Traumatic injury mortality in the Gaza Strip from Oct 7, 2023, to June 30, 2024: a capture–recapture analysis

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Summary

Background Accurate mortality estimates help quantify and memorialise the impact of war. We used multiple data sources to estimate deaths due to traumatic injury in the Gaza Strip between Oct 7, 2023, and June 30, 2024.

Methods We used a three-list capture–recapture analysis using data from Palestinian Ministry of Health (MoH) hospital lists, an MoH online survey, and social media obituaries. After imputing missing values, we fitted alternative generalised linear models to the three lists' overlap structure, with each model representing different possible dependencies among lists and including covariates predictive of the probability of being listed; we averaged the models to estimate the true number of deaths in the analysis period (Oct 7, 2023, to June 30, 2024). Resulting annualised age-specific and sex-specific mortality rates were compared with mortality in 2022.

Findings We estimated 64 260 deaths (95% CI 55 298–78 525) due to traumatic injury during the study period, suggesting the Palestinian MoH under-reported mortality by 41%. The annualised crude death rate was 39·3 per 1000 people (95% CI 35·7–49·4), representing a rate ratio of 14·0 (95% CI 12·8–17·6) compared with all-cause mortality in 2022, even when ignoring non-injury excess mortality. Women, children (aged <18 years), and older people (aged ≥65 years) accounted for 16 699 (59·1%) of the 28 257 deaths for which age and sex data were available.

Interpretation Our findings show an exceptionally high mortality rate in the Gaza Strip during the period studied. These results underscore the urgent need for interventions to prevent further loss of life and illuminate important patterns in the conduct of the war.

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Introduction

Since Oct 7, 2023, Israel's military operation in the Gaza Strip has attracted widespread scrutiny and is the subject of war crimes investigations. Mortality among civilians is a key metric by which a conflict's conduct and its public health consequences might be assessed.[1] In 2021, the Palestinian Ministry of Health (MoH) in the Gaza Strip had achieved good accuracy in mortality documentation, with under-reporting estimated at 13%.[2] The MoH's Health Information Centre sourced mortality data from hospital morgues and recorded these onto an electronic information system.[3] Its published death tolls during one of the previous large-scale Israeli military operations in 2014 were considered reliable, coming within 4% of the UN's and 8% of the Israeli military's estimates.[3] At the onset of the current military operation, the MoH continued to track individual deaths due to traumatic injury, and its reports were shown to be credible.[4–6]

However, in the time since October, 2023, the quality of MoH mortality data appeared to deteriorate, as indicated by increasing numbers of unidentified (ie, no name or other unique identifiers)[3] decedents (table 1, figure 1). The escalation of Israeli military ground operations and attacks on health-care facilities severely disrupted the latter's ability to record deaths electronically. These challenges compelled the MoH to rely on less structured data collection modalities, particularly when hospitals were under siege or experiencing telecommunication blockades. This might have led to incomplete and geographically biased reporting, as seen in other conflict zones where prolonged warfare complicates casualty tracking.[8]

A range of estimates of mortality in the Gaza Strip since October, 2023, have been published. As of June 30, 2024, the MoH reported 37 877 decedents, of whom 28 185 were identified.[7] The UN Office for the Coordination of Humanitarian Affairs (OCHA) estimated around 10 000 individuals were missing under rubble and presumed dead.[9] The International Committee of the Red Cross listed 8617 Palestinians who had been reported missing to them as of June 30, 2024, although these numbers might include people imprisoned by Israel.[10] The Euro-Mediterranean Human Rights Monitor tallied 45 223 deaths as of June 12, 2024, including those under the rubble, but with an unclear method.[11] The Armed Conflict Location & Event Data Project (ACLED) had counted 39 276 deaths from media, civil society, and government sources as of June 30, 2024 (appendix p 2),[12] while Israel's Prime Minister claimed that around 30 000 people had been killed in the Gaza Strip as of

See Online for appendix

Research in context

Evidence before this study

Multiple sources have questioned the accuracy and reliability of mortality figures reported by the Palestinian Ministry of Health (MoH) in the Gaza Strip during the ongoing Israeli military operation. Critics have raised concerns about exaggerated numbers of deaths, citing issues such as potential data manipulation, missing identifications, and inconsistencies in demographic classifications. Others point to potential under-reporting, citing deteriorating data collection systems and unretrieved bodies. No literature search was done.

Added value of this study

Our study uses capture–recapture methods to estimate total deaths from traumatic injury in the Gaza Strip from Oct 7, 2023, to June 30, 2024. By combining three data lists—official hospital lists, an MoH survey, and social media obituaries—we provide an estimate of mortality that accounts for under-reporting. We estimate a total mortality from traumatic injury of 64 260 (95% CI 55 298–78 525), implying that the MoH reports underestimated deaths by 41%. As of October, 2024, the official MoH estimate stood at 41 909, which would suggest that the true mortality figures probably exceeded 70 000. This study emphasises the importance of leveraging statistical methods to accurately estimate armed conflict-related deaths, rather than solely relying on reported figures.

Implications of all the available evidence

The high mortality rates shown by our study, combined with previous evidence, underscore the severe crisis in the Gaza Strip. Our findings validate concerns raised by Palestinian and international organisations, including reputable human rights and humanitarian organisations and UN special rapporteurs, about the scale of civilian casualties. Our study supports the view that the MoH figures are more likely to underestimate than overestimate mortality. This evidence confirms the need for urgent international interventions to prevent further loss of life and address the long-term health consequences of the Israeli military assault in Gaza.

	Time span covered (from Oct 7, 2023)	Hospital-identified decedents	Online survey individual decedents	Unidentified decedents	Cumulative total
Update 1	Oct 26, 2023	6746	NA	280	7026
Update 2*	Jan 5, 2024	14 117	NA	8483	22 600
Update 3	March 29, 2024	18 428	1563	12 632	32 623
Update 4	April 30, 2024	19 730	3257	11 548†	34 535
Update 5	June 30, 2024	22 368	5817	9692	37 877

NA=not applicable. *Hospitals in Gaza City and North Gaza governorates stopped reporting on Nov 2, 2023. †The number of unidentified records decreased after update 3 as the Palestinian Ministry of Health was able to retrospectively attribute an identity to some of these.

***Table 1:* Composition of successive traumatic injury death updates from the Palestinian Ministry of Health**[7]

May, 2024.[13] Although these numbers are understood to refer to deaths due to traumatic injury, others have speculated that the indirect effects of the military operations against Gaza could push all-cause excess mortality to 186 000.[14] On May 8, 2024, OCHA changed its reporting method for mortality in the Gaza Strip, henceforth distinguishing identified and unidentified decedents.[15] This adjustment re-ignited questions about the reliability of official mortality data.

Capture–recapture analysis, initially popularised by ecologists, has been used to estimate mortality and other violent outcomes in armed conflict zones including Kosovo,[16] Colombia,[17] and Sudan.[18] This method, also known as multiple systems estimation or mark–recapture, uses multiple data sources (lists) with sufficient identifying information to accurately link records, identify overlapping cases, and infer the true number of cases (deaths), including those not featured within any list, based on statistical models. We used capture–recapture analysis of three publicly available lists of deceased people to retrospectively estimate mortality due to traumatic injury in the Gaza Strip from Oct 7, 2023, to June 30, 2024.

For the **Gaza MoH survey platform** see https://sehatty.ps/moh-registration/public/add-order

Methods

Data sources

In this capture–recapture study, we composed three lists from successive MoH-collected hospital morgue data, an MoH online survey, and obituaries published on public social media pages. The MoH publicly released five cumulative updates presenting both hospital morgue and online survey mortality and spanning the period Oct 7, 2023, to June 30, 2024 (table 1). These updates comprise 22 368 decedents who died in hospital or who were brought to hospital morgues for whom Palestinian ID numbers, names (first name, father's name, grandfather's name, family name), age at death, and sex were reported. The updates also contain aggregate numbers of hospital-reported and media-reported unidentified deaths (n=9692). The highest proportions of unidentified deaths were observed in the January (38%), March (39%), and April (33%) updates (table 1). The MoH then retrospectively identified some of these decedents, reducing the cumulative proportion of unidentified deaths to 26% (table 1) as of update 5. We used the records of hospital-identified decedents as our first list for capture–recapture analysis (hereafter, the hospital list). We excluded hospital-reported and media-reported unidentified decedents.

On Jan 1, 2024, the MoH launched a rolling mortality and missing persons survey, initially conducted via Google Forms (no longer accepting responses) and later hosted on the Gaza MoH survey platform. The survey was disseminated through various social media platforms (Facebook, WhatsApp, Telegram, and Instagram) to Palestinians living in and outside the Gaza Strip and recorded data on Palestinian ID numbers, names, age at death, sex, location of death, and reporting source. The survey collected data retrospectively back to Oct 7, 2023, and its results were included in MoH mortality updates, albeit separately (table 1). We obtained raw survey data from the MoH and used these as our second capture–recapture list (hereafter, the survey list). We excluded 930 people reported missing from the analysis but conducted a sensitivity analysis including these individuals as assumed decedents and otherwise using the same methods as for the main analysis.

We manually scraped information from open-source social media platforms, including specific obituary pages for *Gaza shaheed*,[19] *martyrs of Gaza*,[20] and *The Palestinian Information Center*[21] to create our third capture–recapture list (hereafter, the social media list). These pages are widely used obituary spaces where relatives and friends inform their networks about deaths, offer condolences and prayers, and honour people known as martyrs (those killed in war). The platforms span multiple social media channels, including X (formerly Twitter), Instagram, Facebook, WhatsApp, and Telegram. Throughout the study period, these pages were updated periodically and consistently, providing a comprehensive source of information on casualties. Obituaries typically included names, age at death, and date and location of death, and were often accompanied by photographs and personal stories. We translated English posts into Arabic to match names across lists and excluded deaths attributed to non-traumatic injuries.

Ethical approval for this study was obtained from the London School of Hygiene & Tropical Medicine (reference number 31101). Analysis code and anonymised data are published on the GitHub platform (https://github.com/ZeinaJamaluddine/gaza_mortality_capture_recapture).

Data management and record linkage

We excluded records with dates of death outside the analysis period (Oct 7, 2023, to June 30, 2024), verified the correct length of Palestinian ID numbers, and checked for implausible ages. We standardised Arabic names across all sources, addressing common issues such as family names with and without the prefix Al (ال); variations in family names such as Abu (أبو) and Bu (بو); names interchangeably ending with tah ة and ha ه; and letters with a shadda ّ (accent). Records with unclear names (only a first name, or descriptors such as daughter of or wife of in lieu of the person's actual name) were considered unsuitable for linkage and excluded.

A multistep approach was used to remove duplicates within each list and match decedents across the three datasets. This process involved Palestinian ID numbers, probabilistic linkage using the reclink2 Stata package version 18, and manual review.

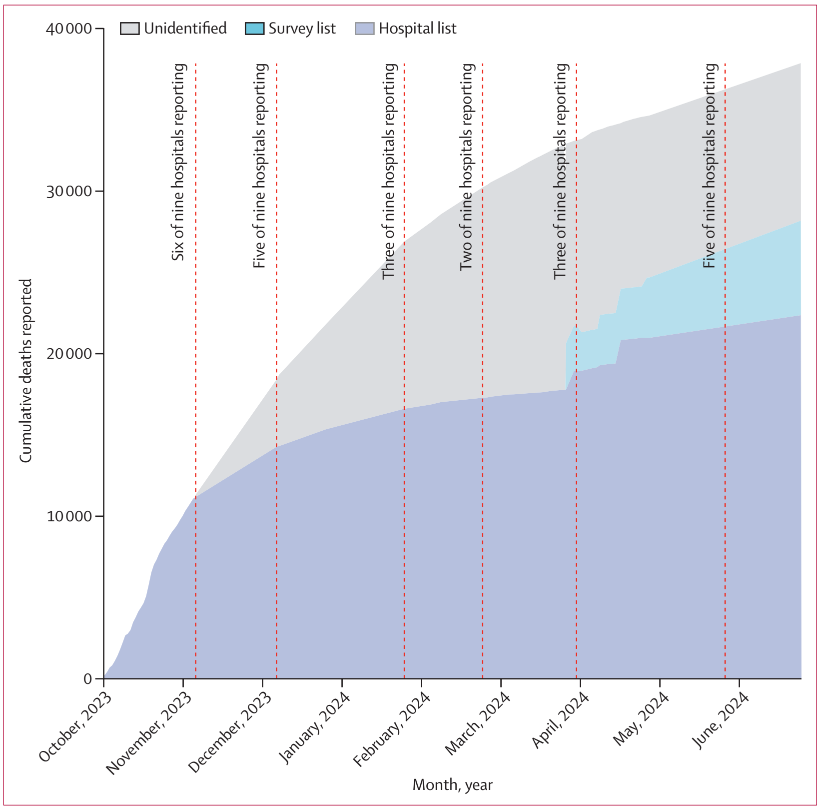

Figure 1: **Cumulative number of deaths from traumatic injury reported by the Palestinian Ministry of Health over time, by source**
Numbers of reporting hospitals are shown to provide context.

De-duplication of data

Each entry on the list was initially de-duplicated using Palestinian ID numbers where available. For records without matching IDs, probabilistic linkage was applied using the reclink2 package. This allows for many-to-one matching between datasets, implementing a matching algorithm that compares records based on specified variables, calculates match probabilities, and selects the best matches using a composite similarity score. We gave greater weight to first and family names, followed by father's and grandfather's names (appendix p 3), reflecting the typical structure of Palestinian names. Duplicates identified by the probabilistic linkage algorithm with a probability of 80% or higher were reviewed manually by two independent researchers who separately reviewed their share of all potential duplicates. If either researcher was uncertain about a match, they discussed the discrepancies to reach consensus. This approach allowed for efficient review while providing a mechanism for addressing uncertain cases. De-duplication of the social media data also involved manually reviewing accompanying photographs.

Cross-list matching

After de-duplication, decedents were matched across the hospital list, survey list, and social media list. Records were first linked deterministically between the hospital and survey lists using Palestinian ID numbers. For remaining unmatched records, reclink2 probabilistic linkage was used with the same weighting criteria used in de-duplication (appendix p 3). Records that did not link automatically and matches with a probability of 95% or higher were subject to manual review as described. The same approach was then used for the social media list.

Cross-list matching yielded 2126 matches between hospital and survey lists (1902 deterministically by ID, 213 probabilistically, and 11 by manual review), 1370 matches between social media and hospital lists (1353 probabilistically and 17 manually), and 548 matches between social media and survey lists (521 probabilistically and 27 manually).

Statistical analysis

The dataset featured missingness in age, sex, and month of death (appendix p 4). For missing value imputation, we generated 100 datasets featuring imputed values of these variables using the R multivariate imputation by chained equations (mice) package[22] (version 3.17.0) with five iteration chains. For age and sex, we used a random forest predictive algorithm after verifying that it yielded an imputation distribution similar to that of non-missing values (appendix p 5). For month of death, we sampled from the distribution of non-missing months, as other imputation methods in the mice package under-represented months with fewer deaths.

Three-list capture–recapture analysis relies on fitting alternative log-linear models to the matched dataset. Eight alternative models are possible: each must contain terms for the probability of appearing on list 1 (hospital list), list 2 (survey list), and list 3 (social media list), plus terms for none, one, or several of the possible two-way interactions among lists. These interactions represent dependencies among lists (for example, a death appearing on list 1 might be more likely than at random to also appear on list 3). Potential covariates that help account for individual heterogeneity in list inclusion can be included in the model, in which case their interactions with the list terms should also feature. In Rossi and colleagues' formulation,[23] generalised Poisson linear models are fitted to an expanded dataset in which each case (decedent) features each of the possible outcomes 000, 001, 010, 100, 011, 101, 110, or 111, where the three dummy 0 or 1 digits denote whether the decedent appears on lists 1, 2, and 3 respectively. The true outcome is attributed value 1, the outcome 000 a missing value, and other outcomes a 0 value. The model predicts the value of each outcome, and the individual predictions of the 000 outcome are summed over all cases to provide an estimate of deaths not appearing on any list, which are then added to deaths appearing on one or more lists to infer total mortality. This formulation also readily allows for covariates (eg, age) to be included in the model formula. We computed Wald 95% CIs for the predictions; while recognising that bootstrapping or profile intervals might have better coverage, these were computationally prohibitive given the large dataset and number of imputations.

For the **Multiple Source Capture Recapture app** see https://fellstat.github.io/shinyrecap/

Instead of selecting one of the candidate models, we averaged their predictions as shown by Rossi and colleagues[24] after weighting each model i by its posterior probability W_i (range 0–1), expressed here as a function of the Akaike Information Criterion (AIC), which combines the desirable characteristics of goodness of fit and parsimony while being a correlate of both Bayes factors and predictive performance. Specifically:

$$W_i = \frac{e^{(-\Delta_i/2)}}{\sum_{r=1}^{R} e^{(-\Delta_i/2)}}$$

where R is the total number of candidate models (eight for the three-list scenario) and $\Delta_i = AIC_i - AIC_{min}$ (ie, the difference between each model's AIC and the lowest AIC among all models). To mitigate bias due to heterogeneous individual probabilities of capture (inclusion within a list), we stratified the analysis as follows: (1) by age category (in 15-year bins) and sex, with (1a) no covariate or (1b) month of death included as a categorical covariate; (2) by month of death, with age (continuous) and sex as covariates. Model averaging was done within strata. We used 1a to compute all-age and all-sex estimates, as it featured lower AIC than stratification 2. We settled on the inclusion of covariates as they improved fit (based on a likelihood-ratio test comparing the models with and without each covariate) or substantially altered the point estimate of unlisted deaths. Although stratification 1b had marginally lower AIC than 1a, its CIs were far wider, hampering interpretation.

Various approaches to capture–recapture analysis have been proposed. To explore how our choice of individual-level log-linear modelling might have affected estimates and to check for any programming errors, we also analysed data as per the age–sex stratification (1a) using the following: a mixed logit model (equivalent to a quasi-symmetry version of the log-linear model);[25] a decomposable graphical Bayesian model averaging (BMA) approach (R package dga),[26] assuming non-informative priors; and a log-linear model minimising AIC, as implemented through the Multiple Source Capture Recapture app. As the described approaches all analyse aggregate contingency tables of list membership, we constructed these for each age–sex stratum by taking the mode of imputed age and sex values. Resulting comparisons are shown in the appendix (p 6).

We also estimated the sensitivity of each list (number of unique deaths present on the list divided by point estimate of total estimated deaths, with 95% CI given by using the CI of estimated deaths in the denominator) and annualised crude and age–sex-specific mortality rates computed by dividing our model estimates or their 95% CI by the UN Population Fund's projections for the 2023 population of Gaza based on the 2017 census, for which we did not assume any uncertainty.[2,27]

Role of the funding source

There was no funding source for this study.

Results

The three lists (hospital, survey, and social media) included unique records for 29 271 named people killed as a result of traumatic injuries sustained in the Gaza Strip between Oct 7, 2023, and June 30, 2024. 22 368 hospital records were initially collected, of which 22 347 were used for the analysis after excluding 21 duplicates or unclear names (appendix p 4). The survey list initially contained 10 544 entries, but 2033 duplicate records and 930 individuals reported as missing rather than killed were excluded, leaving 7581 uniquely identified decedents. We extracted 3190 unique decedent records from social media obituaries after de-duplication. Of the three different lists, the hospital list identified the largest number of deaths and had no missing data, whereas within the social media list, sex was missing for two (0·1%) of 3190 records, month of death was missing for 142 (4·5%) records, and age at death was missing for 957 (30·0%) records (appendix p 4).

The distribution of deaths by month, age, and sex across the different lists (excluding missing values) is shown in figure 2. There were peaks in October, November, and December, 2023, followed by a decrease

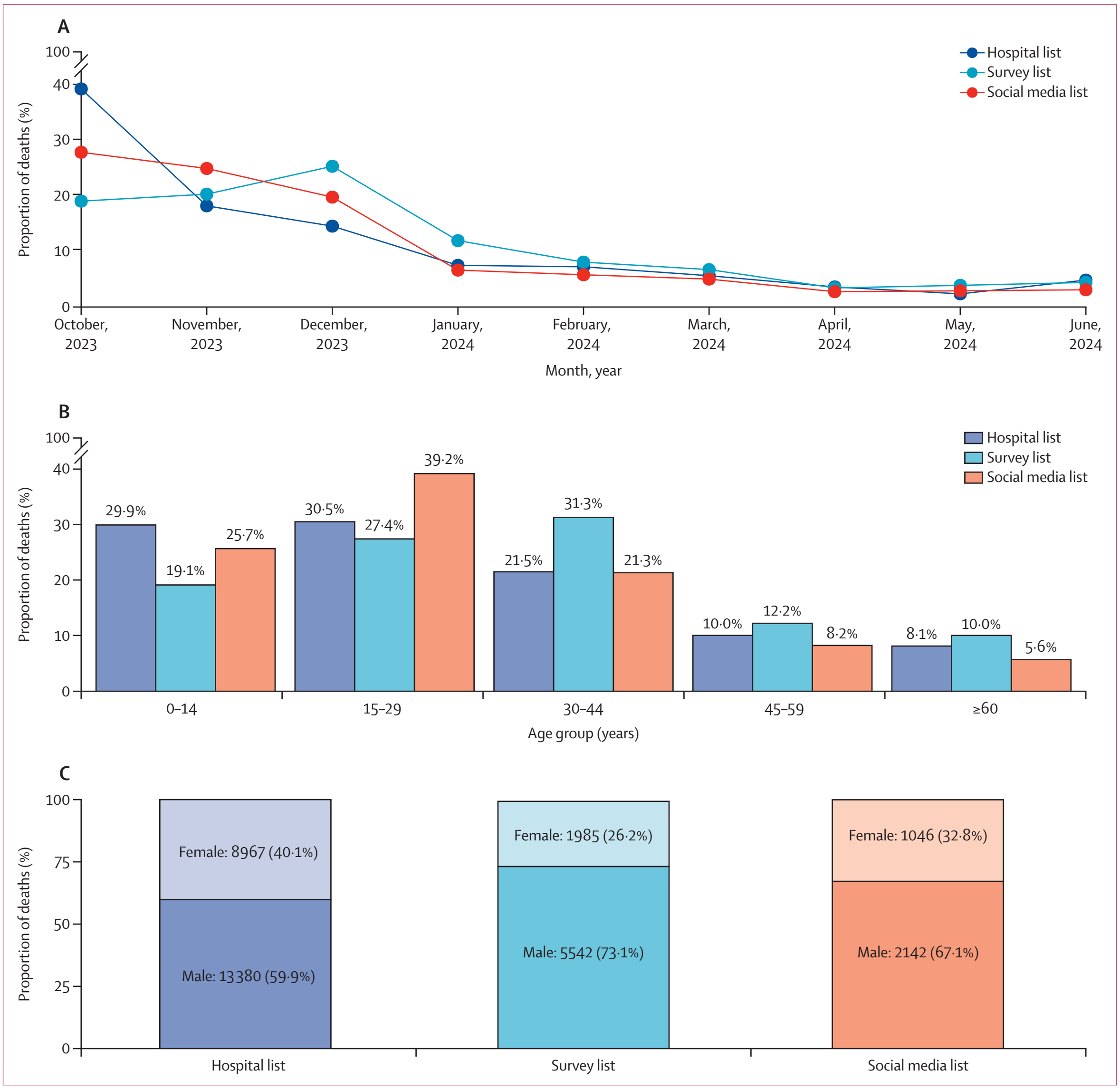

Figure 2: **Percentage distribution of listed deaths from traumatic injury by month of death (A), age (B), and sex (C) within each list**

in April and May, 2024, and a subsequent increase in June, 2024 (coinciding with escalations in Israeli ground and aerial attacks in Rafah and Khan Younis).

Age or sex data were missing for 1014 (3·5%) of the 29 271 total deaths reported by at least one list. 28 257 reported deaths had age and sex data available. 10 499 (37·2%) of those with age and sex data available were female and 17 758 (62·8%) were male. Children younger than 18 years accounted for 9423 (33·3%) deaths, while older adults (aged ≥65 years) accounted for 1628 (5·8%) deaths. Women aged 18–64 years represented 5648 (20·0%) of the total. Overall, women, children, and people aged 65 years or older accounted for 16 699 (59·1%) deaths due to traumatic injury.

1721 (53·9%) of 3190 deaths reported on social media had a match within the hospital or survey lists, or both, while 2477 (32·7%) of 7581 deaths reported in the survey list matched with hospital or social media records, or both (figure 3). The hospital list showed the least overlap, with only 3299 (14·8%) of 22 347 deaths matching with records in other lists (figure 3). The mean estimate of deaths outside any list was 34 995 (95% CI 26 034–49 262; table 2). Collectively, the three lists captured 45·4% (95% CI 37·2–52·7) of the estimated total deaths (appendix p 7). Adding the estimates of deaths outside any lists to those recorded by at least one list yielded a total estimated 64 260 deaths (95% CI 55 298–78 525) caused by traumatic injury. The log-linear model estimated 65 689 deaths (61 044–71 162), and the mixed logit model estimated 61 277 deaths (47 457–88 332), reasonably close to our main estimate. However, the BMA model estimated fewer deaths (50 663 [95% CI 45 912–55 980]) than the other models (appendix p 6). If missing people as reported in the survey list are included in the analysis as decedents, the overall estimate would increase to 68 662 (95% CI 58 735–84 472; see appendix p 8).

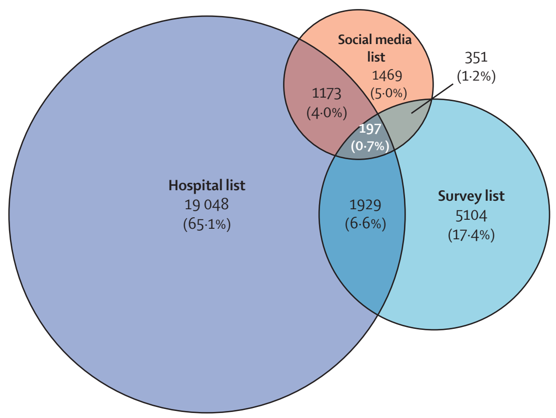

Figure 3: **Overlap of decedents among the three lists (hospital, survey, and social media)**

	Deaths outside any list (95% CI)*	Posterior probability across strata†
No interactions	36 906 (32 181–42 448)	0·015
Hospital × social media, hospital × survey, and social media × survey	36 583 (18 964–80 982)	0·208
Hospital × social media and hospital × survey	20 862 (14 396–31 036)	0·118
Hospital × social media and social media × survey	47 825 (40 236–57 057)	0·250
Hospital × survey and social media × survey	26 091 (19 683–35 419)	0·183
Hospital × social media	42 697 (36 400–50 253)	0·006
Hospital × survey	23 519 (18 501–30 357)	0·115
Social media × survey	39 308 (34 020–45 568)	0·105
Estimated deaths outside any list	34 995 (26 034–49 262)	··

*Median of all imputations, aggregated by age–sex strata, with 95% CIs. †Mean posterior probabilities across all imputations and age–sex strata for each model.

Table 2: **Estimates of traumatic injury deaths outside any list by model**

Mortality was highest in October, November, and December, 2023 (appendix p 9). Combined list sensitivity was lowest in November and December, 2023, coinciding with the heaviest intensity of aerial bombardment during the analysis period (appendix p 2).

We estimated an annualised rate of deaths from traumatic injury of 39·3 per 1000 people (95% CI 35·7–49·4) or 1·1 per 10 000 person-days. In comparison, the crude death rate from all causes in 2022 was 2·8 per 1000 people,[28] yielding a rate ratio of 14·0 (95% CI 12·8–17·6). This ratio is inherently downward-biased as it excludes deaths due to non-injury causes during the military operation period. Age-specific and sex-specific mortality are shown in figure 4. Among females, rates were remarkably flat across the age range, suggesting a uniformly high risk of being killed from childhood into older age; among males, a moderate peak was observed in individuals aged 15–45 years.

Discussion

Our analysis suggests high mortality rates and substantial under-reporting of mortality due to traumatic injury in the Gaza Strip during the first 9 months of the Israeli military operation. We estimated around 64 000 deaths due to traumatic injuries from Oct 7, 2023, to June 30, 2024, implying 41% under-reporting in the MoH estimate over the same period and corresponding to approximately 2·9% of Gaza's projected pre-war population (2 227 000), or approximately one in 35 inhabitants. Although we only analysed data up to June, 2024, the official MoH estimate from Oct 7, 2023, to Oct 6, 2024, was 41 909. Assuming that the level of under-reporting of 41% continued from July to October, 2024, it is plausible that the true figure now exceeds 70 000. Our study demonstrates the utility of integrating existing data from alternative sources, rather than relying on any single figure, to compose an estimate of both reported and unreported deaths in contexts affected by armed

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conflict and extreme violence. Our use of scraped social media data extends previous efforts by Airwars, a casualty tracking organisation, who found that during the first 3 weeks of the Israeli military operation, 75% of publicly reported decedents also appeared on the MoH list[5] (by contrast, we found an overlap of 54% or 1721 of 3190 during the entire study period).

The estimated annualised mortality from traumatic injury of 39·3 per 1000 people is exceptionally high, surpassing rates seen during earlier conflicts in the Gaza Strip.[8,29] Although daily traumatic injury mortality decreased since December, 2023, both the scale and age–sex patterns of traumatic injury deaths raise grave concerns about the conduct of the military operation in Gaza despite Israel stating that it is acting to minimise civilian casualties. The majority of deaths (59·1%) occurred among women, children, and older people, groups considered particularly vulnerable in conflict-affected settings and less likely to be combatants. The age–sex pattern of mortality during violent conflicts might help investigate the motivations of combatants, albeit only within a much broader evidentiary context. A lack of discrimination in killings by age and sex would manifest itself numerically as a relatively flat age–sex risk—eg, as described by the UN Inter-Agency Group for Child Mortality Estimation during the 1994 Rwandan genocide.[30] Our estimates for deaths among women and girls broadly exhibit such a pattern. Among men and boys, we cautiously propose that two processes might be at work: a level of mostly non-discriminant killing across age and sex, with higher risk among young men explained by targeting of combatants (or those presumed to be) plus greater exposures to risk among this stratum—eg, because adult men are more often outdoors procuring supplies, working, or being first responders.

Our findings underestimate the full impact of the military operation in Gaza, as they do not account for non-trauma-related deaths resulting from health service disruption, food insecurity, and inadequate water and sanitation. A recent commentary suggests a potential excess all-cause death toll of 186 000,[14] but it applied multiplication factors from other conflicts (Burundi, 1993–2003; Timor-Leste, 1974–99)[14] to estimate indirect deaths in the Gaza Strip, which might be inappropriate due to obvious differences in the pre-war burden of disease (compared with Burundi and Timor-Leste, the Gaza Strip featured a high burden of non-communicable disease and a very low burden of undernutrition and infectious disease, although infections have become an increasing challenge since October, 2023).[31] Projections we previously coauthored suggested that in an escalation scenario, Gaza would have experienced 2680 excess deaths from non-communicable diseases, 2720 from endemic infectious diseases, 11 460 from potential epidemics, and 330 from maternal and neonatal health complications during the period from February to August, 2024.[32] However, accurately measuring indirect

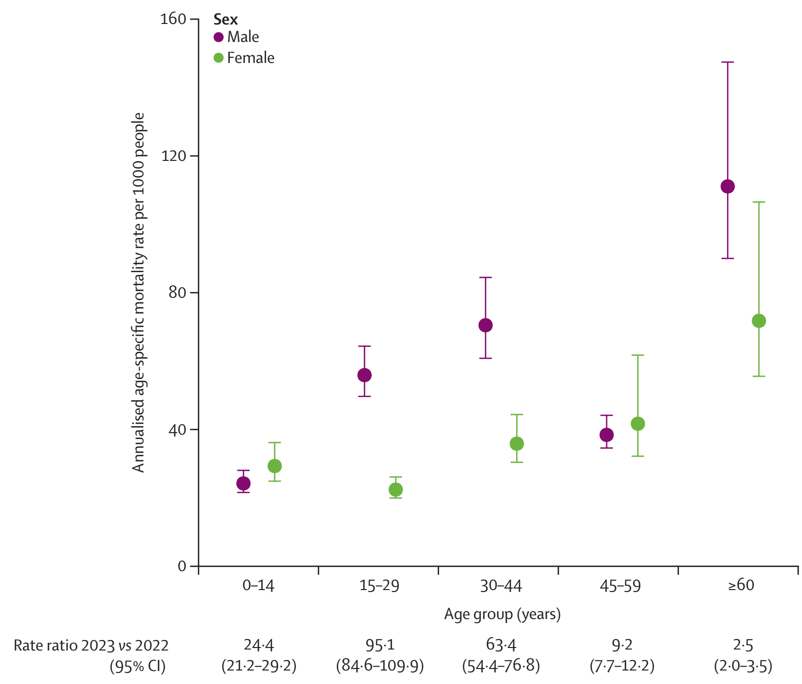

Figure 4: **Annualised age-specific and sex-specific mortality from traumatic injury per 1000 people between Oct 7, 2023, and June 30, 2024**
Age-specific rate ratios (for both sexes combined) are shown, with the 2022 mortality rates as the reference.

mortality during an ongoing war is fraught with challenges and limitations. Although a ground survey could yield robust estimates, the highly unsafe conditions for humanitarian and health workers inside Gaza and access constraints currently make it unfeasible.

Limitations of our study include challenges in data cleaning and standardisation, particularly in reconciling variations in name spellings and translations. The exclusion of individuals identified only by familial relationships might have resulted in overestimation or underestimation depending on the probability of those individuals matching across lists, relative to other decedents. Generally, although key identifier variables for record linkage were consistently available, any misclassification of match status would result in some bias.

The omission of covariates not available in the datasets might have biased model estimates to an unknown extent by insufficiently accounting for heterogeneity in individual capture probabilities. Although three-list analysis with model averaging and stratification generally relaxes the assumption of list independence, some residual dependence among lists might not have been reflected in the estimates due to model misspecification and the theoretical limits of any candidate modelling approach. Additionally, we assumed that MoH hospital and survey lists captured only deaths due to traumatic injury. The survey specifically asked respondents to enter details of those martyred, a term commonly understood to signify victims of war. However, some non-trauma deaths might have been included, potentially resulting in an overestimation of deaths due to traumatic injury. This would not affect estimates of all-cause mortality. Conversely, we excluded people reported as missing because we were unable to discern if they were detained and imprisoned or potentially deceased but unrecovered under rubble. If these missing people were included in the analysis, the overall estimate would increase. Last, we were unable to stratify estimates by geography because location variables included in the lists were frequently missing or reflected the place of reporting or of morgues rather than the exact place of death. ACLED, using a combination of MoH reports and media sources, documented 10 400 geo-located conflict events in the Gaza Strip over our study period,[12] of which 4260 (40·9%) had known casualty numbers, summing to 39 276 deaths. Although ACLED-reported deaths also decreased progressively from October, 2023 onwards, the relative share of mortality shifted towards central and southern governorates over time (Khan Yunis and Deir el Balah first, and later Rafah; appendix p 2). This geographical progression mirrors the pattern of destruction across the Gaza Strip, initially concentrated in Gaza City and North Gaza and expanding southward over time (appendix p 2).

For **Marsad Shireen** see https://www.shireen.ps/home

Our analysis supports the accuracy of the MoH-reported mortality figures but suggests that these are to be treated as a minimum estimate subject to considerable under-reporting. Once the military assault ends, reconstructing Gaza's health information system emerges as an essential priority for accurately assessing impacts and supporting future public health efforts. A robust health information system is crucial for accurate mortality reporting, early disease outbreak detection, efficient resource allocation, and informed long-term health planning.

Our findings highlight the urgent need for expanded humanitarian access to all of the Gaza Strip and protection of health-care personnel, ambulances, and static health facilities so that people with traumatic injuries can access timely and appropriate care, thereby reducing case-fatality. More fundamentally, our findings warrant immediate diplomatic initiatives to achieve an immediate and sustained cessation of hostilities and a lasting deal that includes the release of Israeli hostages and thousands of Palestinian civilians imprisoned by Israel.[10] Just as in other settings, active investigation of potential war crimes committed seems important to affirm justice principles and hold perpetrators from all sides accountable. Quantitative analyses similar to ours have previously informed these investigations.[16] We thus encourage the scientific community to supplement and improve on our work, while also extending it to other settings.

Contributors
ZJ conceptualised the study, extracted, analysed, and visualised the data, and wrote the original draft of the manuscript. HA and SA supported the data extraction and reviewed and edited the manuscript. OMRC contributed to the revision and editing of the manuscript. FC contributed to study conceptualisation, supervised the study, provided statistical input, and reviewed and edited the manuscript. All authors reviewed and approved the final version of the manuscript. ZJ and FC accessed and verified the data and the analysis. All authors have access to all the data and share final responsibility for the decision to submit for publication.

Declaration of interests
We declare no competing interests.

Data sharing
All the data used in this study are publicly available. All the data and analyses are available on https://github.com/ZeinaJamaluddine/gaza_mortality_capture_recapture.

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