War-time mortality in Sudan: a multiple systems estimation analysis

Maysoon Dahab, Rahaf AbuKoura, Francesco Checchi, Aljaile Ahmed, Omama Abdalla, Mona Ibrahim, Nada Abdelmagid, Israa Zain Alabden, Lobaba Omer, Mervat Alhaffar, Promise Ekoriko, Zamzam I A Ali, Chris Grundy, Mortala Ndow, Lucia Cassini, Catherine R McGowan

Summary

Background The mortality impact of war in Sudan, which began in April 2023, remains largely unmeasured due to sparse and methodologically weak data that reflect sparse pre-war vital registration systems and actively restricted access to affected communities. Our study aimed to quantify undocumented war-time mortality levels and patterns in Sudan.

Methods We conducted a retrospective observational study collecting lists of people deceased since April 15, 2023, from three sources: a public social media survey, a survey disseminated through private networks, and public social media obituaries. After probabilistically matching decedent records within and across lists, we described age and cause-of-death patterns by region and month. For Khartoum State, where data were sufficiently abundant, we used multiple systems estimation to estimate all-cause and intentional-injury mortality.

Findings In the war's first 14 months, most reported deaths were from preventable causes, while intentional-injury deaths were disproportionately high in Khartoum State and Gezira State, and highest in the Kordofan and Darfur regions. We estimate that 61 202 all-cause deaths (95% CI 22 286–209 151) occurred in Khartoum State between April 2023, and June 2024, corresponding to a conservatively estimated crude death rate of 9·7 per 1000 persons per year. 26 024 deaths (95% CI 12 571–58 704) in Khartoum were due to intentional injuries.

Interpretation Between April 2023, and June 2024, Sudan's war likely caused a substantial, largely undocumented rise in mortality in Khartoum State, with intentional-injury deaths in the capital alone exceeding the ACLED reported fatalities toll for the same period (ie, 20 178). Across the country mortality was driven by preventable disease and hunger, with intentional-injury deaths predominating in the Darfur and Kordofan regions. Urgent diplomatic and humanitarian action is critical to prevent further avoidable deaths, deter human rights violations, and to support post-conflict recovery and reconciliation.

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Department of Infectious Disease Epidemiology and International Health, Faculty of Epidemiology and Population Health, London School of Hygiene & Tropical Medicine, London, UK (M Dahab PhD, R AbuKoura MPH, Prof F Checchi PhD, N Abdelmagid MSc, M Alhaffar MSc, P Ekoriko BSc, C Grundy MSc, M Ndow MSc, L Cassini BA, C R McGowan PhD); **Youth Peer-to-Peer Education Network (Y-Peer) Sudan, Khartoum, Sudan** (A Ahmed MSc, O Abdalla BSc, I Zain Alabden MSc); **Department of Social Policy and Intervention, University of Oxford, Oxford, UK** (M Ibrahim MSc); **London, UK** (L Omer MBBS); **Centre for Clinical and Translational Science, Mayo Clinic, Rochester, MN, USA** (Z I A Ali MSc)

Correspondence to: Dr Maysoon Dahab, Department of Infectious Disease Epidemiology and International Health, Faculty of Epidemiology and Population Health, London School of Hygiene & Tropical Medicine, London WC1E 7HT, UK **Maysoon.Dahab@lshtm.ac.uk**

Introduction

Sudan's conflict, which started on April 15, 2023, is ranked as extreme by the Global Conflict Index,[1] but its human impact remains largely unquantified. Pre-war crisis mortality estimates, produced during the 2019 revolution and COVID-19 epidemic period, pointed to substantial under-estimation of mortality due to weak and fragmented vital registration systems.[2] Since then, robust estimations of key human health indicators, including conflict-attributable mortality, have become even more difficult due to health service disruptions, collapsed vital registration systems, and restricted ground access.[3]

Although ground mortality surveys of Sudanese refugees in Chad have been possible,[4] similar assessments within Sudan have been constrained by insecurity. Existing estimates largely rely on counts of intentional-injury deaths reported by media or civil-society sources,[5,6] or are either methodologically undocumented[7] or limited to specific attacks.[8] To the best of our knowledge, no population-representative mortality estimate from within Sudan has yet been published.

Accurate, timely mortality data are critical to benchmarking crises' severity, mobilising humanitarian responses, supporting advocacy for conflict resolution, and composing a record for accountability and memorialisation.[9] Given the inaccessibility of large parts of Sudan, we collected data remotely with the aim of documenting levels and patterns of mortality since the conflict's start.

Methods

Design

We conducted a retrospective, observational study to estimate mortality in Sudan, including undocumented deaths. This involved constructing three lists of individual decedents and using multiple systems estimation (MSE), also known as capture–recapture analysis, to model the overlap among lists and thereby estimate deaths missing from all sources, which are then added to observed deaths to calculate total mortality. We previously used MSE to estimate mortality in specific sites within Sudan.[2,10] Although we aimed to estimate

Research in context

Evidence before this study

Sudan has not conducted a national census in more than a decade and has long had a fractured system for the vital registration of births and deaths. Since the outbreak of war in April 2023, this fragility has been further compounded by the conflict to the point of effectively halting mortality reporting systems, including vital registration, in contested conflict areas. As a result, there is a near total absence of empirical evidence on the war's mortality impact. Although media and humanitarian reports provide insights on the areas most affected by war, such as Khartoum State, Gezira State, and Darfur region, these typically focus on specific conflict events in limited geographies. Similarly, the Armed Conflict Location and Event Data Project, which relies heavily on media and local reporting, focuses on tracking reports of violent mortality and is constrained by reporting gaps. Frequent telecommunication blackouts and insecurity further constrain the documentation of deaths. As a result, available methods likely underestimate actual mortality levels. To identify existing estimates on population-level mortality in crises in Sudan, we searched PubMed on May 28, 2024, using the following search string: "mortality AND (Sudan OR Sudanese) AND (conflict OR war OR humanitarian OR crises OR crisis OR displaced OR refugees OR revolution)". We did not apply any language or date restrictions and included studies from database inception. This search returned 220 studies. We screened titles and abstracts, and eight studies met the inclusion criteria of reporting on empirical estimates of population mortality rates during conflict or crises. Three of these were meta-analyses aggregating retrospective ground survey data from Darfur or Sudanese refugees in Chad. Two studies reported primary retrospective survey mortality estimates from West Darfur and South Darfur and among displaced populations in Darfur during an outbreak of hepatitis E. Outside Darfur we found three crisis-related mortality studies, all conducted by members of our research team. Two used a multisystem estimation key-informant approach to estimate unreported mortality, one in North Kordofan and Gezira during COVID-19 and the other in Khartoum during the 2019 revolution. The third study used a modelling approach to estimate unreported COVID-19 deaths in Khartoum State. Since the war that began in 2023, there has been no empirical research to estimate war time all-cause mortality, including unreported deaths, in Sudan.

Added value of this study

This study provides the first empirical estimate of all-cause mortality in Khartoum State since the conflict's escalation in April, 2023. It also captures, to the best of our knowledge for the first time patterns in cause-specific mortality across regions of Sudan and over time during the current war.

Implications of all the available evidence

Our study describes the patterns and levels of mortality, revealing a range of causes—hunger, disease, and violence—that have gone largely unrecorded so far. We highlight the invisible, increasing, and largely preventable nature of the war's mortality impact. Our findings could help by informing efforts to increase resource allocation for urgently needed humanitarian interventions; providing an evidence base for future investigations into war crimes; and evidencing the importance of mortality information in Sudan and other conflict settings.

all-cause and intentional-injury deaths by Sudanese state, data were only sufficient for MSE implementation in Khartoum State. However, we describe patterns in reported deaths across the country.

Data sources and participants

We compiled three lists of individual decedents from several sources: a public survey circulated to respondents on various platforms (eg, Facebook, LinkedIn, X, and Instagram), a private survey circulated using chain-referral recruitment through a bespoke web-based respondent-driven sampling platform (ie, webRDS),[11] and publicly available social media pages containing obituaries posted by first responders, community members, or people in charge of burial sites (appendix 1 p 2). When data from outside Khartoum State were deemed to be insufficient to support MSE, we increased efforts to collect social media data from Khartoum itself.

See Online for appendix 1

Survey questionnaires were available in both English and Arabic and administered using ODK (version 1.3.2 [client] and version 1.3.3 [server]; appendix 1 pp 3–6). Respondents were eligible if aged 18 years or older, they provided consent to participate, and they knew someone who had died in Sudan since April 15, 2023. Respondents could complete the survey more than once. We socialised surveys extensively among formal and informal civil society networks within Sudan and the diaspora. We also identified study ambassadors and social media influencers who shared the surveys within their networks. We began social media data extraction on Oct 15, 2023, and deployed the surveys on Nov 14, 2023. We stopped data collection on June 4, 2024.

We requested the following information for each decedent: names (up to 11; in our study, however, records were frequently incomplete and featured similar names due to the prevalence of a few very common names [eg, Mohamed and Ahmed] and the Arabic naming convention [consisting of a chain of forefathers' names] predominant in Sudan), nickname (if any), sex, age at death, date and location of death (state and specific locality if known), primary occupation, and cause of death (ie, accidental injury, intentional injury, starvation or disease, or other). Records were included in the analysis if they contained at least two reported names (or one name and a unique nickname), a date of death within the study period, a location of death within Sudan, and at least one additional demographic variable (eg, age, occupation, or cause of death). Any record missing these variables was excluded unless record linkage, as described below, identified a match for the record within another list, and the matching record contained the missing variables.

Approval was granted by the London School of Hygiene & Tropical Medicine Observational Research Ethics Committee (number 29595). There was no functional ethics committee in Sudan throughout the study period. Survey participants provided written informed consent through the questionnaire tool.

Data management and analysis

MSE relies on accurate record linkage, such that no cases are duplicated within any list and all matches across lists are conclusively identified.[12] We thus identified potential within-list duplicates by applying a systematic algorithm (appendix 1 p 8) to assign a likelihood score d to each potential duplicate pair of records: 1 (very unlikely), 2 (unlikely), 3 (possible), 4 (probable), or 5 (certain). We similarly assigned a cross-list match score m (ranging from 1 to 5) to any pair of potentially matching records from different lists. We attributed equal importance to all linkage variables as we had no empirical basis for differentially weighting them. However, we revised all scores manually to identify features not captured by the algorithm, including famous names, idiosyncratic nicknames, and very specific death locations or professions. A second reviewer validated all duplicate and cross-list likelihood scores, with discrepancies resolved by consensus.

Combining five duplicate likelihood scores and five cross-list match scores yields 25 alternative datasets depending on which threshold is chosen for either score. An eight-member Arabic-speaking panel of co-authors and additional volunteers reviewed a random sample of duplicate and match candidates and reached consensus that thresholds of 3 or more for the duplication score and 4 or more for the match score would minimise misclassification and optimise record linkage. Accordingly, we present descriptive statistics of the dataset resulting from application of this threshold combination. However, for our primary analysis we dealt with record linkage uncertainty by treating de-duplication and matching probabilistically, as follows.

Candidate duplicate or match pairs with scores of 5 were considered a priori to have duplication or match probabilities of 1. We estimated probabilities for scores of 1 to 4 through simulation. In each of 1000 simulation runs, we naively imputed any missing values of the first six names, nickname, age at death (or age category), month and year of death, occupation, cause of death, and location of death (state and locality) by sampling, with replacement, from all non-missing values of the same variable among other records in the dataset (a single list of names was used to impute each name variable). We re-applied the scoring algorithm to the thusly imputed data and determined the proportion of previously uncertain duplicate and match pairs that, upon imputation, could now be classified as a certain duplicate or match (score=5). We assumed that the distribution of these proportions arising from simulation runs was an accurate estimate of the probability of duplications or matches associated with each score (appendix 1 p 9). As we were interested in the relative distance of scores 1–4 from scores of 5 or probabilities of 1, we normalised the simulated probabilities to unity: this also accounted for the imperfect performance of the scoring algorithm, which did not account for adjustments during manual review.

Next, we sampled from these distributions in over 1000 separate runs, during each of which we: used the score-specific sampled probability to draw a random binomial variate per pair, thereby determining which were a duplicate or match; merged all within-list duplicates and cross-list matches, with further merging if two cross-list pairs shared a common decedent (ie, formed a match across all three lists). When merging pairs, we resolved discrepancies in the values associated with each record by taking the mode of name, location of death, age category, and cause of death; and the mean of date of death. We implemented MSE on the resulting dataset.

We present the median of mortality estimates and 95% percentile intervals (for simplicity renamed confidence intervals or 95% CI) from the 1000 runs as our main analysis. As sensitivity analysis we also present estimates arising from each combination of duplicate and match score thresholds (appendix 1 p 10). In this sensitivity analysis, observations with duplicate scores of d or greater were considered within-list duplicates and merged. Similarly, cross-list pairs with match scores of m or greater were merged.

MSE involves fitting statistical models to the overlap structure of available lists. Given three lists, this corresponds to the vector $N=\{n_{000},n_{100},n_{010},n_{001},n_{101},n_{110},n_{011},n_{111}\}$ where n_{ijk} is the number of cases (ie, decedents) that appear on lists 1, 2, and/or 3. Models are used to estimate $\hat{n}_{000}$ (ie, deaths not on any list). Total deaths are the sum of N (ie, deaths that do not appear on any list plus deaths found within at least one list). In the case of three lists, eight alternative models can be fitted. Each model contains, as independent variables, terms for the probability of appearing on each list, plus zero, some, or all possible two-way interactions between lists. Interaction terms represent how membership of one list affects the chance of appearing on another, thereby relaxing the key assumption of independent lists. A key MSE assumption is that individuals within a list had an equal chance of capture. Our dataset was too sparse to allow MSE stratification by variables that plausibly predict list membership (eg, age), a common strategy to avoid violating this assumption. We instead used the parameterisation of Rossi and colleagues,[13] whereby, instead of fitting log-linear models to aggregate vector N, generalised linear Poisson models were fitted to individual-level data consisting of eight rows per decedent, one for each of the eight possible list membership outcomes, with the observed outcome (ie, the actual list membership pattern for that specific death; eg, x_{011} if the decedent appeared on lists two and three but not list one) attributed a value of 1, the $\hat{x}_{000}$ outcome (ie, not present on any list) a missing value, and all other outcomes a value of 0. These outcomes are the model's dependent variable. This formulation facilitates inclusion of individual-level predictors of list membership. Each model is used to predict the $\hat{x}_{000}$ value for each decedent, which when summed across all decedents, equals $\hat{n}_{000}$ (ie, the estimated number of unlisted deaths).

After screening out any models that yielded implausible estimates (arbitrarily defined as $\hat{n}_{000}$ >100 times the total listed), models' Akaike information criterion (AIC) values were used to construct a posterior probability for each model, used as weight to average model estimates and their 95% CIs:[14] this posterior probability quantifies how likely the model is to be correct, out of all candidate models: the sum of all models' posterior probabilities is 1. We fitted models for all-cause mortality and for deaths due to intentional injuries. After verifying that they improved AIC and substantially modified the point estimate, we included covariates assumed to predict list membership both as additional terms, and in interaction terms of the co-variate with each list membership term: the number of months since the start of the war; the cause of death (intentional injury *vs* other) for the all-cause mortality models; and the number of times that each decedent was listed (ie, the number of duplicates across the three lists), which we assumed would be a proxy of notoriety, social connectedness, and possibly socio-economic status.

For illustration's sake we show the observed list overlap (appendix 1 p 11) based on the consensus threshold scores $d \geq 3$ and $m \geq 4$. The estimates from each candidate model fitted to the resulting dataset are shown in appendix 1 (p 12). Relative differences among models were similar across the main analysis simulations and sensitivity analyses. The fully saturated model (all interactions) was consistently screened out of model averaging. Of the remaining all-cause mortality models, that featuring interactions between either survey and social media list membership had the highest posterior probability; however, this model was screened out of the intentional injury estimate, for which the model with a single interaction between private survey and social media was weightiest.

We computed an estimate for the crude death rate over the analysis period in Khartoum State by dividing estimated all-cause deaths and their 95% CIs by person-time at risk (approximated by forward-projecting pre-war population denominators while subtracting known displacement during the same period; appendix 1 pp 12–16).

Role of the funding source

The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

417 respondents completed 465 surveys, including 328 public network surveys (309 respondents) and 137 private network surveys (108 respondents). We extracted data from approximately 150 social media pages to compose the third list. Between them, lists contained 6715 decedent records.

After de-duplication and matching based on the consensus-based duplication (≥3) and match (≥4) score thresholds, 4884 unique decedents were identified (table). Of these, 3846 (78·7%) had sufficient data and occurred within Sudan since the conflict's start, ie, they were eligible for descriptive analysis.

Characteristics of reported deaths varied across the three lists (appendix 1 p 17). Male decedents comprised most deaths (1045 [69·3%] of 1509 in the private survey, 588 [76·3%] of 771 in the public survey, and 1423 [79·5%] of 1790 in the social media lists); this was consistent over time. The proportion of child (ie, those aged 0–14 years) deaths was low (private survey 53 [3·5%], public survey 12 [1·6%], and social media 90 [5·0%]).

Most unique deaths were from Khartoum State (private survey 1046 [69·3%], public survey 460 [59·7%], and social media 1397 [78·0%]), partly reflecting intensified data collection in this state (figure 1). Intentional injury was the cause of death in 578 (38·3%) decedents from the private survey, 346 (44·9%) decedents from the public survey, and 1039 (58·0%) decedents from social media. The number of reported deaths across the country fluctuated but slightly increased over time (figure 2).

Overall, starvation and disease were the leading causes of death, but intentional injury predominated in Kordofan (80%) and Darfur (69%) regions and was

	N (%)
Total unique observations	4884 (100%)
Sufficient name identifiers	4166 (85·3%)
Died since April 15, 2023	4115 (84·3%)
Died within Sudan (descriptive analysis)	3846 (78·7%)
Died within Khartoum State (estimation all-cause)	2718 (55·7%)
Died within Khartoum State (estimation intentional injury only)	1367 (28·0%)

Table: **Attrition of unique study-reported decedent observations based on merging observations with within-list duplicate scores of ≥3 and between-list match scores of ≥4**

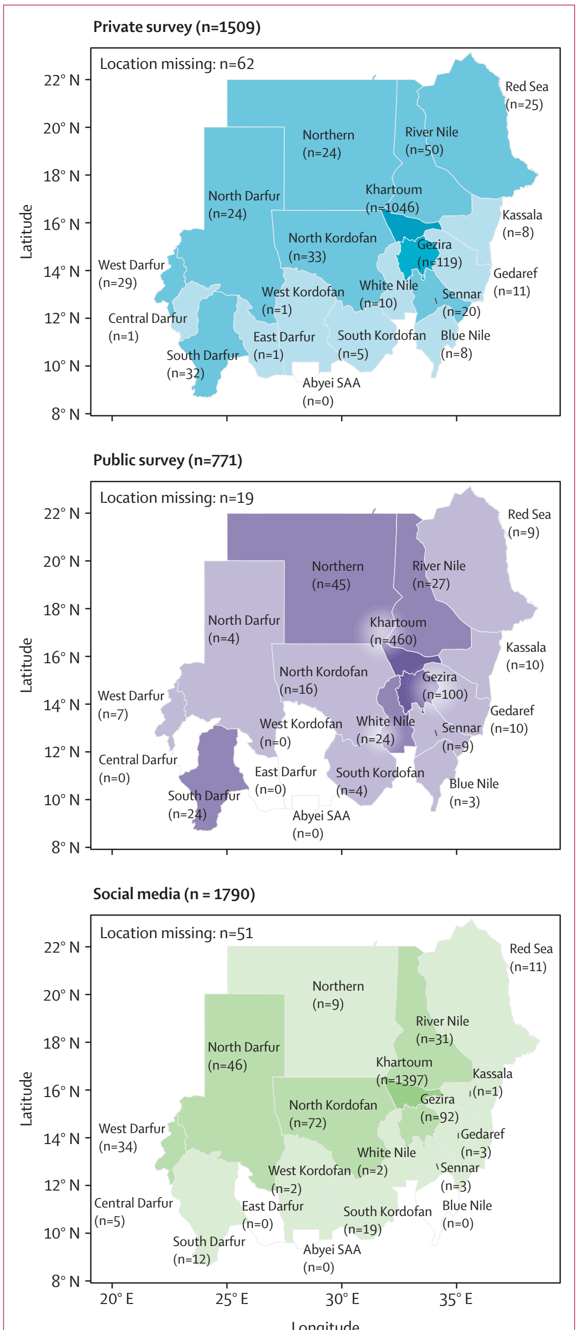

Figure 1: **Number of unique study-reported deaths in Sudan, by state and source during the period between April 15, 2023, and June 4, 2024, based on merging observations with within-list duplicate scores of ≥3 and between-list match scores of ≥4**

SAA=Special Administrative Area.

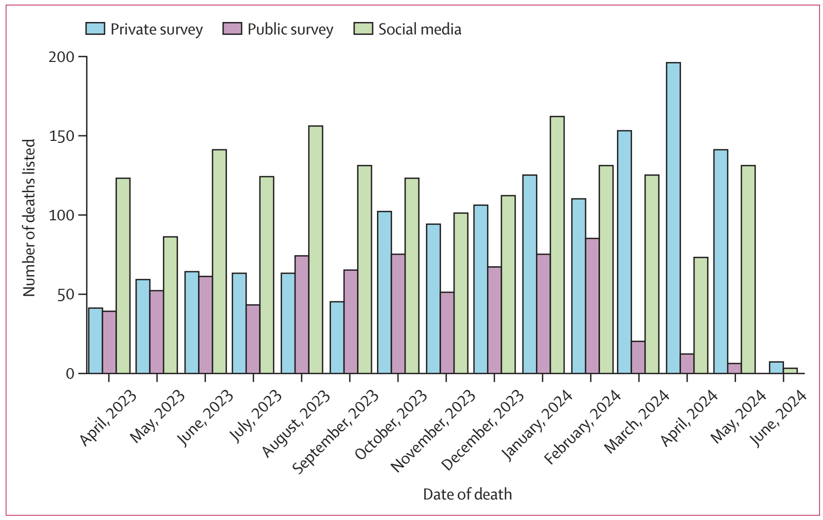

Figure 2: **Number of unique study-reported deaths in Sudan, by date and source during the period between April 15, 2023, and June 4, 2024, based on merging observations with within-list duplicate scores of ≥3 and between-list match scores of ≥4**

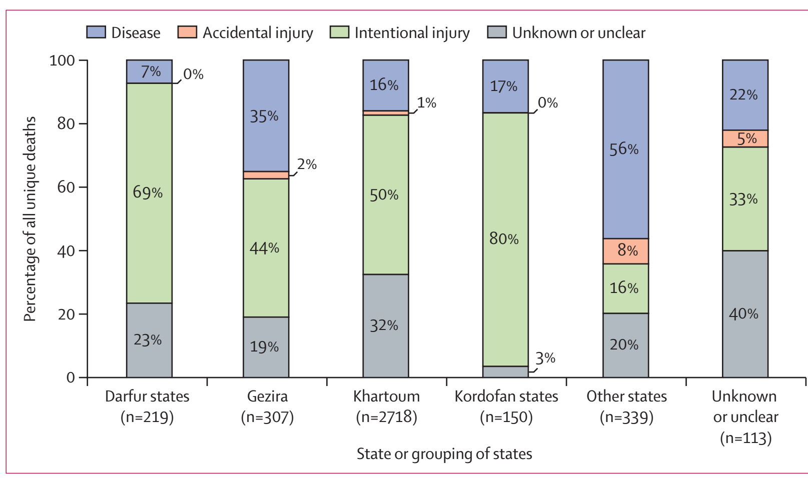

Figure 3: **Relative proportion of cause of death among study-reported deaths, by region during the period between April 15, 2023, and June 4, 2024, based on merging observations with within-list duplicate scores of ≥3 and between-list match scores of ≥4**

common in Khartoum (50%) and Gezira (44%) States (figure 3). Deaths from starvation and disease tended to increase over time (figure 4).

In Khartoum State between April 15, 2023, and June 4, 2024, we estimated, after simulation, 61 202 all-cause deaths (95% CI 22 286–209 151), which corresponded to an estimated crude death rate of 9·7 (95% CI 3·5–33·1) per 1000 persons per year or 0·27 (0·10–0·91) per 10 000 person-days. Among all-cause deaths we estimated 26 024 were due to intentional injuries (12 570–58 704). Overall, 57 957 (19 062–205 932) or 95% of all-cause deaths and 24 244 (17 031–56 292) or 93% of intentional-injury deaths were not captured by any of the three lists.

Sensitivity analyses suggested that varying the duplication score threshold had a moderate effect on overall estimates (appendix 1 p 18). Increasing cross-list matching score thresholds, however, yielded substantially different estimates, from 21 000 to 211 000 all-cause deaths under the most extreme score combinations. When considering more plausible score thresholds

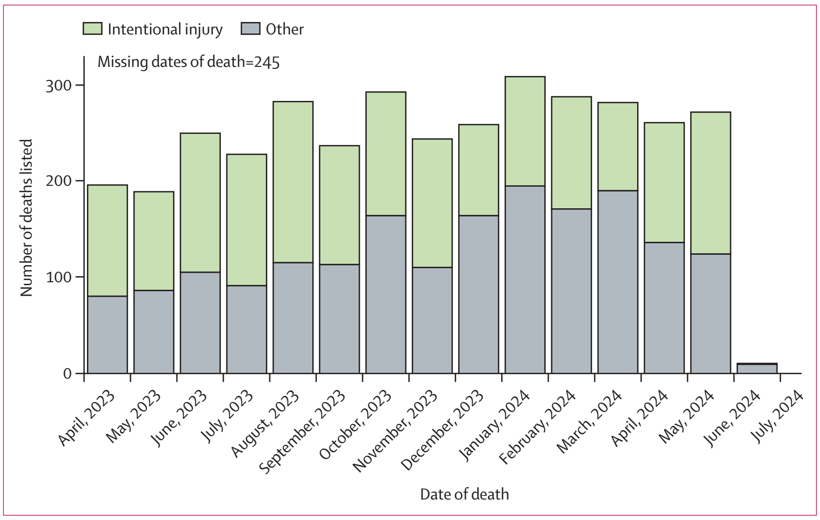

Figure 4: **Number of unique study-reported deaths in Sudan, by cause and date during the period between April 15, 2023, and June 4, 2024, based on merging observations with within-list duplicate scores of ≥3 and between-list match scores of ≥4**

(≥3 to ≥4 for both duplication and match scores) all-cause estimates were relatively stable, but intentional-injury deaths rose from about 7000 to 26 000.

Discussion

To the best of our knowledge, this is the first empirical all-cause mortality study in Sudan since the war began. We were only able to compose a death toll estimate for Khartoum State: our findings of about 26 000 intentional-injury deaths suggest a highly violent armed conflict in this populous region of the country. The estimated all-cause death toll of 61 202 features wide uncertainty and probable under-reporting: our estimated Khartoum State crude death rate (CDR) of 9·7 (95% CI 3·5–33·1) per 1000 person-years represents a considerable increase in mortality from the UN projected pre-war (ie, 2022) CDR of 6·5 deaths per 1000 person-year for Sudan as a whole.[15] Moreover, the pre-war CDR in Khartoum (no estimate of which is available to our knowledge) is likely to have been lower than the countrywide average, reflecting Khartoum's better socio-economic status and health service access. The estimated increase of CDR, albeit somewhat uncertain due to imprecise population denominators, is attributable to the considerable proportion of intentional-injury deaths in this state during the war period but plausibly also to worsened infectious, non-communicable, maternal, neonatal, and nutritional disease outcomes.[16] Our estimate thus illustrates a dramatic shift from what was once a relatively safe urban centre.

Our findings suggest that deaths in Sudan's war have largely gone undetected: we estimated that 95% of deaths did not appear on any of the three lists. Indeed, our estimated number of intentional-injury deaths for Khartoum State (n=26 024) surpasses that recorded by the Armed Conflict Location & Event Data Project (n=20 178) for the entire country during the same period.[17,18] This underreporting is similar to levels observed in past Sudan crises and other conflicts.[19,20]

Intentional injuries accounted for 42·5% of all deaths in Khartoum during the war period; by comparison, injuries (including intentional and accidental) caused an estimated 8·7% of all deaths in Sudan in 2021,[21] showing the extremely violent nature of the war in the country's capital. In Khartoum deaths are nonetheless likely to be more visible than elsewhere in Sudan due to disproportionate media focus and greater connections with diaspora networks able to report deaths.[22] We therefore speculate that other war-affected regions of the country could have experienced similar or worse mortality.

The highest proportions of deaths due to intentional injury were, expectedly, noted in areas of intense conflict, particularly the Kordofan and Darfur regions. Although these proportions are affected by unknown reporting bias (eg, survey participants could have been more likely to report people killed than non-violent deaths), they are consistent with historic and current patterns of ethnically targeted attacks in Darfur.[4,23] Countrywide, a slowly increasing proportion of deaths from non-injury causes is apparent (figure 4), possibly indicating emerging mortality associated with indirect effects of conflict (eg, a lack of access to health care, food insecurity, poor maternal and child health, and infectious diseases).[24]

This study has several limitations. Certain categories of mortality could have been underreported. First, reported child deaths were implausibly low, a pattern observed in previous mortality studies[25,26] and elsewhere,[27,28] despite divergent methods, and potentially reflecting socio-cultural norms; eg, a perception that adult deaths might be of greater public interest. Notably, Khartoum had disproportionate out-migration of women and children during the war, skewing the remaining population (about one third of the pre-war number) towards adult males. We found no alternative data sources to help assess the extent of child death underreporting. Second, we did not collect information about individuals of unknown status (ie, missing or otherwise no longer in contact with their families), some of whom could have died, resulting in further underreporting. Third, some individuals could have been hesitant to report deaths due to trauma, fear of reprisal, or lack of trust. To help address the latter we provided respondents with a dedicated website listing mental health resources and ran an extensive study media campaign highlighting data confidentiality and our impartiality and independence. Some underreporting might nevertheless have persisted due to a reluctance to participate among those most affected by the conflict. Fourth, all sources are likely to have had limited reach in rural, less connected populations, even though we enabled offline survey completion.

We were unable to rely on methods (eg, ground surveys) typically used outside insecure settings and instead leveraged community-reported data. We extensively propagated the surveys across diverse diaspora networks and purposively selected study ambassadors representing civil society and mutual aid networks within Sudan. Despite these steps, the relatively low data yield outside Khartoum State, where 60% and 70% of public and private survey data originated from, constrained the mortality estimation to only the capital state.

Due to data sparsity, we could not account for heterogeneity in capture probability, whereby certain individuals are more likely to be reported, by stratifying analysis by variables predictive of differential list membership probability. Instead, we included covariates (ie, cause of death, month of death, and the number of times the decedent was listed) in the final models, as proxies of possible preferential listing of injury deaths, varying list membership probability, and the effect of social network size or socio-economic status. Estimates would have been more robust if detailed location data and other proxies of connectedness and thus list membership probability, such as how respondents learned about the study, had been collected. Individual decedents' reporting frequency could be correlated with match probability, since duplicated records could, between them, have contained more information with which to confidently perform cross-list record linkage. However, interaction terms of reporting frequency and list membership should have accounted for this correlation.

Record linkage was conducted through a simulation that imputed missing variables (eg, name and age) assuming that they were not correlated. Although this assumption is difficult to assess, any degree of correlation likely increased uncertainty in probability distributions, as well as CIs. Nonetheless, the overall estimates arising from this simulation were within a range consistent with the score thresholds considered by expert consensus as least likely to misclassify duplicate or match status.

The matching process nonetheless remains subject to potential false positives (incorrectly merging individuals) and false negatives (missing true matches). Our attribution of equal weight to each identifying variable in the algorithm could be imperfect but relaxing this assumption while also simulating uncertainty in linkage would have been computationally arduous. Manual review of potential duplicates likely reduced linkage error, but residual misclassification could still bias estimates to an unknown extent. Finally, as with previous MSE mortality estimations in Sudan and elsewhere,[20,29,30] incomplete data, particularly on age and date of death, but also more broadly on circumstances of individual deaths, restricted our ability to fully characterise the circumstances of deaths and infer intentionality.

Sudan's war appears to have led to a substantial, largely unrecorded, rise in the death rate in Khartoum State and likely across the country. The number of intentional-injury deaths in the capital alone surpasses those estimated for the entire country in the war's first 14 months. Outside Khartoum, in historically conflict-affected regions, the exceptionally high proportions of intentional-injury deaths could reflect large-scale ethnically targeted violence, much of which is invisible. These observations should spur more in-depth investigations to support documentation of prevention and accountability for violations of human rights and war crimes. This study also underscores the pressing need for vigorous diplomatic initiatives to end the war and mitigate further substantial loss of life. It also emphasises the need for conflict-adapted and scaled-up humanitarian responses to address the largely preventable death toll across the country. Collaborative, multimethod efforts by researchers, Sudanese civil society, and humanitarian actors could achieve more accurate and geographically representative estimates than our single study and should be pursued in the future.

Contributors

MD, RA, and FC secured funding for the study. MD, RA, NA, AA, OA, IZA, FC, and CRM conceptualised the study and developed the study protocol. MD, RA, ZIAA, AA, OA, IZA, CG, MI, and LO conducted data collection activities. MD, RA, FC, CG, and CRM designed the data collection method and FC developed the analysis method. MD, RA, CRM, AA, MN, and LC carried out project administration. PE, CG, and CRM developed data entry software and resources. MD, CRM, RA, and AA supervised data collection and MD supervised data cleaning and analysis. MD, RA, and FC visualised the results and MD, RA, and CRM drafted the original manuscript. All authors reviewed and edited the manuscript and provided final authorisation for submission. All authors had full access to all the data in the study; all authors had final responsibility for the decision to submit for publication; and eight identified authors (MD, RA, AA, OA, IZA, LO, ZIAA, and MA) directly accessed and verified the underlying data reported in the manuscript.

Equitable partnership declaration

The authors of this paper have submitted an equitable partnership declaration (appendix 2). This statement allows researchers to describe how their work engages with researchers, communities, and environments in the countries of study. This statement is part of The *Lancet Global Health's* broader goal to decolonise global health.

See **Online** for appendix 2

Declaration of interests

We declare no competing interests.

Data sharing

The de-identified dataset and analysis code supporting the conclusions of this Article are available online.

For the **de-identified dataset and analysis code** see https://github.com/francescochecchi/sdn_mortality_2024

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