1 MRC Centre for Global Infectious Disease Analysis, Abdul Latif Jameel Institute for Disease and Emergency Analytics (J-IDEA), Imperial College London, London, UK

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

3 Syria Research Group (SyRG), co-hosted by the London School of Hygiene and Tropical Medicine, London, UK; and Saw Swee Hock School of Public Health, Singapore

4 Eijkman-Oxford Clinical Research Unit, Jakarta, Indonesia

Correspondence to: O Watson
o.watson15@imperial.ac.uk

Under-reporting of deaths limits our understanding of true burden of covid-19

Charles Whittaker and colleagues argue that accurate mortality data are essential for a fair, just, and equitable response to pandemics and suggest how to obtain them

Charles Whittaker, [1] Patrick G T Walker, Mervat Alhaffar, [2, 3] Arran Hamlet, [1] Bimandra A Djaafara, [1, 4] Azra Ghani, [1] Neil Ferguson, [1] Maysoon Dahab, [2] Francesco Checchi, [2] Oliver J Watson[1]

Estimating mortality attributable to different diseases, risk factors, or events is pivotal to inform resource allocation and evaluate public health interventions. Information on death rates and burden also supports wider aims of societal governance, public accountability, and memorialisation. Recent examples of mortality estimation include the true toll of hurricane Maria in Puerto Rico,[1] mortality during famine in Somalia,[2] and the war in South Sudan.[3]

Mortality data have also been essential in understanding the spread of covid-19. However, under-reporting in official death records has greatly obscured this understanding. We explore why under-reporting of deaths should have been expected, examine how use of alternative mortality sources can help advocate for a more equitable pandemic response, and highlight the crucial need for increased investment into civil registration and vital statistics systems before the next pandemic.

Importance of accurate covid-19 mortality data

Accurate understanding of the spread of covid-19 is crucial in navigating the trade-offs that underlie political decision making, including considerations of public health, economic growth, and civil liberties that must be integrated into pandemic responses at the national level.[4] Internationally, it is equally crucial in justifying and framing decisions surrounding global allocation of limited resources such as vaccines and therapeutics. Using case data as a metric for appraising control measures and tracking local epidemics is challenging since the frequency of asymptomatic infections,[5] non-specific symptoms of mild disease[6] and limitations in testing capacity result in substantial underascertainment of cases.[7] Mortality data on covid-19 are thought to be less susceptible to underascertainment than case numbers and have therefore been widely used to understand the dynamics of the pandemic and inform public health responses.

Underascertainment of mortality is common in infectious diseases

A recent global assessment of global health system capacity by the World Health Organization suggested that almost 40% of the world's deaths (irrespective of cause, and in non-pandemic periods) are not registered.[8] Understanding the true extent of mortality associated with infectious diseases is complex and challenging, most notably in resource poor settings where limited diagnostic capacity[9] and access to healthcare[10] mean many deaths are missed. For malaria, less than a quarter of estimated deaths appear in official national statistics[11]; for yellow fever, less than 1% of the estimated 50 000 deaths a year across Africa are reported[12]; for tuberculosis, both global estimates[13] and hospital postmortem studies suggest large numbers of deaths are not correctly attributed to the disease.[14] All of this suggests that relying solely on official mortality statistics for any of these diseases would lead to an incomplete and deeply biased understanding of their impact.

Is this any different for covid-19? The answer, we argue, is no. Accumulating evidence suggests officially reported covid-19 deaths provide an inadequate picture of the true dynamics of SARS-CoV-2 epidemics (table 1). This obscures our ability to understand the true burden of the pandemic, evaluate the complex trade-offs surrounding control of transmission, and advocate for a globally equitable and effective pandemic response.

Table 1 | Estimates of reporting of covid-19 mortality in official figures and sources of data used to produce the estimate

Setting	% of deaths reported*	Timing	Data source
Damascus[15]	1.25	First wave	Obituary notifications
Aden[16]	1.5	First wave	Satellite imagery of cemeteries
Damascus[15]	5.75	Overall	Obituary notifications
Lusaka[17]	7	First wave	Postmortem PCR
Egypt[18]	7.5	First wave	Excess mortality
Jakarta[19]	25	First wave	Funerals
Iran[20]	41.5	Overall	Seasonal excess mortality
Mexico[18 21]	45	Overall	Excess mortality
Spain[18]	53	First wave	Excess mortality
US[22]	78	First wave	Excess mortality
Addis Ababa[23]	82	Jul-Sep 2020	Cemetery burials
New Zealand	100	Overall	Excess mortality

* See individual references for sources of data and different methods deployed to estimate reporting fractions. Data for New Zealand are assumed based on very low covid-19 deaths.

Global variation in underascertainment

Evidence for widespread underascertainment of covid-19 deaths come from various sources. Excess death statistics (total mortality compared with baselines from previous years) have been widely used since the beginning of the pandemic. Although the proportion of excess deaths caused by covid-19 or indirect effects of the pandemic remains uncertain, excess mortality is often viewed as a more objective indicator of the pandemic death toll than officially reported deaths from covid-19.[24]

Modelling of excess mortality trends suggests that at least half of covid-19 deaths have been missed globally and, at worst, 75%.[25] This global estimate, however, masks wide variation between countries. Results from multiple European countries suggest at least 75% of covid-19 deaths feature in official reports,[26] but in other settings this proportion is far lower. In Peru, reanalysis of death certificates and covid-19 case definitions resulted in a tripling of official covid-19 death rates and closer alignment with excess mortality.[27] Across South Africa, estimates of the number of excess deaths have also reached more than three times the number of officially confirmed covid-19 deaths,[28] and estimation from multiple sources in India suggests that only 10% of covid-19 deaths have been officially reported.[29] In Brazil, by contrast, surveillance of severe acute respiratory infections suggests roughly 80% of covid-19 deaths have been recorded.[30]

National estimates are likely to mask further local variation in covid-19 deaths—regional estimates of excess deaths across South Africa highlighted substantial variation among provinces, with covid-19 accounting for 11-68% of excess deaths.[31]

Covid-19 mortality can be estimated from excess deaths only when reliable mortality data are routinely available. In many settings estimates of the number of unreported covid-19 deaths must rely on alternative sources, including data from burials, cemeteries, and crematoriums as well as postmortem surveillance studies from hospital mortuaries (box 1). These unofficial sources confirm substantial variation in the under-reporting of covid-19 deaths across settings without routine collection of mortality data. In addition, these studies help identify the factors that lead to covid-19 deaths being undetected, such as lack of diagnostic testing or limited access to secondary healthcare (leading to deaths from covid-19 in the community).

Box 1: Alternative sources of data on deaths

Burial patterns

In one study from Jakarta, Indonesia, officially reported covid-19 deaths accounted for about 25% of recorded funerals of people who had had confirmed or probable covid-19.[19] Other analyses showed there were 61% more burials in Jakarta from January-October 2020 compared with the same period in 2015-19.[32]

Analyses of city burials have been used in multiple settings in the absence of all-cause mortality data. Rapid mortality surveillance from Addis Ababa, Ethiopia, suggested only limited underascertainment, with covid-19 deaths representing 82% of excess mortality in the third quarter of 2020.[23] Before data on excess mortality were available, crematorium reports during the second wave in India were the first source that indicated extensive underascertainment of deaths, with as few as 1% of covid-19 deaths reported in some places.[33]

Postmortem diagnosis

In Lusaka, Zambia, a postmortem survey in the country's largest tertiary care hospital suggested that only about 10% of people whose deaths were recorded as related to covid-19 had had a diagnostic test before death.[17] Additionally, 73% of the covid-19 deaths captured by the study had occurred in the community, where none of the deceased had had a covid-19 test, highlighting how treatment seeking behaviour can lead to important gaps in surveillance.

Further analysis revealed that covid-19 mortality in Lusaka was highly skewed towards younger age groups compared with higher income countries.[34] This shows how auxiliary data can provide a more complete picture of covid-19 morbidity and mortality than use of officially reported cases and deaths alone.

Gaps in covid-19 surveillance are likely to be even more prevalent in countries affected by conflict, where governance of health systems is often challenged, weakened, or even absent. Recording and sharing information is often difficult in these settings, hindering accountability, accessibility, and transparency.[35] These obstacles have motivated citizen science initiatives operated through social media to identify unreported covid-19 deaths. Such activities often reveal extensive under-reporting of covid-19 deaths (box 2). While unconfirmed covid-19 deaths ascertained from alternative sources should be treated with caution, these results highlight the extent to which covid-19 might have spread unobserved across many parts of the world where surveillance of community deaths is weak or absent, such as Yemen and Syria.

Box 2: Citizen science initiatives

Citizen science initiatives have been relied on in some settings to shed light on the scale of the pandemic. These include drone footage of cemeteries in Aden, Yemen, which provided one of the first indications of under-reporting in the city[36] and later prompted the use of satellite imagery to quantify burials.[16]

Similarly, satellite imagery of mass graves in Damascus, Syria, hinted at higher covid-19 death tolls than officially reported.[37] The images prompted an investigation using obituary certificates uploaded by citizens to model the epidemic in Damascus.[15]

The two studies suggested that as few as 1 in 80 covid-19 deaths feature in officially reported mortality statistics in Damascus[38] and Aden.[16]

In other countries, hackers gained access to non-public datasets to reveal the true scale of mortality during the pandemic. In Belarus, the hacker group Cyberpartisans gained access to data showing that excess deaths between March 2020 and March 2021 were 14 times higher than official covid-19 death tolls.[39] In Mexico, two citizens used a forced browsing approach to access mortality data for Mexico City, uncovering that excess deaths for the city were more than double the official covid-19 death toll by February 2021.

Understanding the past, advocating for an equitable future

These realities paint a complex picture of the spread of covid-19 around the world—one that is fundamentally different from many prevailing narratives. Underascertainment of covid-19 mortality obscures our understanding of the pandemic's progression, the effectiveness of interventions, and the optimal allocation of resources. Modelling studies in Jakarta found that the effect of city-wide physical control measures is most clearly visible in data on excess funerals rather than official cases or deaths.[19]

Accurate mortality data also help track the pandemic's maturity and assess the relative contributions of physical control measures and population level immunity in declining transmission. This in turn helps inform the most appropriate level of interventions and enables more accurate weighing of the benefits of maintaining social distancing against the societal costs of continued closure of schools or workplaces.[40]

The accuracy of mortality data also has consequences for the distribution of vaccines.[41] To date, covid-19 vaccines have overwhelmingly been delivered to higher income countries,[42] and initiatives supporting equitable distribution (such as the Covax facility) have been unable to ensure adequate population coverage elsewhere. This unequal distribution reflects stark global disparities in the access to healthcare resources. A more accurate understanding of the global burden of covid-19 would not wave away the non-technical, structural, and political reasons that have seen many poorer countries excluded from timely access to vaccinations and other resources. But the situation has not been helped by narratives based on inaccurate official covid-19 mortality statistics suggesting some countries have been largely "spared" from the worst effects of the pandemic. These inaccurate data obscure the true picture, both by hiding deaths and by underestimating the effectiveness of interventions in settings that successfully limited transmission of covid-19 through timely implementation of control measures. This perpetuated the myth that public health and social measures were not critical to pandemic control, contributing to the collapse of numerous health systems during successive epidemic waves.

What can and should be done?

Collection and analysis of accurate population mortality data should be urgently scaled up in settings lacking reliable death registration systems. This will prevent existing global inequities in surveillance from conspiring further with parallel inequities in access to treatments and wider determinants of health. Rapid, retrospective, or prospective collection of mortality data is possible and, although not as accurate as estimates of excess mortality, can provide useful, timely, and actionable information in crisis settings. Examples include rapid household surveys,[43 44] records from burial sites[45] or their remote analysis through satellite imagery,[16] key informant studies and capture-recapture analysis of lists of deaths,[46] and verbal autopsy surveys.[47] Social media or other civil society sources can also be used to reconstruct mortality trends in the absence of complete mortality data.[15]

The most suitable method will vary between settings—for example, civilians or social media groups may only collect lists of deaths in response to conflict or in the context of particular religious practices. The use of satellite imagery will be effective only in locations with geolocated and regularly used cemeteries, while postmortem surveys (primarily implemented in urban settings) are unlikely to be representative if people dying in the community are not routinely brought to mortuaries (as is more common in rural areas).

Such data gathering exercises should be seen as short term solutions and not as a substitute for long term investment in civil registration and vital statistics systems. Better death registration and certification should be a cornerstone of future pandemic preparedness plans and is essential for achieving the mission set out in the sustainable development goals to "leave no-one behind."[48] This will require engagement and effort to improve the coverage and capacity of existing registration systems, the establishment of global standards for defining and reporting pandemic deaths, and the creation of robust governance frameworks that help mitigate political interferences in the collation of sensitive data.

Recent efforts by WHO, including its technical advisory group on covid-19 mortality assessment and the report on global health systems capacity,[8] are encouraging. Comprehensive descriptions of the status quo are a good start but must be accompanied by investment to improve civil registration capacity and coverage, targeted implementation of technological innovation, and tailored solutions to overcome the economic, political, and sociostructural barriers that limit progress in each setting.[49]

Equally important is establishing robust safeguards to avoid distortion of official statistics for political motives. Post-disaster death tolls are an important tool for evaluating government responses and are consequently politically sensitive if they expose poor governance. Politicisation of covid-19 death reporting is common and influences how deaths are defined and whether they feature in official statistics.[50] Authorities in many countries have charged citizens under criminal defamation laws for criticising government responses to covid-19.[51] Improvements to registration systems alone are therefore unlikely to resolve the many remaining problems with death ascertainment. A robust governance framework is therefore equally critical and must accompany any future improvements to system capacity to help mitigate potential political influences on how reporting occurs, and what gets reported.

Without these improvements, biases in surveillance that cause the greatest underestimation of cases and deaths where access to care is lowest will continue to obscure our understanding of this pandemic and hinder efforts to prepare more equitably for the next.

Key messages

- Mortality data are considered more complete than case data for covid-19, but official statistics often undercount the true number of deaths

- Underascertainment varies globally but is highest in low income and fragile settings

- Underascertainment biases our understanding of the pandemic's progression and has important consequences for allocation of resources such as vaccines

- Investment in vital registration systems and robust governance are needed to ensure a fair, just, and equitable response to this and future pandemics

1. Sandberg J, Santos-Burgoa C, Roess A, etal. All over the place? Differences in and consistency of excess mortality estimates in Puerto Rico after Hurricane Maria. *Epidemiology* 2019;30:549-52. doi: 10.1097/EDE.0000000000000970 pmid: 30640732

2. Checchi F, Robinson WC. *Mortality among populations of southern and central Somalia affected by severe food insecurity and famine during 2010-2012.* Food and Agriculture Organization of the United Nations, 2013.

3. Checchi F, Testa A, Warsame A, Quach L, Burns R. Estimates of crisis-attributable mortality in South Sudan, December 2013–April 2018: a statistical analysis. 2018. https://www.lshtm.ac.uk/south-sudan-full-report

4. Oliu-Barton M, Pradelski BSR, Aghion P, etal. SARS-CoV-2 elimination, not mitigation, creates best outcomes for health, the economy, and civil liberties. *Lancet* 2021;397:2234-6. doi: 10.1016/S0140-6736(21)00978-8 pmid: 33932328

5. Mizumoto K, Kagaya K, Zarebski A, Chowell G. Estimating the asymptomatic proportion of coronavirus disease 2019 (COVID-19) cases on board the Diamond Princess cruise ship, Yokohama, Japan, 2020. 2020;25. doi: 10.2807/1560-7917.ES.2020.25.10.2000180 pmid: 32183930

6. Wynants L, Van Calster B, Collins GS, etal. Prediction models for diagnosis and prognosis of covid-19: systematic review and critical appraisal. *BMJ* 2020;369:m1328. doi: 10.1136/bmj.m1328 pmid: 32265220

7. Russell T, Golding N, Hellewell J, etal. Reconstructing the global dynamics of under-ascertained COVID-19 cases and infections. *medRxiv* 2020. [Preprint.] doi: 10.1101/2020.07.07.20148460.

8. WHO. SCORE for health data technical package: global report on health data systems and capacity 2020. 2021. https://reliefweb.int/report/world/score-global-report-health-data-systems-and-capacity-report-2020

9. Caliendo AM, Gilbert DN, Ginocchio CC, etalInfectious Diseases Society of America (IDSA). Better tests, better care: improved diagnostics for infectious diseases. *Clin Infect Dis* 2013;57(suppl 3):S139-70. doi: 10.1093/cid/cit578 pmid: 24200831

10. Fullman N, etalGBD 2016 Healthcare Access and Quality Collaborators. Measuring performance on the Healthcare Access and Quality Index for 195 countries and territories and selected subnational locations: a systematic analysis from the Global Burden of Disease Study 2016. *Lancet* 2018;391:2236-71. doi: 10.1016/S0140-6736(18)30994-2 pmid: 29893224

11. World Health Organization. *World malaria report.* WHO, 2019.

12. Garske T, Van Kerkhove MD, Yactayo S, etalYellow Fever Expert Committee. Yellow fever in Africa: estimating the burden of disease and impact of mass vaccination from outbreak and serological data. *PLoS Med* 2014;11:e1001638. doi: 10.1371/journal.pmed.1001638 pmid: 24800812

13. Korenromp EL, Bierrenbach AL, Williams BG, Dye C. The measurement and estimation of tuberculosis mortality. *Int J Tuberc Lung Dis* 2009;13:283-303.pmid: 19275787

14. Garcia-Basteiro A, etal. Unmasking the hidden tuberculosis mortality burden in a large postmortem study in Mozambique. *Eur Respir J* 2019;545:PA5287. doi: 10.1183/13993003.congress-2019.pa5287

15. Watson OJ, Alhaffar M, Mehchy Z, etalImperial College COVID-19 Response Team. Leveraging community mortality indicators to infer COVID-19 mortality and transmission dynamics in Damascus, Syria. *Nat Commun* 2021;12:2394. doi: 10.1038/s41467-021-22474-9 pmid: 33888698

16. Koum Besson ES, Norris A, Bin Ghouth AS, et al. Excess mortality during the covid-19 pandemic: a geospatial and statistical analysis in Aden governorate, Yemen. *BMJ Glob Health* 2021;6. doi: 10.1136/bmjgh-2020-004564 pmid: 33758012

17. Mwananyanda L, Gill CJ, MacLeod W, etal. Covid-19 deaths in Africa: prospective systematic postmortem surveillance study. *BMJ* 2021;372. doi: 10.1136/bmj.n334 pmid: 33597166

18. Karlinsky A, Kobak D. The world mortality dataset: tracking excess mortality across countries during the covid-19 pandemic. *medRxiv* 2021. [Preprint.] doi: 10.1101/2021.01.27.21250604.

19. Djaafara BA, Whittaker C, Watson OJ, etal. Quantifying the dynamics of COVID-19 burden and impact of interventions in Java, Indonesia. *medRxiv* 2020. [Preprint.] doi: 10.1101/2020.10.02.20198663.

20. Ghafari M, Kadivar A, Katzourakis A. Estimates of anti-SARS-CoV-2 antibody seroprevalence in Iran. *Lancet Infect Dis* 2021;21:602-3. doi: 10.1016/S1473-3099(21)00053-0 pmid: 33600759

21. *Covid-19: Mexico revises coronavirus death toll up by 60.* BBC News 2021 Mar 28. https://www.bbc.co.uk/news/world-latin-america-56558059

22. Weinberger DM, Chen J, Cohen T, etal. Estimation of excess deaths associated with the covid-19 pandemic in the United States, March to May 2020. *JAMA Intern Med* 2020;180:1336-44. doi: 10.1001/jamainternmed.2020.3391 pmid: 32609310

23. Endris BS, etal. Excess mortality in the face of covid-19: evidence from Addis Ababa mortality surveillance program.2021. [Preprint.] doi: 10.2139/ssrn.3787447.

24. Karlinsky A, Kobak D. Tracking excess mortality across countries during the COVID-19 pandemic with the world mortality dataset. *Elife* 2021;10. doi: 10.7554/eLife.69336 pmid: 34190045

25. There have been 7m-13m excess deaths worldwide during the pandemic. *Economist* 2021 May 15. https://www.economist.com/briefing/2021/05/15/there-have-been-7m-13m-excess-deaths-worldwide-during-the-pandemic

26. Vestergaard LS, Nielsen J, Richter L, et al; ECDC Public Health Emergency Team for COVID-19. Excess all-cause mortality during the covid-19 pandemic in Europe - preliminary pooled estimates from the EuroMOMO network, March to April 2020. *Euro Surveill* 2020;25. doi: 10.2807/1560-7917.ES.2020.25.26.2001214 pmid: 32643601

27. Dyer O. Covid-19: Peru's official death toll triples to become world's highest. *BMJ* 2021;373:n1442. doi: 10.1136/bmj.n1442 pmid: 34088698

28. Kathryn Cleary for Spotlight. Spotlight covid-19: South Africa's 33 000 excess deaths: what we know so far. 2020. https://www.dailymaverick.co.za/article/2020-08-14-south-africas-33000-excess-deaths-what-we-know-so-far/

29. Subramanian AAJS. *Three new estimates of India's all-cause excess mortality during the covid-19 pandemic. CGD working paper 589.* Center for Global Development, 2021. https://cgdev.org/publication/three-new-estimates-indias-all-cause-excess-mortality-during-covid-19-pandemic.

30. Alves THE, de Souza TA, Silva SA, Ramos NA, de Oliveira SV. Underreporting of death by COVID-19 in Brazil's second most populous state. *Front Public Health* 2020;8:578645. doi: 10.3389/fpubh.2020.578645 pmid: 33384978

31. Moultrie T, Dorrington R, Laubscher R, Groenewald P, Bradshaw D. *Correlation of excess natural deaths with other measures of the covid-19 pandemic in South Africa.* 2021. https://www.samrc.ac.za/sites/default/files/files/2021-03-03/CorrelationExcessDeaths.pdf

32. Elyazar IRF, Surendra H, Ekawati LL, etal. Excess mortality during the first ten months of COVID-19 epidemic at Jakarta, Indonesia.*medRxiv* 2020. [Preprint.] doi: 10.1101/2020.12.14.20248159.

33. Findlay S. India's devastating second wave: 'It is much worse this time'. *Financial Times* 2021 Apr 20. https://www.ft.com/content/683914a3-134f-40b6-989b-21e0ba1dc403

34. Van Gordon MM, Mwananyanda L, Gill CJ, McCarthy KA. Regional comparisons of COVID reporting rates, burden, and mortality age-structure using auxiliary data sources.*medRxiv* 2021.08.18.212622482021. [Preprint.]

35. Siddiqi S, Masud TI, Nishtar S, etal. Framework for assessing governance of the health system in developing countries: gateway to good governance. *Health Policy* 2009;90:13-25. doi: 10.1016/j.healthpol.2008.08.005 pmid: 18838188

36. Cemeteries overflow in Aden as COVID-19 deaths spike in Yemen. *Al Jazeera* 2020 May 25. https://www.aljazeera.com/videos/2020/05/25/cemeteries-overflow-in-aden-as-covid-19-deaths-spike-in-yemen

37. Syria in Context Investigation. Covid-19 spreads out of control in Damascus. 2020. https://tande.substack.com/p/syria-in-context-investigation-covid

38. Report 31. Estimating under-ascertainment of COVID-19 mortality: an analysis of novel data sources to provide insight into COVID-19 dynamics in Damascus, Syria. 2021. https://www.imperial.ac.uk/mrc-global-infectious-disease-analysis/covid-19/report-31-syria/.

39. Время Н. Excess mortality—32 thousand people. Belarusian authorities repeatedly underestimate statistics during the coronavirus epidemic—leak data. 2021. https://www.currenttime.tv/a/smert-nost-v-belarusi/31401342.html

40. Barnett-Howell Z, Watson OJ, Mobarak AM. The benefits and costs of social distancing in high- and low-income countries. *Trans R Soc Trop Med Hyg* 2021;115:807-19. doi: 10.1093/trstmh/traa140 pmid: 33440007

41. Hogan AB, Winskill P, Watson OJ. Imperial College Covid-19 Response Team. Report 33. Modelling the allocation and impact of a covid-19 vaccine. https://www.imperial.ac.uk/mrc-global-infectious-disease-analysis/covid-19/report-33-vaccine/

42. Beyrer C, etal. Commissioners of and collaborators with the International AIDS Society–Lancet Commission on Health and Human Rights. Human rights and fair access to COVID-19 vaccines: the International AIDS Society-Lancet Commission on Health and Human Rights. *Lancet* 2021;397:1524-7. doi: 10.1016/S0140-6736(21)00708-X pmid: 33773117

43. Warsame A, Frison A, Gimma A, Checchi F. Retrospective estimation of mortality in Somalia, 2014-2018: a statistical analysis. https://www.lshtm.ac.uk/media/40136

44. Alkhuzai AH, Ahmad IJ, Hweel MJ, etalIraq Family Health Survey Study Group. Violence-related mortality in Iraq from 2002 to 2006. *N Engl J Med* 2008;358:484-93. doi: 10.1056/NEJMsa0707782 pmid: 18184950

45 Counting the burials: African nations scramble to track COVID-19. Reuters 2020 Jul 13. https://www.reuters.com/article/us-health-coronavirus-africa-death-idUSKCN24E0KF

46 Dahab M, Abdelmagid N, Kodouda A, Checchi F. Deaths, injuries and detentions during civil demonstrations in Sudan: a secondary data analysis. *Confl Health* 2019;13:16. doi: 10.1186/s13031-019-0199-8 pmid: 31073326

47 At least half of mystery deaths in Nigeria's Kano due to covid-19— minister. *Reuters* 2020 Jun 8. https://www.reuters.com/article/health-coronavirus-nigeria-kano-idUSL8N2DL4Z7

48 United Nations General Assembly. Transforming our world: the 2030 agenda for sustainable development. A/RES/70/1. 2015. https://sdgs.un.org/2030agenda

49 Lopez AD, McLaughlin D, Richards N. Reducing ignorance about who dies of what: research and innovation to strengthen CRVS systems. *BMC Med* 2020;18:58. doi: 10.1186/s12916-020-01526-9 pmid: 32146906

50 Rukmini S. Why audits, reconciled death data are still missing covid deaths. *IndiaSpend* 2020. https://www.indiaspend.com/why-audits-reconciled-death-data-are-still-missing-covid-deaths/

51 Kisa S, Kisa A. Under-reporting of COVID-19 cases in Turkey. *Int J Health Plann Manage* 2020;35:1009-13. doi: 10.1002/hpm.3031 pmid: 32744745