 1.5M excess deaths.

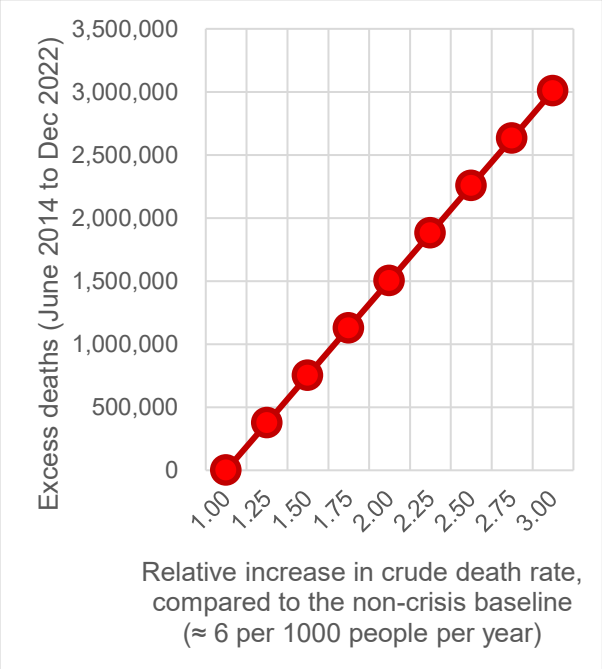

Figure 3. Number of excess deaths from the start of armed conflict to the end of 2022 across Yemen, assuming varying relative increases in death rate compared to the non-crisis level (1.00 = no increase; 3.00 = three times higher).

It's noteworthy that our final study samples were all **biased towards urban settings**; generally, we underrepresented areas controlled by the Sana'a government, and the diaspora survey reached a relatively high-income sample. If we assume that rural, lower-income populations in Yemen were relatively more impacted by food insecurity and service disruptions, it is plausible that **our studies may under-estimate** overall mortality in Yemen.

We cannot speculate whether the estimates we generated also apply to a **more recent period**, or will extend into the future: this depends on the evolution of armed conflict and other public health risk factors, as well as on how impactful the humanitarian response will be.

Methodological insights

The project broke **new ground with respect to several methods** for estimating mortality and population changes in populations affected by crises, by developing and documenting:

- Geospatial and statistical methods to analyse sequential satellite images of cemeteries;
- A generic statistical approach for analysing decedent lists collected from key informants;
- An approach for cleaning and combining demographic estimates and internal displacement tracking data to reconstruct population denominators at small resolution;
- A web, respondent-driven survey of a country's diaspora to measure health status within the country itself, supported by a bespoke survey platform.

All of the above are, to our knowledge, 'first-ever' studies; our work is curated in the form of openly available datasets and analysis scripts.

In addition to these methodological advances, we learned more about the **advantages, challenges and limitations of each method**, and how to best leverage these in the design of future studies. We have since applied these methods in Sudan (key informant studies), Somalia (satellite imagery) and Tigray, Ethiopia (diaspora survey).

The unexpectedly long duration of the project (a year and a half longer than planned) illustrates the **difficulty in setting up studies** in a complex setting from a standing start, and suggests a need for availing adequate and stable resources for global and local expertise to conduct data collection and analysis in real-time across different humanitarian responses.

Questions and feedback

If you would like to share your feedback or ask further questions about the project, please contact Mervat.Alhaffar1@lshtm.ac.uk (Arabic) or Francesco.Checchi@lshtm.ac.uk (English).