

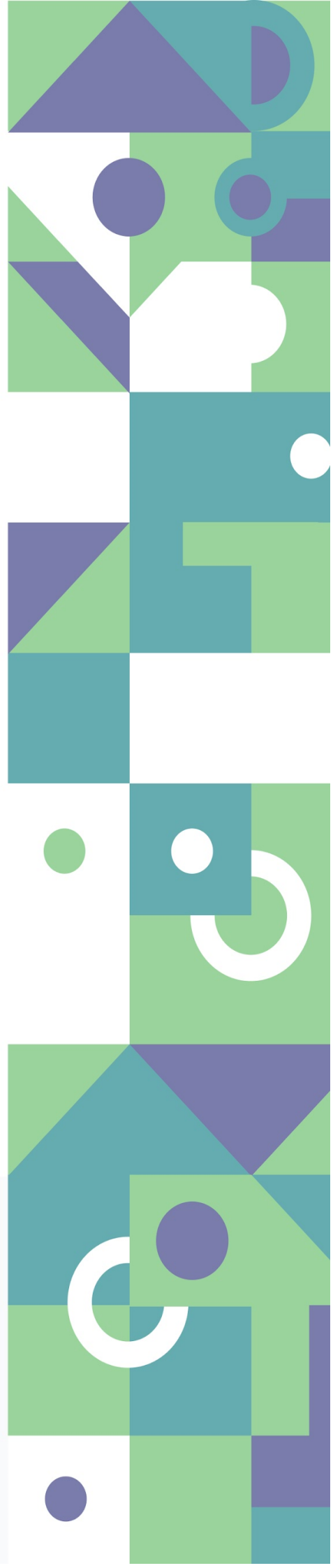
# Crisis in Gaza:

## Projected Deaths due to Traumatic Injuries in the Rafah Governorate

Report 2: 20 May to 17 August 2024

London, Baltimore– 4 June 2024

Funded by:  United Kingdom Humanitarian Innovation Hub



## Crisis in Gaza: Projected Deaths due to Traumatic Injuries in the Rafah Governorate. Report 2: 20 May to 17 August 2024

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The findings do not necessarily represent the views of the funder, the Johns Hopkins University, or the London School of Hygiene & Tropical Medicine.

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### Feedback and further information:

All reports, data and analysis code produced as part of this project are available at [www.gaza-projections.org](http://www.gaza-projections.org).

Please direct any questions to [info@gaza-projections.org](mailto:info@gaza-projections.org).

# Table of Contents

<b>Executive Summary</b> .....	<b>4</b>
<b>Introduction</b> .....	<b>6</b>
<b>Methodology</b> .....	<b>7</b>
Data sources .....	7
Assumptions and Timeframe.....	7
Imputation of ACLED fatality reports .....	9
Adjustment to match MoH fatality reports .....	10
Projected counted fatalities in Rafah .....	11
Accounting for uncounted fatalities .....	11
<b>Results</b> .....	<b>12</b>
Uncertainty estimation.....	13
<b>Discussion</b> .....	<b>15</b>
<b>Conclusion</b> .....	<b>15</b>
<b>References</b> .....	<b>16</b>
<b>Annex: Imputation and analysis of ACLED data</b> .....	<b>17</b>
Description of the ACLED dataset.....	17
Fatality data recoding and imputation .....	17
Reference .....	18

## Executive Summary

The ongoing Israel-Gaza war has heavily affected civilians in both the Gaza Strip and Israel. Over 85% of Gazans have been displaced, many multiple times. They live in overcrowded conditions with insufficient access to water, sanitation and food, and health services have been severely disrupted. Researchers from the London School of Hygiene and Tropical Medicine and the Center for Humanitarian Health at the Johns Hopkins University have initiated a project to estimate the potential public health impact of the crisis under different future trajectories of its evolution to inform humanitarian and other decision-makers working on the Gaza crisis. In February 2024, we released a report entitled [Crisis in Gaza: Scenario-based Health Impact Projections](#). Since the first report was published, the war has continued throughout Gaza with an expansion southward towards Rafah.

Since the majority of Gazans fled to Rafah by December 2023, there has been an intense focus on how the war will be executed there. Following the 6 May 2024 evacuation order for Gazans to leave eastern Rafah, bombardment and land incursions began, with hundreds of thousands of Gazans fleeing the area and an increase in deaths occurring due to traumatic injuries. The objective of the phase 2 of the Gaza Projections Project is to provide a projection of the number of deaths due to traumatic injuries in the Rafah governorate from 20 May to 17 August 2024 (90 days) to inform strategies and decisions by policymakers and humanitarians. Ultimately, it is hoped that these projections will make some contribution to saving lives.

Four sources of available data were used for this projection: 1) Ministry of Health (MoH) data on conflict fatalities; 2) Armed Conflict Location & Events Data Project (ACLED) data on fatalities for the five governorates in Gaza since 7 October 2023; 3) United Nations Relief and Works Agency for Palestine Refugees in the Near East (UNRWA) reports of traumatic injury fatalities among its employees; and 4) Estimates of population by governorate since 7 October, adjusted for displacement by the Oxford Population Health Unit. The first three sources are publicly available, and the latter is available upon request.

Our projection for Rafah is based on empirical observations from the Israeli military operation that began in Khan Younis in December 2023. We hypothesize, based on available evidence, that the patterns and outcomes witnessed during this phase of the conflict could resemble potential developments in Rafah under comparable circumstances. They are based on the time series of traumatic injury fatalities from Khan Younis over the 90-day period starting from 16 December 2023 (14 days after the 2 December 2023 evacuation notice for Khan Younis) to 14 March 2024, adjusted for differences in population size.

The Gaza Ministry of Health's reporting on fatalities does not include geographic locations. Consequently, we used the ACLED database, which was incomplete, but did include the locations of traumatic injury deaths. We then resolved this uncertainty through machine learning imputation and adjusted the ratio of traumatic injury deaths reported by the MoH and ACLED to remove some potential bias due to incomplete detection of deaths by ACLED. Finally, to obtain the projection of the number of counted Rafah fatalities, the number of counted fatalities in Khan Younis was scaled by the ratio of the Rafah and Khan Younis populations at day 14 following their respective evacuation orders.

As we did in our first report, we used the UNRWA staff death reports as an independent source and compared it to the MoH mortality database to estimate the uncounted deaths from the latter; these include people who died under the rubble and other deaths that may not have been reported through the MoH system.

We project 3,509 (95% uncertainty level 3,143 to 3,946) of traumatic injury deaths to occur between 20 May to 17 August 2024 solely in the Rafah governorate. That is the equivalent to 39 deaths/day for 90 days.

This scenario is focused solely on Gazans who are likely to die directly due to trauma and does not include deaths that have already occurred in Rafah previously, including those since the 6 May evacuation order, deaths that will occur in Rafah after the projection period due to non-fatal traumatic injuries sustained during that period, and deaths indirectly caused by the war, including deaths due to infectious diseases, non-communicable diseases and maternal and child health issues. Many more traumatic injury deaths are continuing to occur throughout Gaza. Furthermore, we would expect to see increased deaths due to other causes, such as infectious diseases, non-communicable diseases and those due to maternal and child health occurring in the Rafah Governorate and beyond.

This projection of possible traumatic injury deaths in Rafah highlights the urgent and lifesaving need for an immediate ceasefire to reduce the mortality amongst civilians. International diplomacy and humanitarian efforts must prioritize the cessation of hostilities. Advocacy for a ceasefire and the urgent need for civilian protection must be sustained.

## Introduction

The ongoing Israel-Gaza war has heavily affected civilians in both the Gaza Strip and Israel. Since the 7 October 2023 attack by Hamas on Israel, a serious public health crisis has continued to evolve in the Gaza Strip due to large scale Israeli military operations including ground invasions as well as sea and aerial bombardments. As of May 20, 2024, the Gaza Ministry of Health reported 35,562 people in Gaza killed and 79,562 injured [1]. Nearly 85% of the 2.2 million Gazans have been displaced to overcrowded shelters with limited access to water and sanitation; more than 900,000 Gazans (40% of entire population) have been displaced, many multiple times between 6-18 May (812,000 from Rafah and over 100,000 persons in northern Gaza [1]. As of May 18, 2024, no hospitals were fully functional, 42% (15 of 36) were partially functioning, and 35% (33 of 93) primary health care facilities were functional, severely limiting healthcare services for the population [2]. Food insecurity is severe, and parts of the population are facing famine [3]. As of 15 May 2024, there has been 450 attacks on health care, including 102 health facilities and 723 people killed in these attacks [2].

In February 2024, we released a report entitled [Crisis in Gaza: Scenario-based Health Impact Projections](#) [4]. The projections were based on a range of publicly available data from the current and past Gaza crises, data from similar crises, and peer-reviewed published research into excess death estimates and took into account the limitations and biases of different data sources. These projections were designed to help humanitarian organisations, governments, and other actors plan their response to the crisis and take sound, evidence-based decisions. We projected excess deaths according to three scenarios: ceasefire, status quo and escalation over a 6 month period from 7 February to 6 August 2024.

Since the first report was published, the war has continued throughout Gaza with an expansion southward towards Rafah. There continues to be conflict throughout Gaza with people being displaced multiple times. Since the majority of Gazans fled to Rafah by December 2023, there has been an intense focus on how the war will be executed there [5]. Following the 6 May 2024 evacuation order for Gazans to leave eastern Rafah, bombardment and land incursions by the Israeli Defense Forces began, with hundreds of thousands of Gazans fleeing the area and increased deaths due to traumatic injuries occurring.

**The objective of this phase 2 of the Gaza Projections Project is to provide a projection of the number of deaths due to traumatic injuries in the Rafah governorate from 20 May to 17 August 2024 (90 days) to inform strategies and decisions by policymakers and humanitarians.**

## Methodology

### Data sources

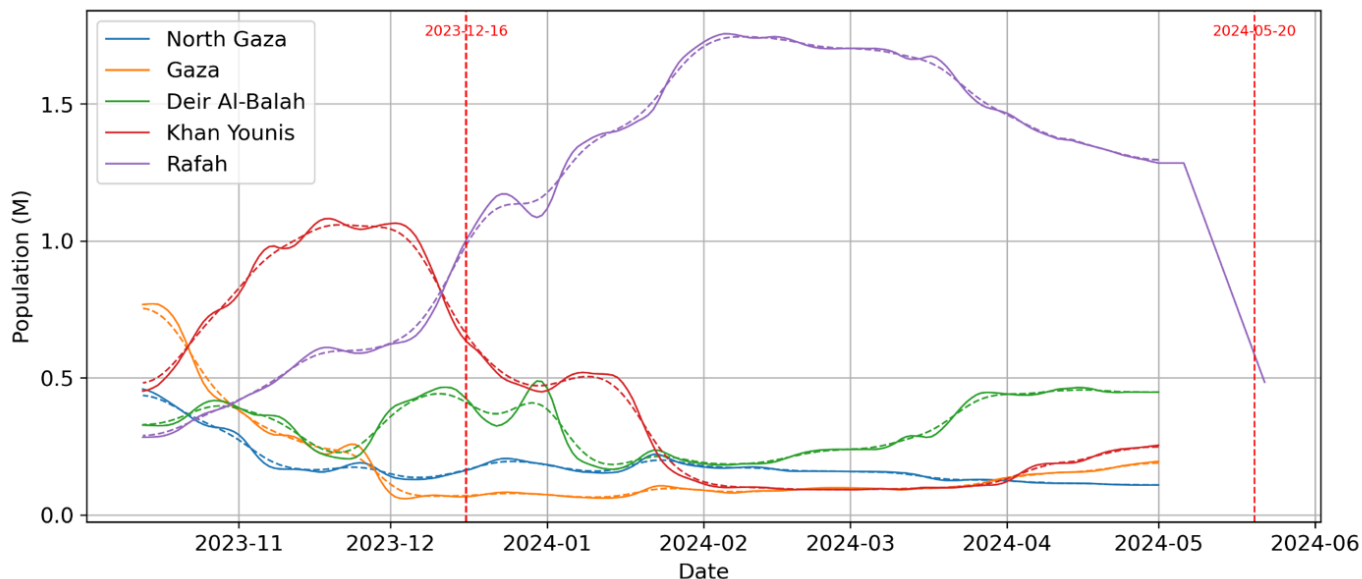
Four sources of data were used for this projection:

- 1) Ministry of Health (MoH) data on conflict fatalities** as referenced by the United Nations [6]. These data are publicly available. While the MoH has historically been a relatively reliable source of accurate conflict fatality counts, it has reported increased difficulties in obtaining complete fatality information in different governorate beginning mid-December 2023 [7]. It is also noted that the MoH fatality count is for the entire Gaza Strip and is not subdivided by governorates. Hence, a supplementary source of information on fatality counts was needed for the Rafah projection.
- 2) Armed Conflict Location & Events Data Project (ACLED) data on fatalities for the five governorates in Gaza since 7 October 2023.** These data are publicly available. ACLED provides data at the event level, with location, type of warfare, and estimated or recorded fatalities and injuries [8]. Multiple sources of information are used to describe each event and quantify the associated casualties. ACLED does acknowledge that it does not have access to the types of information that can be gathered by the MoH or other on-the-ground actors. Hence, many of the events have unknown casualty numbers, and/or the fatalities associated with some events are adjusted so that the total ACLED fatality count matches the MoH fatality records. Details of these adjustments are annotated in the ACLED dataset.
- 3) United Nations Relief and Works Agency for Palestine Refugees in the Near East (UNRWA) reports of traumatic injury fatalities among its employees.** These data are publicly available. UNRWA has been providing periodic updates on the number of traumatic injury fatalities among UNRWA staff [9]. This information is used to estimate the number of traumatic injury fatalities that are not included in the MoH official counts.
- 4) Estimates of population by governorate since 7 October, adjusted for displacement.** The Oxford Population Health Unit (Oxford) has provided an alternate source of information on population movement in each governorate, based on daily counts of active social media users [10]. These data are available upon request.

### Assumptions and Timeframe

Our projection for Rafah are based on empirical observations from the Israeli operation in Khan Younis that began in December 2023. We hypothesize that the patterns and outcomes witnessed during this phase of the conflict could resemble potential developments in Rafah under comparable circumstances. In Khan Younis and Rafah, population size, including internally displaced persons, far exceeded the pre-war number with over 1.0 million people in Khan Younis and over 1.7 million in Rafah at their peaks respectively. Figure 1 shows the evolution of the population estimates over time for the five Gaza Strip governorates from October 7, 2023, to May 20, 2024 [10]. In both governorates, evacuation orders (2 December 2023 in Khan Younis and 6 May 2024 in Rafah) were immediately followed by a series of Israeli air strikes, beginning 2 December 2023 in Khan Younis, and 6 May 2024 in Rafah. Rapid and large-scale displacement of the resident population occurred during the first few weeks of the Israeli military operations in each governorate. Notably, the population of Khan Younis experienced a significant decline during December 2023 and continued to decrease throughout the latter half of January 2024, while the population of Rafah slowly decreased in February followed by a large decline on 6 May 2024 when the first evacuate order for Rafah was declared

(Figure 1). We used the ratio of population size in Rafah and Khan Younis on the 14<sup>th</sup> day of the evacuation order, respectively (Figure 1) when applying the mortality due to traumatic injury deaths in Khan Younis to Rafah (figure 7).

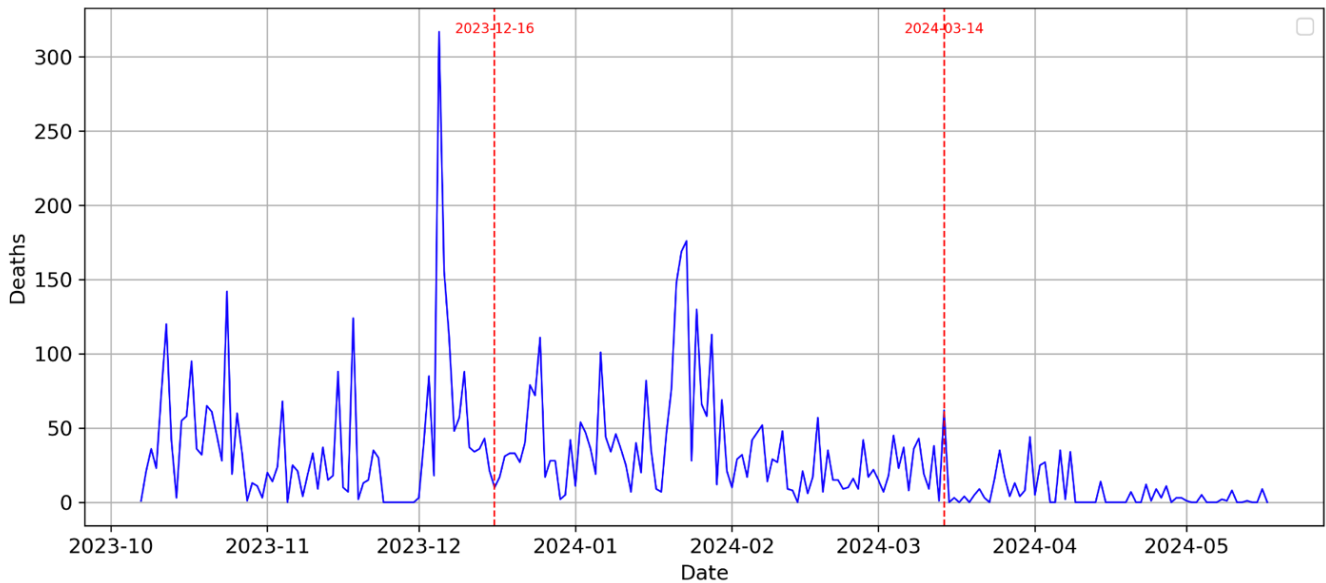


**Figure 1. Estimated population movements among the five Gaza Strip governorates from October 2023 to May 2024 [10]**

Note: The most recent update to the population data from Oxford University was dated May 1, 2024. Subsequent estimates beyond this date are based on information from OCHA report No. 169, dated May 22, 2024, which noted that over 800,000 individuals have been displaced from Rafah since May 6. Using these data, we extrapolated the population figures for Rafah for the period between May 6 and May 22. The dashed lines for each governorate are a locally smoothed trend.

Figure 2 shows the number of traumatic injury fatalities per day based on the ACLED data set. An increase in fatalities in Khan Younis began on 2 December 2023 and was characterized by a sharp peak during the first 9 days (2-10 December 2023). While data are still being collected and verified in Rafah presently, a similarly large peak in fatalities per day was not observed in Rafah after the evacuation order on 6 May 2024. So as to account for this pattern, which may reflect changes in military strategy by Israel, as well as the large reduction in population within Rafah since 6 May, we chose to consider as reference for Rafah the 90-day period in the Khan Younis time series starting two weeks after the evacuation orders, namely from 16 December 2023 (14 days after the 2 December 2023 evacuation notice for Khan Younis) to 14 March 2024 (Figure 2).



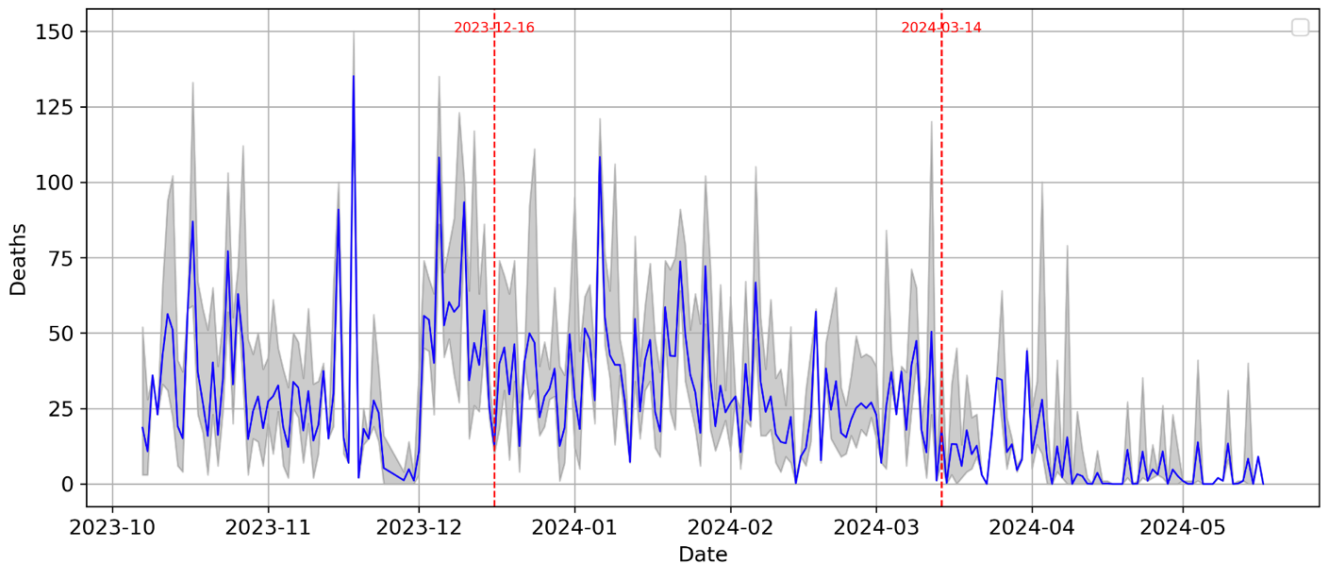


**Figure 2. Traumatic injury fatalities per day in Khan Younis from October 2023 to May 2024, as reported by ACLED [8].** Red-dashed vertical lines delimit the reference period used in the analysis.

We projected traumatic injury-related deaths in the governorate of Rafah for the period from 20 May to 17 August 2024 (90 days). This projection begins 14 days after the evacuation order issued by the Israeli government on 6 May 2024. Our estimates are based on the time series of traumatic injury fatalities from Khan Younis over the 90-day period starting from 16 December 2023 (14 days after the 2 December 2023 evacuation notice for Khan Younis) to 14 March 2024, adjusted for differences in population size.

### Imputation of ACLED fatality reports

A substantial proportion of ACLED records featured uncertainty in the number of fatalities. We resolved this uncertainty through machine learning imputation. To enhance robustness and propagate statistical error through the analysis, 200 imputation chains were generated; for a detailed explanation of the imputation process, please refer to the Annex. Imputed ACLED daily fatalities occurring in Khan Younis during the 90 days after 16 December 2023 (Figure 3) were then carried into the following analysis.

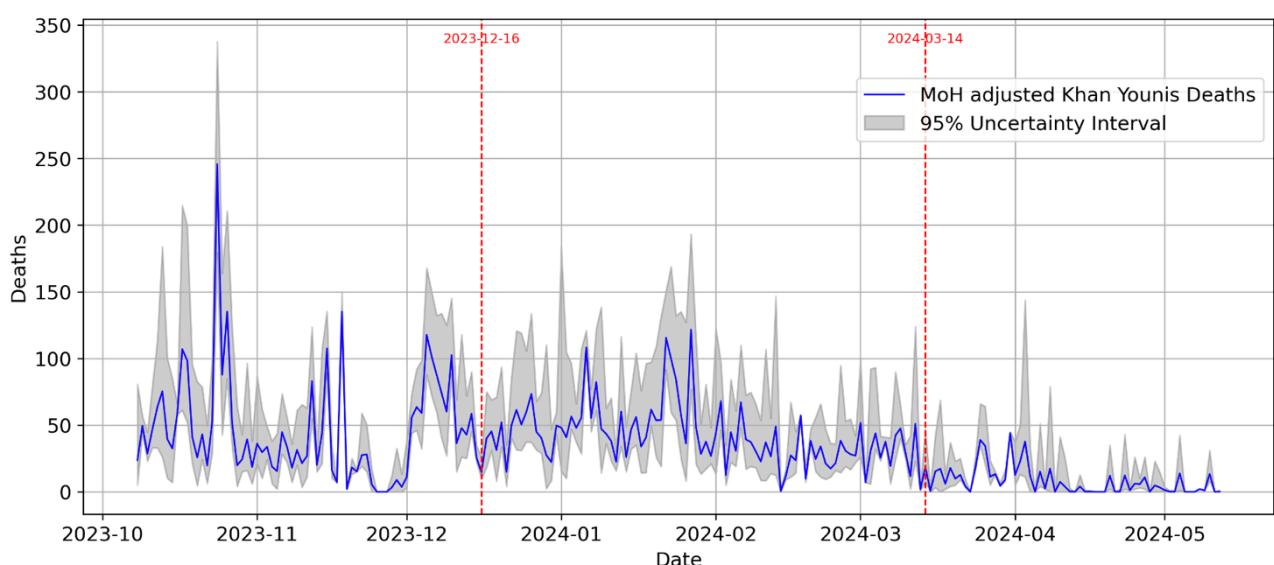


**Figure 3. Traumatic injury fatalities per day in Khan Younis after imputation with uncertainty interval from October 2023 to May 2024**

Note: Two hundred imputation chains of MICE-processed ACLED data were utilized to estimate the 95% uncertainty interval surrounding the daily trauma fatalities in Khan Younis.

#### Adjustment to match MoH fatality reports

The ratio of traumatic injury deaths reported by the MoH and ACLED was calculated to adjust the imputed fatalities derived from ACLED to match those reported by the MoH, and thus remove some potential bias due to incomplete detection of deaths by ACLED. This ratio was determined by dividing the daily death rates reported by the MOH by the daily death rates imputed from ACLED data across all governorates, with the ratio truncated at a ceiling of 1 to ensure a consistent decision of considering the MoH values as the reference. We then applied this ratio to the imputed Khan Younis daily fatalities from ACLED to obtain an adjusted number of ‘counted’ trauma fatalities in Khan Younis.



**Figure 4. Traumatic injury fatalities per day in Khan Younis after imputation and scaled to MoH data with uncertainty interval from October 2023 to May 2024**

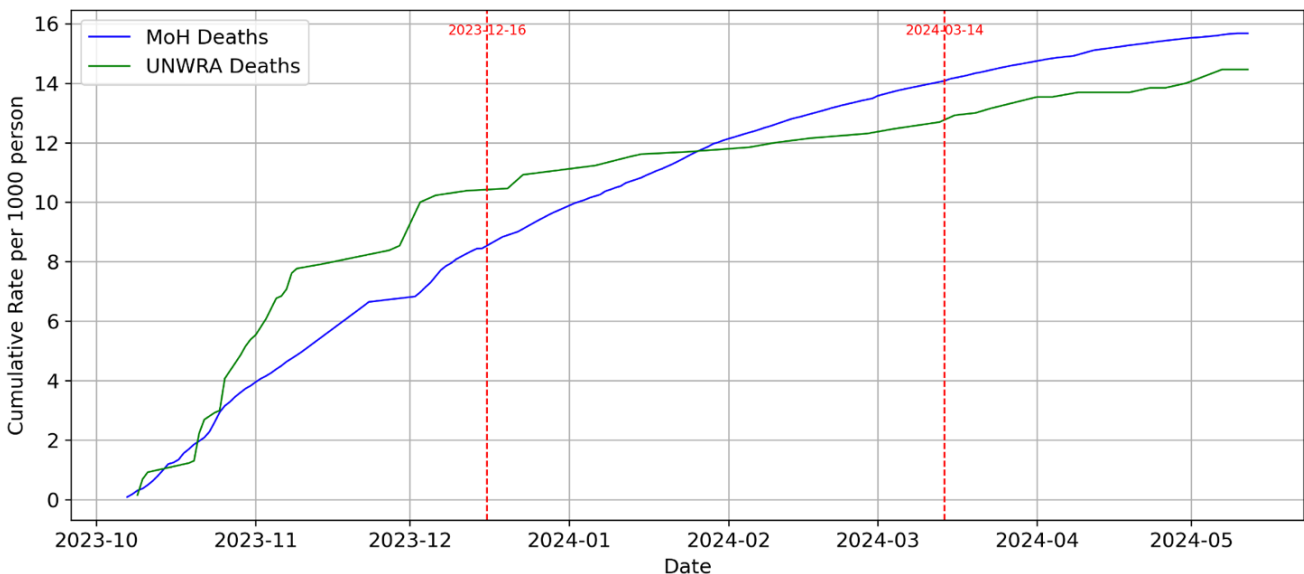
## Projected counted fatalities in Rafah

To obtain the projection of the number of counted Rafah fatalities that will occur over the 90 days starting 20 May 2024, the number of counted fatalities in Khan Younis as shown in Figure 4 was scaled by the ratio of the Rafah and Khan Younis populations at day 14 following their respective evacuation orders.

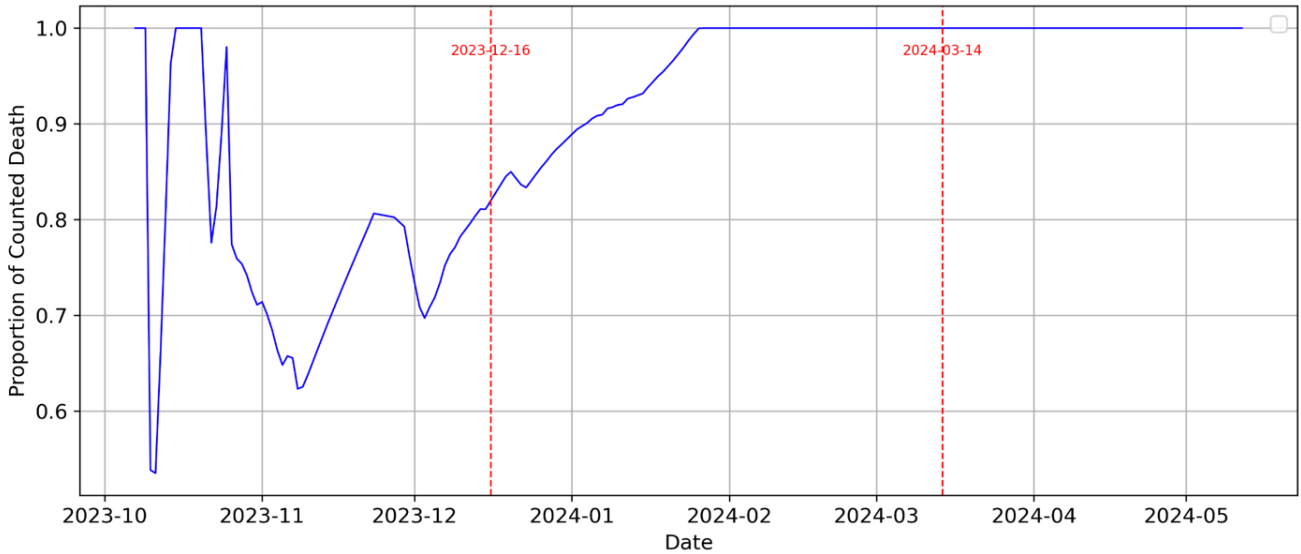
## Accounting for uncounted fatalities

For the February 2024 [Gaza Projections report](#) [4], the traumatic injury death rate among UNRWA staff was compared with the MoH reported death rate for the Gaza Strip population. The UNRWA rate was considerably higher, and given the accuracy of the records for tracking staff fatalities as well as the large size and geographic extent of UNRWA staff (over 13,000 employees and 300 installations throughout the Gaza Strip), this traumatic injury death rate was considered to be the most reliable available estimate of population mortality in Gaza. The ratios of the MoH daily death rates and the (higher) UNRWA death rates (Figure 5) were accordingly used as an estimate of the proportion of counted fatalities. The resulting estimated proportion of counted traumatic injury fatalities is shown in Figure 5.

For the present report, we used daily estimated proportions of counted fatalities over the 90-day reference period (16 December 2023-14 March 2024), assuming that these would be the same in Khan Younis as they were in Gaza as a whole. As shown in Figure 6, the UNRWA-based estimate of proportion of counted traumatic injury fatalities increased to 100% during the last week of January 2024 and remained 100% thereafter. This may be due to a variety of reasons, including the shifting geographic displacement of UNRWA staff to avoid conflict casualties that may have resulted in a lower fatality rate on average than the fatality rate of the remainder of the Gaza population (see Discussion). Consequently, after 27 January 2024, as the MoH death rate exceeded the UNWRA rate, we applied a ceiling value of one.



**Figure 5. Ministry of Health death rate and UNWRA staff death rate from October 2023 to May 2024**

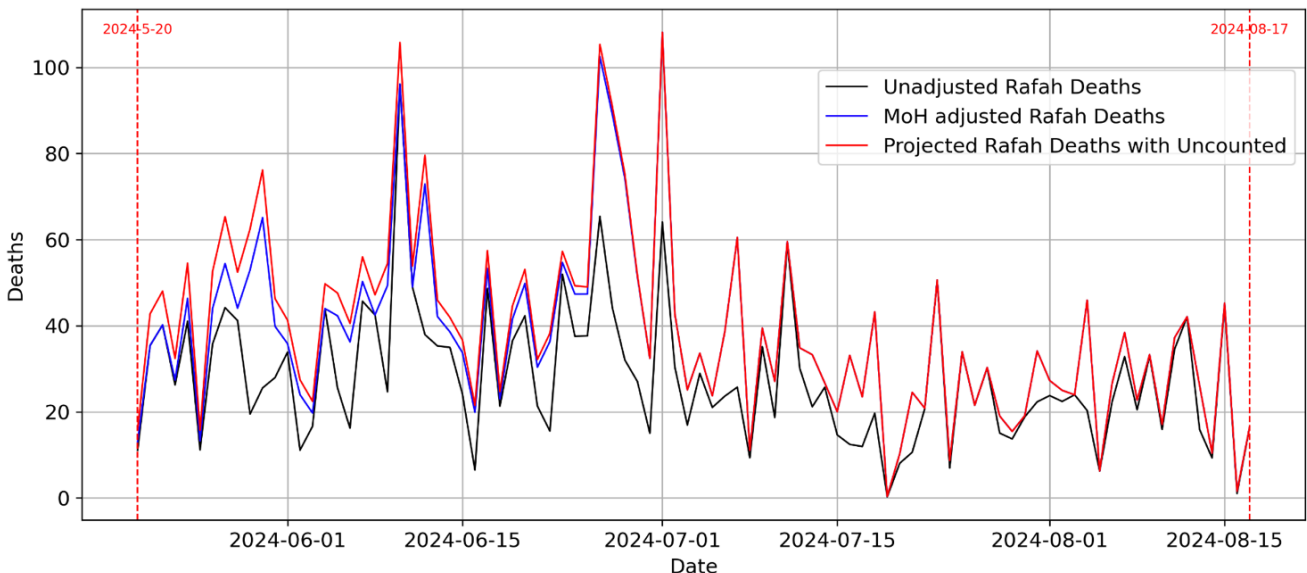


**Figure 6. Proportion of counted deaths based on UNWRA data from October 2023 to May 2024**

Note: The proportion of counted deaths was determined by dividing the MoH death rate by the UNWRA staff death rate. After 27 January 2024, as the MoH death rate exceeded the UNWRA rate, we applied a ceiling value of 1.

## Results

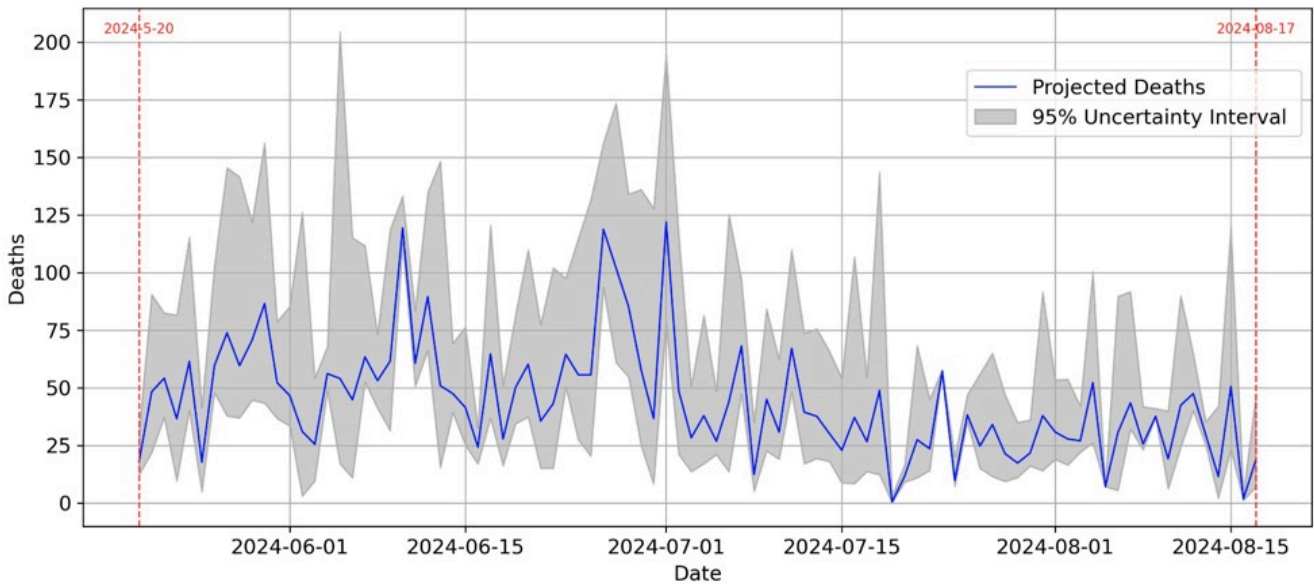
We divide the MoH-adjusted daily projected counted fatalities in Rafah by the corresponding daily proportions of deaths counted over the reference period in Khan Younis to get total projected traumatic injury fatalities in Rafah as shown in Figure 7. This figure shows the application of the steps listed above and provides the projected traumatic injury fatalities according to unadjusted Rafah deaths, MoH adjusted Rafah deaths, and projected Rafah deaths including uncounted deaths.



**Figure 7. Projecting traumatic injury fatalities in Rafah according to different steps, 20 May-15 August 2024**

## Uncertainty estimation

Several sources of variability are combined to propagate uncertainty into the final estimate of projected fatalities. Gaza population data are assumed to be composed of two additive components: a time-varying mean trend (obtained by Gaussian filtering) and a noisy stochastic fluctuation. The standard deviation of the fluctuating component is used as a measure of the variability of the population ratio. The empirical distribution of 200 imputation chains is used to sample ACLED-reported fatalities. Daily MoH-reported deaths are also decomposed into a time-varying trend and a noisy fluctuation, used for error sampling. Each error distribution is sampled 10,000 times and the resulting distribution of run outputs is used to obtain 95% uncertainty intervals for the projected fatalities (Figure 8). The point estimates and 95% uncertainty intervals are shown in Table 1 below.



**Figure 8. Projected traumatic injury fatalities in Rafah governorate from 20 May-15 August 2024, with 95% uncertainty interval**

Note: These 95% uncertainty levels are based on the model using the Khan Younis data (16 December 2023-14 March 2023)

**Table 1. Projected traumatic injury fatalities in a 90-day escalated conflict in Rafah from 20 May-15 August 2024 based on the conflict in Khan Younis (16 December 2023-14 March 2024)**

Location, dates	Description	Mean	Lower 95% uncertainty interval	Upper 95% uncertainty interval
Khan Younis 16 December 2023 – 14 March 2024	Counted deaths	3,748	3,451	4,088
	Uncounted deaths	216	191	248
	Total deaths	3,957	3,648	4,328
–	Ratio of populations: Rafah / Khan Younis	0.89	0.82	0.95
Rafah 20 May – 17 August 2024	Counted deaths	3,326	2,972	3,729
	Uncounted deaths	192	165	225
	Total deaths	<b>3,509</b>	<b>3,143</b>	<b>3,946</b>

## Discussion

The war in Gaza has continued for nearly eight months with a devastating effect on civilians. Since the Israeli government's evacuation order on May 6 for eastern Rafah, more than 800,000 people residing in shelters and tents have been displaced, most of whom had previously fled the conflict from other parts of Gaza [1]. They continue to live in overcrowded, unsanitary and insecure areas throughout the Gaza strip with insufficient food, water, shelter and health care.

We project that 3,509 Gazans (uncertainty level of 3,143 – 3,946) could die directly due to traumatic injuries in Rafah governorate over a 90-day period from 20 May to 18 August 2024 if Israeli forces' pattern of intervention in Rafah is similar to that previously observed in Khan Younis. Our projection equate to 39 persons per day dying directly due to traumatic injuries.

The projected number of deaths does not include those deaths that have already occurred in Rafah previously, including those since the 6 May evacuation order. In addition, our projection does not include deaths that will occur in Rafah after the projection period due to injuries related to traumatic injuries, as well as deaths indirectly caused by the war, and from causes including infectious diseases, non-communicable diseases and maternal and child health issues. Furthermore, many more deaths due those causes as well as traumatic injury will plausibly continue to occur in the four other Gaza governorates. It is noteworthy that, despite the focus on operations in Rafah, aerial and ground attacks have continued across the Gaza Strip. We did not disaggregate the deaths due to age and sex, nor were we able to differentiate between civilians and combatants.

There are limitations to this projection. We applied the mortality in Khan Younis to Rafah as there were similarities in terms of evacuation orders and military strategy, including the use of aerial bombardment and land incursions by sector. However, the military strategy employed in Rafah may or may not be the same as that used in Khan Younis, and consequently, the number of people killed due to traumatic injuries may differ. During the course of the conflict, the UNRWA staff may have developed different strategies to avoid conflict casualties as compared with the rest of the civilian population in the Gaza Strip. Furthermore, they do not include children, so do not represent the whole population. This could explain the relative changes in traumatic injury fatality rates between the two populations, and consequently, the number of uncounted deaths is likely an under-estimate.

## Conclusion

The projection of possible traumatic injury deaths in Rafah highlight the urgent and lifesaving need for an immediate ceasefire to reduce the mortality amongst civilians. International diplomacy and humanitarian efforts must prioritize the saving of civilians lives in Gaza. Advocacy for a ceasefire and the urgent need for civilian protection must be sustained.

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## Annex: Imputation and analysis of ACLED data

### Description of the ACLED dataset

The dataset used for this analysis, sourced from the Armed Conflict Location & Event Data Project (ACLED), comprises a collection of 8,843 records detailing conflict-related events spanning from 7 October 2023, to 17 May 2024. The information within this dataset is derived from a variety of media sources and reporting organizations. Events are classified into numerous categories, such as armed clashes, air/drone strikes, and shelling/artillery/missile attacks, among others, providing a broad spectrum of conflict data relevant to the analysis.

ACLED records fatalities linked to specific events based on reported information. Due to reporting difficulties in Gaza, data on specific events are limited and often incomplete. Fatality reports are aggregated by the MoH for all of Gaza over several days rather than linked to specific events. To avoid undercounting, ACLED includes MoH-reported aggregate fatality counts in its dataset (details on the ACLED coding strategy can be found [here](#)).

### Fatality data recoding and imputation

We recoded the entire ACLED dataset based on the notes provided for each record, categorizing events into three levels of uncertainty, each with two subcategories, as shown in Table A1. A few additional details on these uncertainty levels are summarized below:

- **Certain:** Records that contain data verified as accurate. The two subcategories are (1) no fatalities and (2) at least one fatality.
- **Partially certain:** Records for which the number of fatalities is only partly known. The two subcategories are (1) no adjustment or (2) MoH partial adjustment. In subcategory (2), a subset of the fatalities are based on ACLED information and the remaining fatalities are estimated based on MoH reports.
- **Uncertain:** Records for which fatalities are unknown. The two subcategories are (1) no further adjustment or (2) MoH adjusted in which all fatalities are estimated based on the MoH totals. In subcategory (1), no fatalities are reported, whereas in subcategory (2), fatalities are estimated based on MoH reports over multiple days and/or events in the same area.

**Table A1. Categorization and imputation of ACLED records for dates between 7 October 2023 and 17 May 2024**

Category	Subcategory	Any fatalities reported?	Number of records	Imputed?
Certain	No fatalities	no	890	no
	Non-zero fatalities	yes	2129	
Partially certain	No adjustment	yes	158	
	MoH partial adjustment	yes	24	
Uncertain	No adjustment	no	5158	yes
	MoH-adjusted	yes	484	

Statistical imputation was performed for the 3201 (36.2%) records in the uncertain category, using data from the remaining 5642 (63.8%) records. Multiple Imputation by Chained Equations (MICE), utilizing a random forest technique [1], was used for the imputation method. The predictors were: disorder type, event type, sub event type, actor, associate actor, type of actor, civilian targeting label, sub-national administrative region, and latitude and longitude of event location. Two-hundred (200) imputation chains were generated. It is assumed that the data are missing at random (MAR).

The total number of fatalities recorded in the ACLED dataset prior to imputation amounts to 35,864. When considering only data in the certain category, the total number of fatalities is 18,844. After imputation, the revised number of fatalities based on the mean of the 200 chains is 35,262 (SD = 1,396). By comparison, the MoH reported a total of 34,706 fatalities over the same period.

## Reference

- [1] Wilson, S. (2023). micforest: Fast, Memory Efficient Multiple Imputation by Chained Equations with LightGBM (Version 5.7.0) [Software]. Available from <https://pypi.org/project/micforest/>