Armed conflict and child mortality in Africa: a geospatial analysis

Zachary Wagner, Sam Heft-Neal, Zulfiqar A Bhutta, Robert E Black, Marshall Burke, Eran Bendavid

Summary

Background A substantial portion of child deaths in Africa take place in countries with recent history of armed conflict and political instability. However, the extent to which armed conflict is an important cause of child mortality, especially in Africa, remains unknown.

Methods We matched child survival with proximity to armed conflict using information in the Uppsala Conflict Data Program Georeferenced Events Dataset on the location and intensity of armed conflict from 1995 to 2015 together with the location, timing, and survival of infants younger than 1 year (primary outcome) in 35 African countries. We measured the increase in mortality risk for infants exposed to armed conflicts within 50 km in the year of birth and, to study conflicts' extended health risks, up to 250 km away and 10 years before birth. We also examined the effects of conflicts of varying intensity and chronicity (conflicts lasting several years), and effect heterogeneity by residence and sex of the child. We then estimated the number and portion of deaths of infants younger than 1 year related to conflict.

Findings We identified 15 441 armed conflict events that led to 968 444 combat-related deaths and matched these data with 1·99 million births and 133 361 infant deaths (infant mortality of 67 deaths per 1000 births) between 1995 and 2015. A child born within 50 km of an armed conflict had a risk of dying before reaching age 1 year of 5·2 per 1000 births higher than being born in the same region during periods without conflict (95% CI 3·7–6·7; a 7·7% increase above baseline). This increased risk of dying ranged from a 3·0% increase for armed conflicts with one to four deaths to a 26·7% increase for armed conflicts with more than 1000 deaths. We find evidence of increased mortality risk from an armed conflict up to 100 km away, and for 8 years after conflicts, with cumulative increase in infant mortality two to four times higher than the contemporaneous increase. In the entire continent, the number of infant deaths related to conflict from 1995 to 2015 was between 3·2 and 3·6 times the number of direct deaths from armed conflicts.

Interpretation Armed conflict substantially and persistently increases infant mortality in Africa, with effect sizes on a scale with malnutrition and several times greater than existing estimates of the mortality burden of conflict. The toll of conflict on children, who are presumably not combatants, underscores the indirect toll of conflict on civilian populations, and the importance of developing interventions to address child health in areas of conflict.

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Introduction

The extent to which armed conflicts—events such as civil wars, rebellions, and interstate conflicts—are an important driver of child mortality is unclear. While young children are rarely direct combatants in armed conflict, the violent and destructive nature of such events might harm vulnerable populations residing in conflict-affected areas.[1,2] A 2017 review[3] estimated that deaths of individuals not involved in combat outnumber deaths of those directly involved in the conflict, often more than five to one. At the same time, national child mortality continues to decline, even in highly conflict-prone countries such as Angola or the Democratic Republic of the Congo.[4] With few notable exceptions, such as the Rwandan genocide or the ongoing Syrian Civil War, conflicts have not had clear reflections in national child mortality trends.[5–7] The Global Burden of Disease study[8] estimated that, since 1994, conflicts caused less than 0·4% of deaths of children younger than 5 years in Africa, raising questions about the role of conflict in the global epidemiology of child mortality.

The extent to which conflict matters to child mortality therefore remains largely unmeasured beyond specific conflicts.[9–11] In Africa, conflict-prone countries also have some of the highest child mortality, but this might be a reflection of generalised underdevelopment resulting in proneness to conflict as well as high child mortality, rather than a direct relationship.[12] In this analysis we aimed to shed new light on the effects of armed conflict on child mortality in Africa. We established the effects on child mortality of armed conflict in whom conflict-related deaths are not the result of active involvement in conflict, but of other consequences of conflict. We examined the duration of lingering conflict effects, and the geographical breadth of the observed effects, using geospatially explicit information on conflict location and

Research in Context

Evidence before this study

The burden of armed conflict on child mortality is unclear. On one hand, the vulnerability of young children and the destructiveness and intensity of armed conflict suggest that conflict exacts a high toll on children. On the other hand, child mortality continues to fall even in countries heavily affected by conflict, and the Global Burden of Disease study 2015 estimates that conflict accounts for less than 0·4% of child deaths in Africa. Empirical studies of the effects of armed conflict on the civilian population show effects on educational attainment, personal economic outcomes, and national economic growth. Studies from specific conflicts also show effects on stunting of growth in children and maternal health care. However, the continent-wide effect of armed conflict on mortality remains unknown. We searched Google Scholar using the terms "child mortality, Africa, and [conflict or war]." We then read all relevant studies published since 1995.

Added value of this study

To our knowledge, our study is the first comprehensive analysis of the large and lingering effects of armed conflict events on the health of non-combatant populations. We provide unique insights along several important dimensions into the study of armed conflict in Africa, between 1995 and 2015. First, our analysis encompasses the entire African continent. Second, we quantify the increase in the risk of dying before reaching age 1 year among infants born within 50 km of armed conflict, and show that this risk is related to the number of deaths in nearby armed conflicts, and to the duration of the conflict. Third, we identify the boundaries in space (up to 100 km) and time (up to 8 years after conflict) of increased risk of infant mortality. Finally, we estimate that the number of infant deaths related to conflict is several times greater than the number of direct deaths in armed conflicts.

Implications of all the available evidence

The burden of conflict on infant and child mortality is substantial and higher than available estimates. The available evidence suggests that conflict increases child mortality risk through effects on maternal health, infectious disease risk, and malnutrition. These findings have implications for the targeting of interventions for promoting child health during and after armed conflicts. Future analyses should identify effects in other conflict-prone regions. This work should prompt re-examination of armed conflict as a cause of, or risk factor for, child mortality.

number of conflict-related casualties. We then used our findings to estimate the burden of armed conflict on children younger than 5 years in Africa.

We used a dataset of geospatially explicit information on armed conflict in Africa, including location, timing, and number of armed conflict deaths. These data have been used primarily in political science to study features of armed conflict, such as why armed conflicts erupt or end and the role of state and non-state participants in conflict.[13,14] The availability of data on location and timing of conflicts, however, enables identification of the relationship with location and timing of child births and deaths. We use this identification throughout this analysis. Recognising the extent to which armed conflicts spill over to jeopardise the lives of young children would help prioritise approaches to deliver crucial services and other protective measures to populations living in unstable areas.

Methods

Overview

This analysis proceeds in several stages. We first estimated the relationship between armed conflict and child mortality. We examined the mortality response of infants (children younger than 1 year) to the intensity and duration of nearby armed conflicts. We then presented a series of extended analyses on the long-term destructive effects of conflict, on the spatial limits of conflict's effects, on possible mechanisms leading from conflict to child mortality, and on the mortality implications for children up to age 5 years. Finally, we used these findings to project the portion and number of deaths of infants younger than 1 year and children younger than 5 years related to armed conflict across the entire continent. Below we detail our primary data sources and empirical strategies.

Conflict data

Our primary data on armed conflict come from the Uppsala Conflict Data Program Georeferenced Events Dataset (UCDP GED).[15,16] The UCDP GED includes detailed information about the time, location, type, and intensity of conflict events from 1946 to 2016 (exact location available from 1989). A distinctive feature of this dataset is that it was created for research purposes and includes a stringent definition of conflict events. An event is defined as "the incidence of the use of armed force by an organised actor against another organised actor, or against civilians, resulting in at least one direct death in either the best, low or high estimate categories at a specific location and for a specific temporal duration".[17] The data were collected by use of a standardised process, in which potential events were identified from news sources, non-governmental organisation reports, case studies, truth commission reports, historical archives, and other sources of information.[17,18] Potential events were then triple-read, coded, and subjected to data quality checks.[16] Where conflicts took place is determined by use of the conflict source information, and the process is described with UCDP GED documentation.[13,16] We used all conflict events with at least one armed conflict death in the UCDP's best estimates of the number of deaths from 1989 to 2015.

The only alternative source with a scope approaching that of the UCDP GED is the Armed Conflict Location Events Dataset (ACLED).[19] The ACLED has a more limited time span, and in addition was found to be more prone to data quality concerns and inconsistent subnational coding in comparison with the UCDP GED.[13] As a result, we used the UCDP GED in the primary analyses and show results with the ACLED in the appendix.

	Conflict events	Conflict deaths	Children exposed
Total deaths	15 441	968 444	252 027 (12·7%)
One to four deaths	8095	16 362	69 683 (3·5%)
Five to 18 deaths	4309	40 854	57 050 (2·9%)
19 to 74 deaths	2181	76 157	62 952 (3·2%)
75 to 1000 deaths	793	174 552	50 663 (2·6%)
>1000 deaths	63	660 519	11 679 (0·6%)

Data are n or n (%). Only conflicts to which children in our sample were exposed are included.

Table 1: **Descriptive statistics, armed conflicts**

See Online for appendix

Infant and child mortality data

We used all available Demographic and Health Surveys done in African countries from 1995 to 2015 as the primary data sources on child mortality in this analysis. The Demographic and Health Surveys are nationally representative surveys that are done in many low-income and middle-income countries.[20,21] We used all surveys with individual-level information on child survival and geospatial information.[22] In georeferenced surveys, enumerators use global positioning system devices to identify the central point of each cluster's populated area (a cluster is analogous to a village or a neighbourhood). These coordinates are displaced by up to 2 km in urban clusters, 5 km in 99% of rural clusters, and 10 km in a random sample of 1% of rural clusters.[23] We used 105 surveys done in 35 African countries between 1995 and 2015, which contained data on 45 815 clusters. We created a child-level indicator of whether or not the child survived their first year of life, which we use as our primary outcome in all analyses of infants younger than 1 year. As a secondary outcome, we use the child's height-for-age (children must have been alive during the survey) to create an indicator for whether or not the child's growth was stunted (defined as two SDs below the median of the National Center for Health Statistics and WHO growth reference).[24] All births and deaths were assigned to the cluster's global positioning system location at the time of the survey. However, because conflict might induce migration and displacement, we tested this assumption in sensitivity analyses.

Estimation framework

Our empirical approaches exploited the longitudinal aspect of the information from each Demographic and Health Survey cluster, and did not depend on cross-sectional differences. We estimated the conflicts' effects by comparing death probabilities associated with infant outcomes within the same Demographic and Health Survey cluster over time. In doing so, we controlled for all stable cross-sectional differences between Demographic and Health Survey clusters. Our models answer the question, "What does infant mortality look like in cluster A during times of conflict compared with times without conflict?", and not the question, "What does infant mortality look like in cluster A near a conflict compared with cluster B that is not near a conflict?" We modelled the relationship between armed conflict and child mortality using the following linear probability models:

$$1)\ y_{ilcmt}=\beta_1 D_{lct}+\beta_2 \boldsymbol{X}_{ilcmt}+\eta_{lc}+\phi_{cm}+\tau_t+\varepsilon_{ilcmt}$$

$$2)\ y_{ilcmt}=\sum_{q=1}^{5}\beta_q D^q_{lct}+\beta_6 \boldsymbol{X}_{ilcmt}+\eta_{lc}+\phi_{cm}+\tau_t+\varepsilon_{ilcmt}$$

Where y, an indicator that equals 1 if the child did not survive their first year of life and 0 otherwise, is indexed for child i, cluster l, country c, birth month (January to December) m, and year of birth t. In secondary analyses, y represents whether or not the child's growth was stunted. The main predictor in equation 1, D_{lct}, is an indicator, indexed to the child's cluster and year, representing whether or not the child was exposed to armed conflict (of any intensity) within 50 km during their first year of life. In equation 2, the main predictors are a vector of indicators, D^q_{lct}, representing exposure to conflict of intensity q. We classified conflict intensity in two distinct ways: first, the intensity index q represents the quartile of the number of conflict deaths for all conflicts in our data, plus one indicator for conflicts with more than 1000 conflict deaths to capture very large conflicts (five indicators in total); second, the intensity index q represents the consecutive years of conflict in the child's cluster leading up to the first year of life (censored at 5 years), which captures the chronicity of conflict. We estimated the β_q terms, which represent the effect of armed conflict exposure of intensity q on mortality of infants younger than 1 year.

We used a series of fixed effects to avoid cross-sectional comparisons, including η (Demographic and Health Survey cluster fixed effects), ϕ (country-month fixed effects), and τ (birth year fixed effects). The Demographic and Health Survey cluster fixed effects allowed the main effects to be identified within each Demographic and Health Survey cluster; the country-month fixed effects controlled for seasonal differences (eg, January in Kenya effects); and the birth year fixed effects controlled for shared effects over time (eg, global component of rising

	Births	Deaths	Mortality
Total sample	1985109	133361	67·18%
Conflict in first year of life	252027	18795	74·58%
One to four deaths	69683	4297	61·66%
Five to 18 deaths	57050	3948	69·20%
19 to 74 deaths	62952	4776	75·87%
75 to 1000 deaths	50663	4540	89·61%
>1000 deaths	11679	1234	105·66%
No conflict in first year of life	1733082	114566	66·11%

Data are n or %. Birth, death, and mortality data for children younger than 1 year for 1995–2015 are from the Demographic and Health Surveys. Infant outcomes indicate the mortality in our sample overall and among those exposed to conflicts of different intensity. The mortality data are based on a cross-section over the entire study period. These cross-sectional differences do not capture within-cluster mortality in times of conflict relative to times of no-conflict.

Table 2: **Descriptive statistics, infant outcomes**

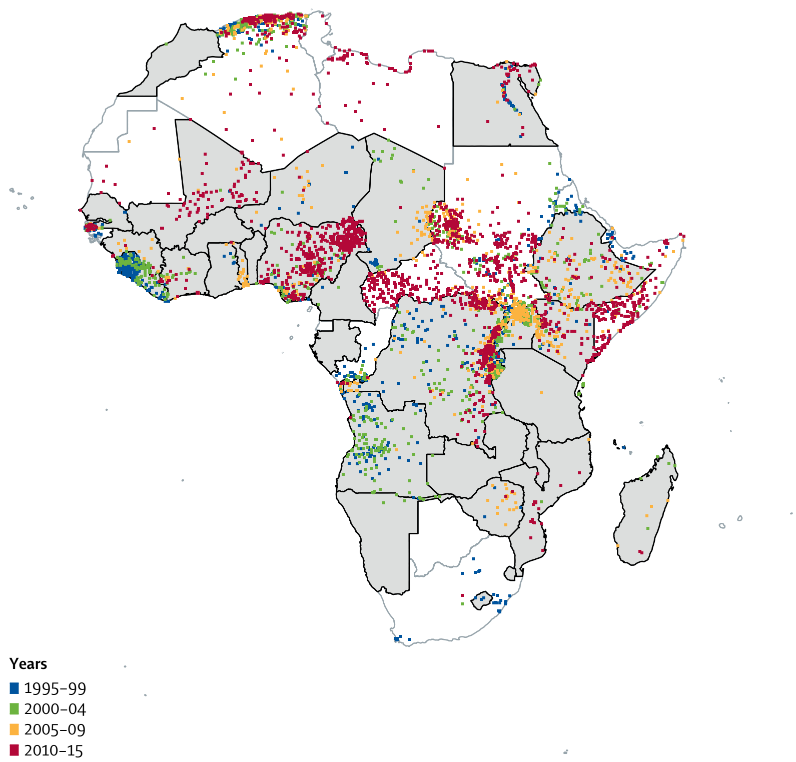

Figure 1: **The distribution of armed conflict events in Africa, 1995–2015**
The map shows the Uppsala Conflict Data Program conflict location data in the continent, with changing location over time. The study countries are grey with thick borders. The regional changes in high-density conflicts, and the absence of any obvious decline in the frequency of conflict in more recent years, are shown.

temperatures). Our models isolated variation in conflict exposure from other time-invariant, seasonal, or time-trending factors that could be correlated with mortality. For example, by including cluster fixed effects, we used only within-cluster variation in conflict and mortality over time, which controls for all time invariant cross-sectional differences between clusters (eg, that wealthier and healthier villages also have less conflict than in poorer villages with higher infant mortality). We used a total of 45815 Demographic and Health Survey cluster fixed effects, 410 country-month fixed effects, and 21-year fixed effects (a total of 46243 indicator variable fixed effects). We used robust SEs clustered at the level of the Demographic and Health Survey cluster throughout (we used the first cluster to refer to statistical clustering of the SEs, and the second to refer to the physical Demographic and Health Survey cluster).[25]

The X represents a vector of child-level, mother-level, or time-varying cluster-level controls. This vector includes several variables that, at a local level, could plausibly affect both the risk of conflict as well as child mortality, including average temperature and rainfall (which have been shown to influence conflict incidence), night light luminosity (a correlate of poverty), and food price index (if food insecurity might simultaneously exacerbate conflict risk and infant mortality risk).[26–28] We also controlled for the child's sex, the mother's age, and the mother's level of education.

In addition to examining the effect of contemporaneous nearby conflict, we estimated the lagged and distant effects of conflict over time and space. For this analysis, we added temporal and spatial bands to equation 1. We added indicators to identify the delayed effects of conflicts, one for each of the 10 years leading up to birth. We then use our findings to estimate the portion and number of deaths of infants younger than 1 year and children younger than 5 years related to conflict. To extrapolate the number of deaths from conflict to the entire continent, we used the following procedure: we obtained the number of births in each 0·1 degree latitude by 0·1 degree longitude cell (roughly 10 km×10 km) in each year, and identified in which cells and years were children born and exposed to armed conflict.[29,30] We then used estimates of mortality of infants younger than 1 year and children younger than 5 years in that grid cell to estimate the number of deaths of infants younger than 1 year and children younger than 5 years.[31] Next, we applied our coefficients to scale down the mortality of infants younger than 1 year and children younger than 5 years in exposed cells to what would be expected if there had been no conflict. Finally, we took the difference between the observed number of child deaths and those in the conflict-free counterfactual (see the appendix for more details on this method). We show findings for infants younger than 1 year and children younger than 5 years.

We did multiple robustness checks and extended analyses. The sensitivity of our findings to the choice of fixed effects and adjustors are shown in the appendix. We then tested the sensitivity of our main estimates to leaving each country out of the analysis, in turn. We also examined the assumption of stable residence. Conflict can force migration, such that the location of the women's interview would be different from the location of the child's first year of life. To examine this potential bias, we restricted our sample to the mothers who indicated they had lived in the same house for at least 10 years before the child's birth. We then examined our primary models using a different source of conflict data, from ACLED.[13] Our last robustness check tested the sensitivity of our findings to the precision of the conflict event location in UCDP.

Our extended analyses focused on testing our observed effects in different populations. We first focused on the mortality effects of conflict (during the year before birth) on neonatal mortality, as a suggestion of the effects of conflict on maternal health (appendix). We then show an analysis of effects on children up to age 5 years. We discuss our approach to this analysis and the findings. We show how conflicts of different intensities persist over time. We show effect heterogeneity by place of residence (urban and rural) and by child sex (boys and girls). Finally, we show the effects by our two measures of intensity—conflict chronicity and deadliness—simultaneously (from short conflicts with few casualties to very prolonged conflicts with ≥1000 casualties), and we show response of stunting to armed conflict.

Significance was defined at $p<0{\cdot}01$. We used R statistical software, version 3.5.1, for all analysis, and statistical code is available on request.

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. ZW and EB had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results

Our data consisted of 1·99 million births, 133 361 deaths of infants younger than 1 year, and 204 101 deaths of children younger than 5 years in 35 countries between 1995 and 2015. These data were linked to 15 441 armed conflict events with 968 444 conflict-related deaths. Aggregate data on the study sample, including information on the number of births, child deaths, and conflicts available for analysis are given in tables 1 and 2. Country-level data are given in the appendix. The distribution of armed conflict events recorded in the UCDP GED database between 1995 and 2015, separated into four 5-year periods, is shown in figure 1 (see appendix for conflict sizes).

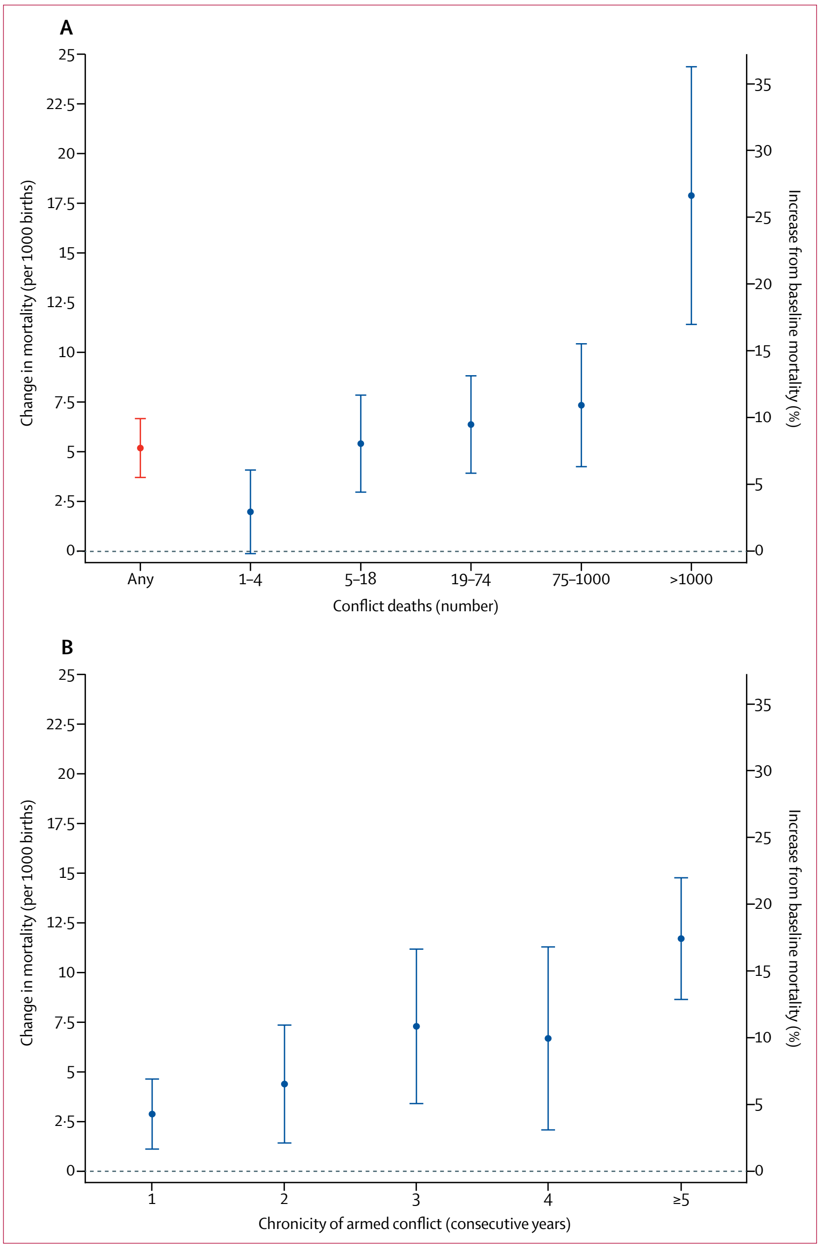

Figure 2: **Effect of armed conflict in first year of life on mortality of infants younger than 1 year**
The effect of any conflict within 50 km of the infant's cluster (red bar), and the rising risk from conflicts of increasing intensity (blue bars) is shown in (A). The increasing risk from conflicts of increasing duration is shown in (B). We estimated the exposure based on the number of consecutive years of conflict near the infant's cluster.

We found a large and significant increase in the probability of dying before reaching age 1 year from nearby armed conflict. Deadly conflict within 50 km during a child's first year of life leads to an increase of 5·2 infant deaths per 1000 births (95% CI 3·7–6·7; figure 2; table 3). This increase represents a 7·7% (95% CI 5·5–9·9) increase in the mortality risk compared with the infant mortality in the entire sample (67 deaths per 1000 births). This effect increases with exposure to conflicts with higher intensity: the infant mortality effect size rises by approximately 75% with each quantile increase in conflict intensity—2·0 deaths per 1000 births for conflicts with one to four deaths (3·0% increase from the sample's 67 deaths per 1000 births), 5·4 for five to 18 deaths (8·1% increase), 6·4 for 19 to 74 deaths (9·6% increase), 7·4 for 75 to 1000 deaths (11·0% increase), and 17·9 for conflicts with more than 1000 deaths (26·7% increase). The effects of conflict increase for more chronic conflicts (figure 2): the effect of conflict lasting at least 5 consecutive years is more than four times greater than an unsustained

	Statistical model of infant mortality (1)	Statistical model of infant mortality (2)	Statistical model of infant mortality (3)	Statistical model of infant mortality (4)
Any number of deaths	5·201* (0·756)	··	5·075* (0·756)	··
Number of deaths				
One to four	··	1·991 (1·073)	··	1·827 (1·073)
Five to 18	··	5·423* (1·245)	··	5·298* (1·246)
19 to 74	··	6·385* (1·25)	··	6·280* (1·251)
75 to 1000	··	7·355* (1·577)	··	7·290* (1·575)
>1000	··	17·904* (3·307)	··	17·695* (3·308)
Person-level controls				
Mother's education				
Primary	··	··	–4·312* (0·635)	–4·298* (0·635)
Secondary	··	··	–11·935* (0·747)	–11·947* (0·747)
Tertiary or above	··	··	–16·956* (1·221)	–16·980* (1·221)
Age of mother	··	··	–0·523* (0·035)	–0·523* (0·035)
Female child	··	··	–11·442* (0·366)	–11·441* (0·366)
Cluster-level, time-varying controls				
Temperature, °C	··	··	3·431* (0·633)	3·369* (0·633)
Rainfall, mm	··	··	–0·001 (0·001)	–0·001 (0·001)
Night lights, intensity	··	··	–0·003 (0·002)	–0·003 (0·002)
Food prices, price index	··	··	0·12 (0·087)	0·123 (0·087)
Observations	1 985 109	1 985 109	1 984 717	1 984 717
R^2	0·047	0·047	0·048	0·048

Data are coefficient (SE) or n. Conflict is represented as a binary exposure in columns 1 and 3, and is broken down into categorical indicators representing conflict intensity in columns 2 and 4. The estimates in the first seven rows represent the increase in the probability of death (per 1000 births) before reaching age 1 year for infants exposed to conflict during their first year of life, as compared with infants born in the same area during years without conflict. All models include Demographics and Health Survey cluster fixed effects, country-month fixed effects, and birth year fixed effects. *p<0·01.

Table 3: **Regression results for the effect of conflict on mortality of infants younger than 1 year (per 1000 births)**

(<1 year) conflict in the child's first year of life (11·7 *vs* 2·8 deaths per 1000 births).

The lingering effects of conflict are shown in figure 3. The mortality effect of conflict (of any intensity) up to 10 years before birth (births from 1995 to 1998 include conflict information for <10 years before birth, because conflicts were only geocoded as far back as 1989). We found that conflict is followed by elevated mortality risk for infants born up to 8 years after the conflict event (appendix). We also show the cumulative 10-year effect of armed conflict by distance from the conflict: 31·4% increase for conflicts 0–50 km away (95% CI 22·9–39·8), 11·4% for conflicts 51–100 km away (3·5–19·4), and –3·1% for conflicts 101–250 km away. These cumulative effects represent an increase in infant mortality two to four times greater than the contemporaneous increase. Finally, we examined the extent to which conflict elevates related risk factors.

Analysis of neonatal mortality identifies a strong effect of conflict in the year leading up to birth on survival in the first month of life, suggesting possible harms to maternal health and care during pregnancy, labour, and delivery; we find that the effect decreases by nearly 30%, when excluding deaths in the first month of life (appendix). We found that the risk of dying before age 5 years is increased both for children in the first year of life as well as in the second year of life (appendix). While the absolute risk increase for children in the second year of life is smaller than in the first year, the baseline mortality is also lower, and the proportional increase is nearly as high as that for infants younger than 1 year (4·8% increase). Finally, an analysis of effect heterogeneity by the child's residence (urban or rural) revealed a significantly stronger effect in rural areas: an increase of 6·6 deaths per 1000 births in rural areas compared with 2·4 in urban areas (p value on rural by conflict interaction term <0·01; appendix). Being born near a conflict results in increased risk of being stunted (appendix). Although we have fewer observations for this analysis, we identify a consistent effect, with an overall conflict effect leading to 1·0% (95% CI 0·2–1·8) higher proportions of stunting, a 2·9% increase above a 34·4% average prevalence.

Multiple robustness analyses are shown in the appendix. The effect size is stable when countries are excluded, remaining between 4·1 (Liberia excluded) and 6·9 (Nigeria excluded) deaths per 1000 births. When restricting our sample to children who have not migrated, we lose nearly 75% of our sample, but observe an overall effect size only moderately attenuated (3·7 per 1000 births, 95% CI 0·5–7·0).

We used our findings to estimate the number of conflict-related child deaths throughout Africa (appendix).

We geospatially linked births and child mortality from 1995 to 2015 to all conflicts in Africa from 1989 to 2015, and used the increased mortality of infants younger than 1 year and children younger than 5 years related to conflict to estimate the number of children who would not have died in the absence of conflict.[32,33] We estimate that 4·9–5·5 million deaths of children younger than 5 years between 1995 and 2015 were related to armed conflict (6·6–7·4% of all deaths of children younger than 5 years). The distribution of deaths of children younger than 5 years related to armed conflict is shown in figure 4. We estimate that 3·1–3·5 million deaths of infants younger than 1 year are related to conflict from 1995 to 2015 (6·6–7·3% of all deaths of infants younger than 1 year during the entire period). Compared with the number of armed conflict deaths in the UCDP dataset, the ratio of deaths of infants younger than 1 year to armed conflict deaths is 3·2–3·6:1 (5·0–5·7:1 for deaths of children younger than 5 years). To the extent that conflict also probably elevates the mortality risk of other non-participant vulnerable groups, such as school-age children, adolescents, women, men who are not directly involved in combat, or the elderly, our estimates represent a floor to the indirect effects of conflict on mortality.

Discussion

More frequent and more intense armed conflicts have taken place in Africa over the past 30 years than in any other continent.[34,35] This analysis shows that the effects of armed conflict extend beyond the deaths of combatants and physical devastation: armed conflict substantially increases the risk of death of young children, for a long period of time. It might not be surprising that young children are vulnerable to nearby armed conflicts, but we show that this burden is substantially higher than previously indicated. We present evidence that armed conflicts contribute to death and stunting of growth for many years, and over wide areas. While we stop short of directly examining the effects on other vulnerable populations like young women, we find indirect evidence of harms to these populations as well.

The Global Burden of Disease study[8] indicates that conflict and interpersonal violence make up around 0·4% of deaths of infants younger than 1 year and children younger than 5 years in Africa, and does not otherwise constitute a risk factor. While these estimates might reflect efforts to count casualties of conflict and violence, our analysis suggests that this is a substantial underestimate: the portion of deaths among infants younger than 1 year and children younger than 5 years related to conflict is approximately ten times higher than in the Global Burden of Disease study.[8] The risk is clearest for conflicts contemporaneous with a child's first year of life, although the effects are even larger for chronic conflicts and when considering long-term effects.

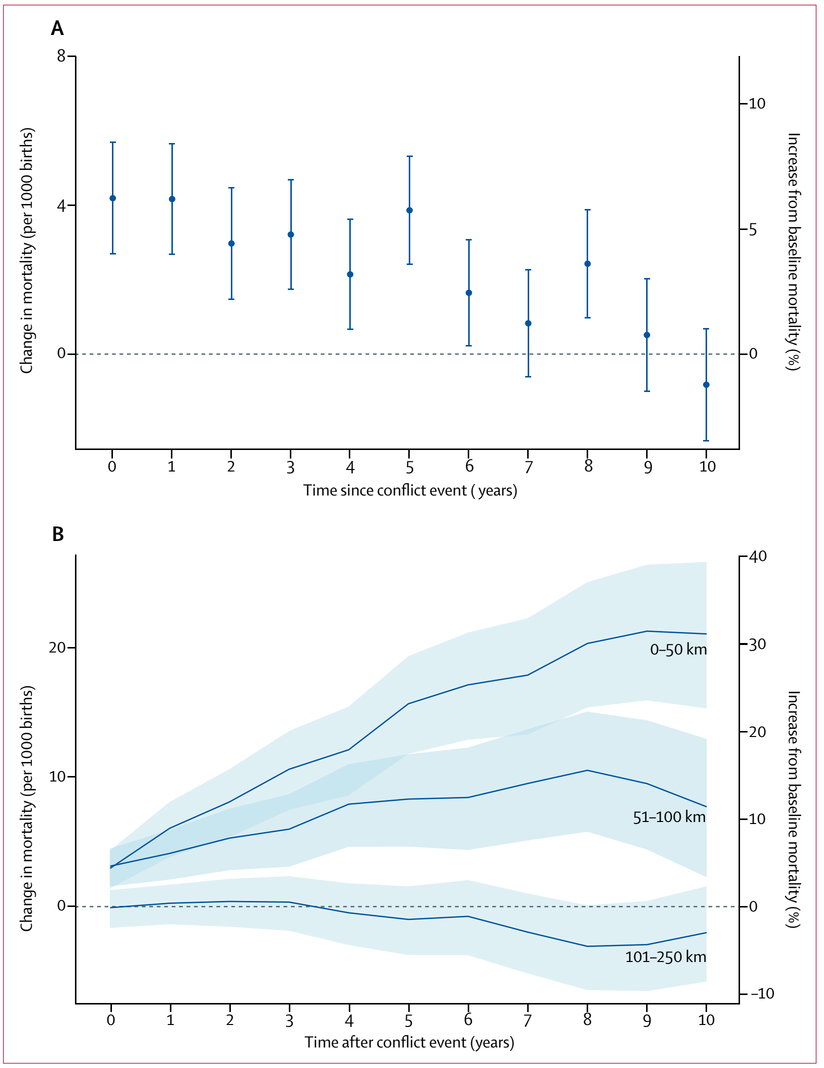

Figure 3: **Effect of conflict on mortality of infants younger than 1 year, over time**
(A) The coefficients from a regression with conflict exposure indicators for each year up to 10 years before birth. Each coefficient represents the independent lingering risk of mortality in the first year of life from historical conflict taking place up to 10 years before birth. Conflicts up to 8 years before birth show an independent relationship with increased mortality of infants younger than 1 year. (B) The cumulative mortality risk over time for conflicts within 0–50 km, 51–100 km, and 101–250 km from a child's birth, estimated in one regression, showing an attenuated effect at greater distances. Blue shading represents 95% CIs.

This study supports a complex role for conflict in child mortality. The contemporaneous and geographically proximate increase in mortality is consistent with direct compromise of the safety of young children—ie, deaths from direct injuries or harm to the parents or homes of young children. However, we also found increasing risk of stunting and neonatal mortality, suggesting additional pathways are involved. Complications of labour and delivery, and infectious diseases exacerbated by nutritional deficiencies are dominant causes of death in these age groups in Africa and, in addition to direct injuries and harm, might be the most relevant proximate causes of death involved in the observed increased risk. However, the chronic and long-term effects might additionally

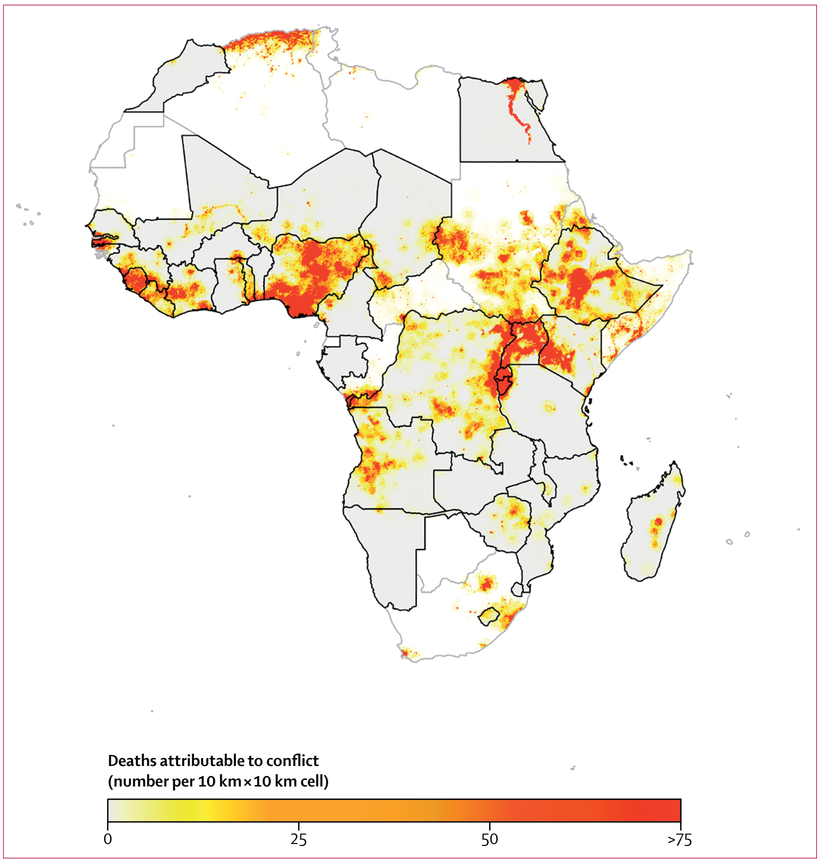

Figure 4: **Number of deaths of children younger than 5 years due to conflict in Africa**
We used 0·1 degree x 0·1 degree gridded estimates of the number of births, infant mortality, and conflict timing and location, to estimate the number of observed deaths in each grid cell, and then the number of deaths expected in the absence of conflict. We aggregated the grid cell-level estimates for 1995 to 2015. We used national infant mortality for countries without gridded infant mortality. The scale indicates the number of deaths in each grid cell (roughly 10 km × 10 km). The biggest clusters of child deaths are apparent in Nigeria, east-central Africa (Uganda, Democratic Republic of the Congo, Burundi, and Kenya), Ethiopia, Libya, Egypt, and west Africa (centered around Sierra Leone). Thick borders and grey background represent study countries.

involve increased risk from a compromised environment—the destruction of infrastructure for basic goods such as vaccinations, water, sanitation, food security, maternal and antenatal care, and potential effects on human resources for health. In particular, the elevation of risk among neonates and the observed effects from conflict in the year before birth supports pathways that affect maternal health and health care, including nutrition.

The findings of this study depend on data and approaches with some limitations. First, we attempted to identify the causal effects of armed conflict, but our interpretations are limited by the observational nature of the data. Our various fixed effects control for differences between areas where conflict does and does not occur (cluster fixed effects), general time trends (year fixed effects), and seasonality (country-month fixed effects). However, residual confounders that change within the same Demographic and Health Survey cluster over time, that we did not control for, and that are correlated with conflict and infant mortality, limit the causal strength of this work.

Second, the fact that conflict leads to migration and displacement could have biased our estimates. Displacement could have the effect of biasing our observed estimate up (eg, if healthier families leave the conflict zones and we count them as not near conflict) or down (eg, if the mortality risk of displaced populations is the same as those who stayed, in which case the mortality effect of conflict far from conflict areas would look more like the mortality effect inside conflict areas). We tested for this by restricting our sample to mothers who indicated they lived in the same house for at least 10 years before the child's birth (appendix), and results were similar. However, only 40% of households were asked this migration question, leading to imprecise estimates.

Third, to estimate the number of deaths related to conflict, we assumed the average effect of conflict in our sample was applicable to the rest of the countries in Africa. It is possible that conflict has a different effect in countries like Somalia, Sudan, or the Central African Republic, which have all been plagued by conflict for decades. If the effect is substantially different in these countries, this could lead to unpredictable bias of our estimates.

Finally, our analysis relied on location estimates from Demographic and Health Surveys and the UCDP conflict data. Imprecision in location estimates would create measurement error in exposure to conflict, which would attenuate our estimates toward the null. Demographic and Health Survey clusters are randomly scrambled, by up to 2 km in urban areas and up to 5 km in rural areas, which could create measurement error in conflict exposure. The use of a 50 km radius to measure conflict exposure should make this measurement error small, while not expanding the annulus to a size that might affect the plausibility of conflict effects. The location of some conflict events is also not perfectly precise, increasing the chance for measure error within a small geographic unit of exposure. However, when we drop conflict events that lack precision (indicated by UCDP) or weight observations are weighted by the level of precision, our results are unchanged (appendix).

The echoes of armed conflict are reflected in child mortality data. This analysis suggests several implications. First, our findings suggest the burden of conflict on child health in Africa—and probably elsewhere—is largely unknown. Our estimates of the effect of armed conflict are large, and suggest that conflict might be a sizeable, under-recognised risk factor for child mortality. Second, the distribution of deaths by age, distance, and duration of conflict provide important clues about which populations might be most vulnerable, including their locations and the causes of death that might be most directly implicated. Third, this study leads to several analyses into the burden of conflict beyond Africa, into additional spillovers of conflict on families and health systems, mechanisms by which conflicts increase mortality risk, and the effectiveness of potential interventions for building resilience and expediting recovery in conflict zones. Finally, we hope this revised awareness of the civilian toll of conflict will increase awareness and work into the prevention of armed conflict and its consequences.

Contributors

EB, REB, ZAB, and MB conceived the research idea. ZW, SH-N, MB, and EB contributed to the analytical design, data analysis, and interpretation. All authors contributed to the drafting and revising of the manuscript.

Declaration of interests

ZAB reports grants from the Bill & Melinda Gates Foundation and the International Development Research Centre. All other authors declare no competing interests.

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