

1-1-2018

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## Repository Citation

Guha-Sapir, Debarati; Schluter, Benjamin; Rodriguez-Llanes, Jose Manuel; Lillywhite, Louis; and Hicks, Madelyn J. Hsiao-Rei, "Patterns of civilian and child deaths due to war-related violence in Syria: a comparative analysis from the Violation Documentation Center dataset, 2011-16" (2018). *Open Access Articles*. 3340.  
<https://escholarship.umassmed.edu/oapubs/3340>

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## Keywords

Syria, civil war, conflict-related violent deaths, civilians, children, deaths, violence, causes of death

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# Patterns of civilian and child deaths due to war-related violence in Syria: a comparative analysis from the Violation Documentation Center dataset, 2011–16



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## Summary

**Background** Since March, 2011, the Syrian civil war has lowered life expectancy by as much as 20 years. We describe demographic, spatial, and temporal patterns of direct deaths of civilians and opposition combatants from conflict-related violence in 6 years of war.

**Methods** We analysed conflict-related violent deaths with complete information on date, place, and cause of death and demographic group occurring from March 18, 2011, to Dec 31, 2016, recorded by the Violation Documentation Center (VDC). We included civilian and combatant deaths in all Syrian governorates, excluding government-controlled areas. We did not include detainees and missing persons, nor deaths from siege conditions or insufficient medical care. We categorised deaths based on VDC weapon type. We used  $\chi^2$  testing to compare deaths from different weapons in civilian men, women, boys, and girls and adult and child combatants. We analysed deaths by governorate and over time.

**Findings** The VDC recorded 143 630 conflict-related violent deaths with complete information between March 18, 2011, and Dec 31, 2016. Syrian civilians constituted 101 453 (70·6%) of the deaths compared with 42 177 (29·4%) opposition combatants. Direct deaths were caused by wide-area weapons of shelling and air bombardments in 58 099 (57·3%) civilians, including 8285 (74·6%) civilian women and 13 810 (79·4%) civilian children, and in 4058 (9·6%) opposition combatants. Proportions of children among civilian deaths increased from 8·9% (388 of 4354 civilian deaths) in 2011 to 19·0% (4927 of 25 972) in 2013 and to 23·3% (2662 of 11 444) in 2016. Of 7566 deaths from barrel bombs, 7351 (97·2%) were civilians, of whom 2007 (27·3%) were children. Of 20 281 deaths by execution, 18 747 (92·4%) were civilians and 1534 (7·6%) were opposition combatants. Compared with opposition child soldiers who were male ( $n=333$ ), deaths of civilian male children ( $n=11 730$ ) were caused more often by air bombardments (39·2% vs 5·4%,  $p<0\cdot0001$ ) and shelling (37·3% vs 13·2%,  $p<0\cdot0001$ ) and less often by shooting (12·5% vs 76·0%,  $p<0\cdot0001$ ).

**Interpretation** Aerial bombing and shelling rapidly became primary causes of direct deaths of women and children and had disproportionate lethal effects on civilians, calling into question the use of wide-area explosive weapons in urban areas. Increased reliance on aerial bombing by the Syrian Government and international partners is likely to have contributed to findings that children were killed in increasing proportions over time, ultimately comprising a quarter of civilian deaths in 2016. The inordinate proportion of civilians among the executed is consistent with deliberate tactics to terrorise civilians. Deaths from barrel bombs were overwhelmingly civilian rather than opposition combatants, suggesting indiscriminate or targeted warfare contrary to international humanitarian law and possibly constituting a war crime.

**Funding** None.

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## Introduction

The Syrian conflict started in March, 2011, with peaceful demonstrations. By June, 2011, these had escalated into an armed rebellion against President Bashar Al-Assad and his government that involved a spectrum of anti-government factions including Salafi jihadist groups, the Islamic State of Iraq and the Levant (ISIL), the mostly Kurdish Syrian Democratic Forces, and a more moderate Free Syrian Army. Warring parties in Syria have since proliferated to include additional jihadist groups, Russian air forces, US-led coalition air forces, and Iranian, Palestinian, Russian, and coalition special forces.

The continuing civil war has displaced over half the population. By late 2016, 6·3 million Syrians were

internally displaced, with an estimated 6100 newly displaced people daily.<sup>1</sup> Over 1 million fled to Europe<sup>2</sup> and an additional 5 million are refugees living in neighbouring countries,<sup>1</sup> of whom 2·4 million are children.<sup>3</sup> Among Syrians unable to escape the violence, over 1 million have been injured and hundreds of thousands have died from indirect and direct effects of war, resulting in a drop in life expectancy of up to 20 years by 2014.<sup>4</sup> Indirect deaths from the conflict arise for many reasons including increased disease and severe shortages of medical staff, supplies, and access to facilities.<sup>1,5–8</sup> Direct conflict deaths are from injuries inflicted by violent methods used by warring parties. The aim of this study was to describe demographic, spatial, and temporal patterns of direct deaths of civilians

*Lancet Glob Health* 2018;  
6: 103–10

Published Online  
December 6, 2017  
[http://dx.doi.org/10.1016/S2214-109X\(17\)30469-2](http://dx.doi.org/10.1016/S2214-109X(17)30469-2)  
See [Comment](#) page e14

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### Research in context

#### Evidence before this study

We searched PubMed, Scopus, and Google Scholar using a wide array of combinations including the terms “mortality”, “death”, “lethal”, “autopsy”, “casualty”, “violence”, “Syria”, “war”, and “conflict” for reports published before March 6, 2017.

We scrutinised 457 article titles and abstracts and downloaded 62 full papers, which included 47 academic and 15 white papers and reports. We examined reference lists for additional sources. Most reports were published by international organisations, such as the UN, UNICEF, Human Rights Watch, Physicians for Human Rights, and the Oxford Research Group. These reports focused primarily on human rights violations against civilians involving the use of explosive weapons in populated areas, chemical weapons, barrel bombs, execution, and targeted attacks on schools and hospitals. The medical literature primarily described attacks on medical facilities and medical personnel and injury profiles. Specific methods of war used in Syria were analysed in one paper through the lens of international humanitarian law. Several small studies described conflict-related deaths and injuries of Syrians who reached medical facilities in Turkey. We previously reported the effect of weapons causing 78 769 Syrian civilian direct deaths up to January, 2015, with a focus on vulnerable demographic groups.

#### Added value of this study

This study makes use of the systematic recording of violent deaths from the Syrian civil war by the Violation Documentation Center over 6 years of conflict to provide

a systematic analysis of civilian and opposition combatant violent deaths, their demographic characteristics, the causative method or weapon, and spatial and temporal patterns of direct deaths during the conflict. We relate patterns and causes of death to possible violations of international humanitarian law.

#### Implications of all the available evidence

This study shows that the Syrian civil war saw a shift to the systematic use of air bombardments, including barrel bombs, on populated areas. This caused increasingly high proportions of deaths of civilian women and children over the 6 years of conflict, which is arguably disproportionate and thus contrary to international humanitarian law. Deaths of children from air bombardments were increasingly concentrated in Aleppo over 6 years. By the end of 2016, one in four Syrian civilians killed by barrel bombs was a child. Cause of death of child soldiers differed significantly from that of child civilians and adult combatants. Civilian men were disproportionately represented among those executed and tortured, which supports allegations of a policy of targeting civilians as a means of conducting the war, contrary to international humanitarian law. The relatively small effect of wide-area weapons against combatants, together with their disproportionate effect on civilians, calls into question the use of such weapons in urban conflicts containing a large civilian population. Use of explosive weapons might minimise deaths among combatants but do so at a disproportionate cost in civilian deaths. Therefore, forces fighting in urban areas should employ tactics carefully to comply with international humanitarian law.

and opposition combatants from conflict-related violence during the first 6 years of the Syrian war.

## Methods

### Data source

Staff at the Violation Documentation Center (VDC) gave permission to the authors to use VDC data. The VDC is a non-profit non-governmental organisation registered in Switzerland that tracks and documents human rights violations from the armed conflict in Syria dating from March 18, 2011, including war-related deaths and missing and detained people. The VDC applies international standards for documentation of human rights violations. When the group formed in April, 2011, it retrospectively added data starting from March 18, 2011, and subsequently compiled data on conflict-related deaths on a daily basis. To ensure independence and neutrality, the VDC only accepts funding from independent, unbiased, or neutral entities. The VDC was founded by Razan Zeitouna, a human rights lawyer who was subsequently kidnapped with her husband and two other VDC staff members in January, 2013, in Duma, Syria. Since then, VDC has been led by a group of administrators inside and outside of Syria (initially in Turkey and then Switzerland) and two database

managers. Depending on the period, the VDC has a team of about 30–35 investigators and a ground network covering every governorate consisting of more than 30 internationally trained field reporters, who collect data in three steps. First, initial information on one or more victims is gathered, mainly from hospitals, morgues, relatives of the victims, and media sources. Second, the initial report is further confirmed, when possible, by supporting information on victims such as videos or photographs. Third, once the record has been established, key information missing on victims is actively investigated until completion of record. For each death, the record consists in demographics, date, location, cause of death, and civilian versus combatant status (with combatant defined as any member of the government, opposition, or non-state armed groups). The VDC compiles information on every death captured by its ground-reporting network. Its registries are verified daily and updated with new information. Data are available in both Arabic and English.

The VDC gathers information on conflict-related violent deaths from all governorates in Syria, regardless of the perpetrator of the violation. It does not claim to be fully exhaustive; in particular, information on victims in government-controlled areas can be difficult to obtain

For more on the Violation Documentation Center see <http://vdc-sy.net/en/>

because these areas are often not safely accessible to VDC staff. Therefore, we chose not to include data from government-controlled areas, contained in the so-called regime fatalities dataset, because of the uncertainties in the dataset (ie, key missing information in available records and few data from recent years). Instead, we analysed data from non-government-controlled areas; these data are contained in the so-called martyrs dataset and describe deaths of civilians and non-government combatants in non-government-controlled areas. The VDC identified combatant deaths by an iterative process including multiple sources of information and validation as described above. Further details on the VDC datasets and data collection are described in our previous paper<sup>9</sup> on Syrian civilian deaths. We defined children as individuals younger than 18 years of age, consistent with the Convention on the Rights of the Child.<sup>10</sup>

The Ethical Board of the Université catholique de Louvain advised that informed consent was not required for analysis of these mortality data collected for purposes other than this study and in the public domain.

### Data analysis

We included all conflict-related, direct violent deaths occurring from March 18, 2011, to Dec 31, 2016, with complete information on date, place (listed as “Province” in the database), and cause of death and demographic group (men, women, male children, or female children). Our analysis only included deaths from the killed dataset, and did not include detainees or missing persons. We did not include deaths from siege conditions (eg, starvation) or inability to seek medical care.

We categorised weapons based on VDC weapon types. Shelling comprised artillery, tanks, mortars, rocket launchers, ground-launched missiles, and shells. Ground-level explosives comprised improvised explosive devices such as suicide bombs, vehicle bombs, and roadside bombs; landmines; explosive remnants; grenades; explosive booby-traps; and unidentified ground-level explosives not delivered by a plane or helicopter. Chemical weapons were toxic substances delivered in any form. Shooting comprised handheld small arms, machine guns, and snipers. VDC deaths by execution in the field or after detention or abduction, with and without torture, were collapsed into one execution category, although we also analysed use of torture before execution separately. We categorised VDC warplanes as air bombardments because they included not only aeroplane-delivered explosives but also barrel bombs dropped by helicopters and aeroplanes. Barrel bombs are improvised, fragmenting explosives, made of barrels or cylinders filled with explosives, shrapnel, nails, and oil. They weigh approximately 90 kg to 900 kg and fragment on impact into a large blast radius capable of decimating a city block.<sup>11</sup> We searched the note section of air bombardment records for the term “barrel” to identify direct deaths from barrel bombs in the Syrian conflict.

We used  $\chi^2$  tests to compare demographic group (ie, civilian vs combatant, adult vs child, male vs female). Additionally, we provide descriptive statistics on cause of death by weapons type. We used R software (version 3.3.2) to calculate proportions and  $\chi^2$  testing. All p values are two-tailed with one degree of freedom and  $\alpha=0.05$ .

### Role of the funding source

No funding was received for this study. All authors had full access to all the data and are jointly responsible for the decision to submit for publication.

### Results

The VDC recorded 145 849 deaths in non-government-controlled areas from March 18, 2011, to Dec 31, 2016. We excluded 2219 deaths due to unspecified cause of death (n=1354), missing location (n=558), missing or erroneous data (n=73), and death by siege (n=23) or insufficient medical care (n=211), resulting in a dataset of 143 630 deaths with complete information on date and place of death, demographic group, civilian or combatant status, and cause of violent death. Approximately 99% of combatants had information on their military rank or armed group and were all affiliated with opposition groups; the remaining 1% were of unknown affiliation. Civilians constituted 70.6% (n=101 453) of violent deaths from conflict, and opposition combatants constituted 29.4% (n=42 177; table). Among the civilians killed, 72 940 (71.9%) were men, 11 112 (11.0%) were women, and 17 401 (17.2%) were children. Violent deaths of civilian men were caused in almost equal proportions by shelling, shooting, executions, and aerial bombardments (table). Civilian women were killed primarily by wide-area weapons of shelling and air bombardments, as were civilian children (table). In all, more than half (58 099, 57.3%) of civilian deaths from conflict violence resulted from wide-area explosive weapons, with 29 983 (29.6%) caused by shelling and 28 116 (27.7%) by air bombardments, and 20 372 (20.0%) deaths resulted from shooting. By comparison, only 9.6% of opposition combatant deaths resulted from wide-area explosives (2870 [6.8%] by shelling and 1188 [2.8%] by air bombardments), whereas 35 416 (84.0%) died from shooting (table). Among opposition combatants, 99.2% of those killed were men, 0.8% were boys, and 0.01% were women (table).

Almost all of the 7566 deaths from barrel bombs were civilians (7351, 97.2%), of which more than a quarter were children (2007, 27.3%; table). The proportion of civilian children who died from aerial bombardments with barrel bombs was nearly twice that of civilian men ( $p<0.0001$ ; table). Among civilians killed by barrel bombs, women were significantly over-represented compared with men ( $p<0.0001$ ; table). Civilian deaths from barrel bombs were concentrated in time, with 5322 (72.4%) occurring in the 18 months from Jan 1, 2014, to June 30, 2015. 4820 (65.6%) civilian deaths from barrel bombs occurred in Aleppo,

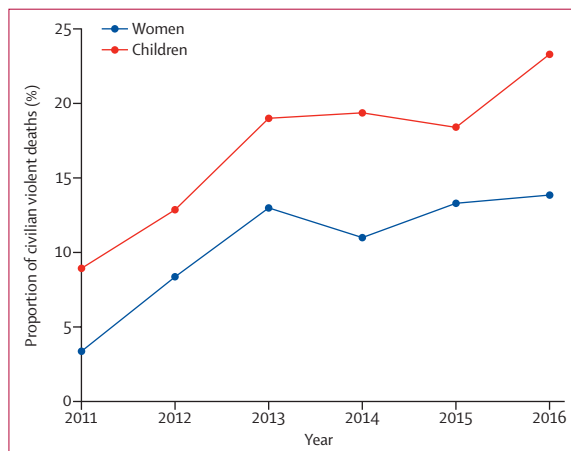
For the **regime fatalities dataset** see <http://www.vdc-sy.info/index.php/en/otherstatistics>

For the **martyrs dataset** see <http://www.vdc-sy.info/index.php/en/martyrs>

	Civilian				Combatant	
	Adult, male	Adult, female	Child, male	Child, female	Adult, male	Child, male
Shelling	19 216 (26.3%)	4189 (37.7%)	4381 (37.3%)	2197 (38.7%)	2826 (6.8%)	44 (13.2%)
Shooting	17 026 (23.3%)	1445 (13.0%)	1466 (12.5%)	435 (7.7%)	35 163 (84.0%)	253 (76.0%)
Executions	17 025 (23.3%)	798 (7.2%)	714 (6.1%)	210 (3.7%)	1528 (3.7%)	6 (1.8%)
Air bombardments	16 788 (23.0%)	4096 (36.9%)	4604 (39.2%)	2628 (46.3%)	1170 (2.8%)	18 (5.4%)
Barrel bomb explosives	4253 (5.8%)	1091 (9.8%)	1274 (10.9%)	733 (12.9%)	211 (0.5%)	4 (1.2%)
Ground-level explosives	2311 (3.2%)	282 (2.5%)	489 (4.2%)	142 (2.5%)	1063 (2.5%)	12 (3.6%)
Chemical weapons	574 (0.8%)	302 (2.7%)	76 (0.6%)	59 (1.0%)	88 (0.2%)	0
Total	72 940	11 112	11 730	5671	41 838	333

This table does not show the six adult female combatants whose deaths are included in the study dataset (one by shooting; two by air bombardments, of which one by barrel bomb explosives; and three by ground-level explosives). No child female combatants were recorded.

**Table: Cause of violent death of Syrian civilians and opposition combatants, 2011–16**



**Figure 1: Proportion of civilian violent deaths composed of women and of children in years 2011–16 of the Syrian conflict**

794 (10.8%) in Daraa, and 664 (9.0%) in Idlib. Nearly two thirds of all child deaths from barrel bombs occurred in Aleppo (1264, 63.0%), where more than a quarter (26.2%) of civilians killed by barrel bombs were children. Of all child deaths from barrel bombs, 285 (14.2%) occurred in Daraa and 172 (8.6%) in Idlib, comprising 35.9% and 25.9%, respectively, of civilian deaths by barrel bombs in those areas.

Of 20281 deaths by execution, 18747 (92.4%) were civilians and 1534 (7.6%) were opposition combatants (table). Among civilian men, nearly a quarter were killed by execution compared with 3.7% of adult male opposition combatants ( $p < 0.0001$ ; table). Among civilian men killed by execution, 7237 (42.5%) were tortured before execution compared with 411 (26.9%) executed adult male combatants ( $p < 0.0001$ ). Executed civilian men were subjected to torture significantly more often than were executed civilian women (*vs* 65 [8.1%];  $p < 0.0001$ ) and children (*vs* 124 [13.4%];  $p < 0.0001$ ). Executed civilian children were subjected to torture significantly more often than were executed civilian women ( $p < 0.0001$ ).

The Syrian conflict claimed an increasing proportion of children among civilian deaths as fighting continued, up to and including 2016 (figure 1). At the beginning of the conflict (ie, until the end of 2011), children composed 8.9% ( $n=388$ ) of all 4354 civilian deaths; in 2013, they composed 19.0% ( $n=4927$ ) of 25972 civilian deaths that year; and by Dec 31, 2016, they composed 23.3% ( $n=2662$ ) of 11444 civilian deaths that year, increasing by 14.4 percentage points over the 6 years. The proportion of adult female deaths more than quadrupled during this period, rising from 3.4% (146 deaths) in 2011 to 13.8% (1582 deaths) by the end of 2016 (figure 1). Throughout the conflict, the proportion of deaths among children has been higher than the proportion of deaths among women, and the gap between these two proportions reached its maximum, nearly 10.0 percentage points, by 2016 (figure 1).

In the first 2 years of the war, the single-target method of shooting caused most civilian deaths (figure 2). In early 2013, shelling became the predominant cause of civilian death and rapidly escalated. Civilian deaths from air bombardments were initially low until August, 2012, when they accelerated rapidly, causing air bombardments to become the second greatest cause of civilian violent death by the end of 2016. By this point, 44289 (52.7%) of all adult civilian violent deaths had resulted from wide-area explosive weapons, with 23405 (27.8%) of all deaths caused by shelling and 20884 (24.8%) by air bombardments (table).

Patterns of death differed substantially between demographic groups, changing over the period of the conflict. Civilian men died mostly from shooting from March, 2011, to January, 2014, after which point most died from shelling (figure 2). By contrast, the primary cause of violent deaths of civilian women and children shifted from shooting to shelling earlier in the conflict, beginning in August, 2012 (figure 2). Air bombardment deaths of women and children increased more rapidly than among men, becoming the leading cause of death for civilian women and children by September, 2016. By the end of 2016, 22095 (77.5%) of 28513 civilian women and children

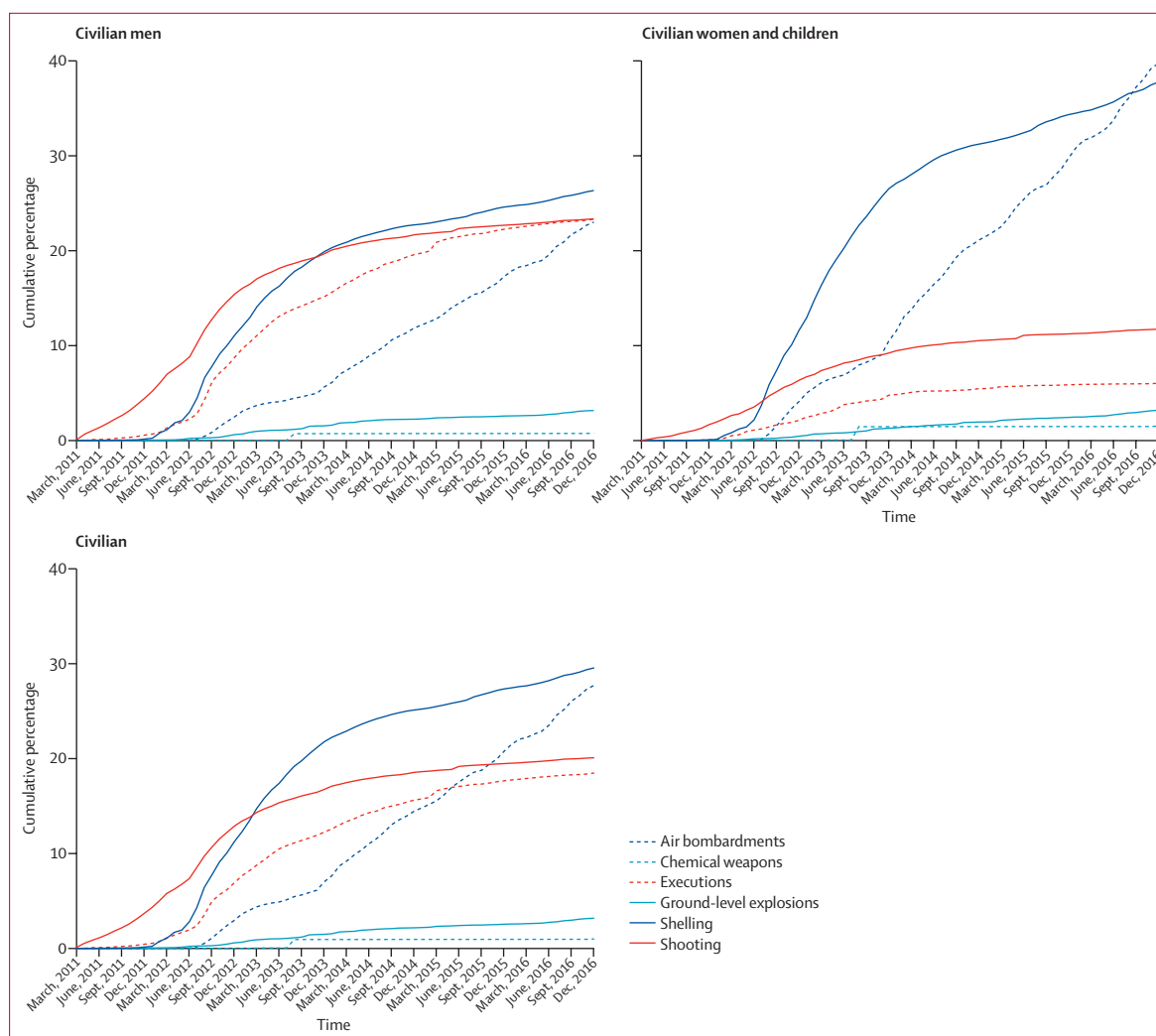


Figure 2: Civilian deaths by weapon type and demographic group

killed had resulted from wide-area explosive weapons, with 10767 (37·8%) of all deaths caused by shelling and 11328 (39·7%) caused by air bombardments (table).

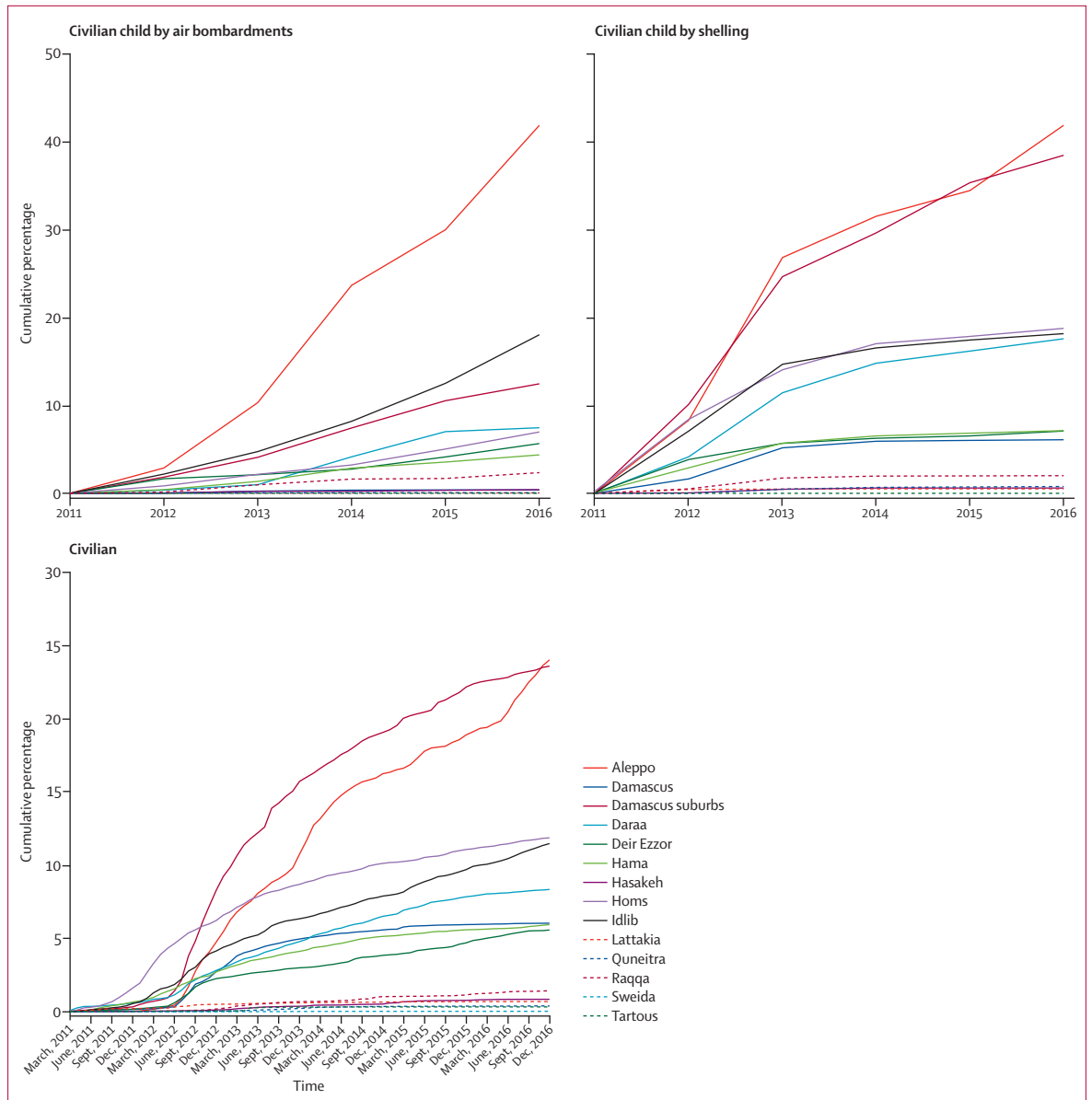
The greatest numbers of civilian violent deaths were documented in Homs until late 2012; at this point, Homs was overtaken by Damascus suburbs and Aleppo, which each witnessed nearly 25% of all deaths (figure 3). The highest proportions of civilian child deaths by shelling occurred substantially and consistently in Aleppo and in Damascus (figure 3). Over 40% of child deaths by air bombardment were concentrated in Aleppo. This proportion escalated in 2013, reaching over twice that of other governorates (figure 3).

A greater proportion of civilian male children died from air bombardments and from shelling than did child combatants (both  $p < 0\cdot0001$ ; table), whereas a greater proportion of child combatants died from shooting than did civilian male children ( $p < 0\cdot0001$ ; table). Shooting was the most frequent cause of death of

child and adult combatants (table). Compared with adult combatants, child combatants were more likely to die from shelling ( $p < 0\cdot0001$ ) and from air bombardments ( $p < 0\cdot0069$ ). Child combatant deaths documented by the VDC were distributed in multiple governorates, mostly in Aleppo (101 [30%] deaths) and Damascus suburbs (55 [17%] deaths). Of 327 child opposition combatants of known affiliation, 290 (89%) were associated with the Free Syrian Army, 24 (7%) with ISIL, and small percentages with other groups. Of 292 child combatants of known age, 241 (83%) were 16–17 years of age. However, violent deaths of child combatants as young as 11 years of age were documented.

## Discussion

Our study shows that 70% of direct violent deaths of civilians or opposition combatants in the first 6 years of the Syrian civil war were civilians. The total number of direct conflict deaths of men in Syria substantially exceeded that



**Figure 3: Civilian and civilian child deaths by governorate**

No child deaths by air bombardment or shelling were recorded in Sweida. Governorates are written as listed in the Violation Documentation Center database.

of women, which is consistent with the greater loss of life expectancy of male Syrians than of female Syrians that was primarily attributed to war violence, as shown by the Global Burden of Disease Study.<sup>12</sup> We found shifts in cause and location of death that reflected the path of the Syrian war. Shootings, summary executions, grenades, and ground-launched shells initially characterised both government and rebel forces. Aerial bombardments were then initiated by the Syrian Government and intensified with the entry of international powers including the US-led coalition in 2014 and Russian forces in 2015. Consistent with this trajectory of war, our analysis shows that most civilians were killed by shooting in the first 2 years, after

which shelling became the predominant cause of civilian death, accompanied by a rapid increase in deaths from air bombardments from 2012 until the end of 2016. Approximately three quarters of recorded incidents of explosive weapon use in Syria have occurred in densely populated civilian areas, putting civilians at very high risk and suggesting a degree of intentionality.<sup>5,13,14</sup>

Most notable among our findings was the relatively minimal effect of wide-area explosive weapons on opposition combatants in the Syrian conflict. The proportion of civilian deaths by wide-area explosives was five times higher than that of opposition combatants (57·3% vs 9·6%), and these wide-area weapons had



a severe impact on civilian children, accounting for 79% (n=13 810) of direct deaths. Over the course of the conflict, the proportion of children among civilian deaths increased from 8·9% in 2011, to 19·0% in 2013, and reached 23·3% in 2016. Increased use of aerial bombing by Syrian Government forces and international partners was a likely contributor to this pattern and to our finding that the proportion of civilian women and children killed by explosive weapons increased earlier in this conflict, more rapidly and more severely than in civilian men, as aerial bombardments on densely populated areas increased. Concentrated bombing on Aleppo increased child deaths disproportionately beyond that of any other governorate. A possible contributor to increasing proportions of women and children among civilian deaths could be that numbers of civilian men in the population decreased over time as some took up arms to become combatants. Children are less likely to survive explosive blast injuries in armed conflict due to anatomical and physiological vulnerabilities, and so might have contributed a greater proportion to deaths by wide-area explosives.<sup>15,16</sup> Among injured Syrians who fled to Turkey, head injuries from explosive weapons were more common in children<sup>17</sup> and a post-mortem study found that 54% of Syrian children who died from bombing and shrapnel injuries had injuries to multiple body parts.<sup>18</sup> An analysis of attacks on Syrian hospitals, which were primarily by aerial bombardment, found that most of the dead were male, but the highest case fatality was seen in children younger than 5 years.<sup>19</sup>

Among the explosive weapons used, the impact of barrel bombs on civilians, compared with their relatively small effect on combatants, was striking. Barrel bombs can cause three times as many injuries to survivors as do rockets and missiles, and cause higher numbers of deaths.<sup>11</sup> They were dropped by Syrian Government forces on hospitals, markets, and homes.<sup>20</sup> A first barrel bomb was sometimes followed by a second bomb dropped minutes later in a so-called double-tap strike to eliminate first responders and medical services.<sup>11</sup> Our study shows that by the end of 2016, more than a quarter of all civilians killed by barrel bombs were children, with the highest numbers in Aleppo, Idlib, and Daraa. We found an extreme disparity from the use of barrel bombs in which nearly all barrel bomb deaths (97·1%) were civilians and only 2·8% of deaths were of opposition combatants. This excessive disparity between civilian and combatant deaths from wide-area explosives, and especially from barrel bombs, together with high rates of child deaths, are consistent with allegations that the Syrian Government's use of wide-area explosives was in violation of the Third and Fourth Geneva Conventions and Associated Protocols I & II that grant general civilian protection and special protection to children.<sup>5,21-23</sup> The little effect on combatants and exceptionally disproportionate impact on civilians, especially on children, support assertions that barrel bombs were used indiscriminately, or that they constitute an indiscriminate weapon, contrary to international

humanitarian law.<sup>23</sup> An additional finding of extreme disparity was that among those killed by execution, 92·4% were civilians compared with 7·6% who were opposition combatants. This finding is consistent with a deliberate tactic of terrorising civilians, also contrary to international humanitarian law.

Recruitment of Syrian youth and children into conflict-related roles has been reported in 90% of surveyed subdistricts, with adolescent boys at particular risk.<sup>1</sup> The recruitment or use in armed conflict of children under age 15 is a war crime and compulsory recruitment or direct participation in hostilities of children ages 15-17 is prohibited by international humanitarian law.<sup>24</sup> Our data indicated that opposition child soldier deaths were primarily among boys in their late teens and as young as 11 years of age. We do not know whether the children associated with opposition forces in the VDC dataset were actively recruited or volunteered, or whether they were in combat roles or other high-risk roles documented in Syria such as assisting emergency services and being porters or lookouts.<sup>25</sup>

Limitations of our study include that VDC data collection can vary over space and time due to intensity of conflict, changes in control of areas, blocked access, or threats to data collectors. Witnesses and families might decline to provide information due to fear of reprisal. Electricity and internet interruptions affect data communication.<sup>9,26,27</sup> Data collection or categorisation can be biased by motivations of academic, government, or advocacy groups. These limitations are shared by studies using data from conflict areas. A limitation specific to our study is that we did not compare direct deaths of combatants on opposing sides. We did not include data from government-controlled areas because we considered data reporting in these areas to be more limited by the difficulty of obtaining data, as was considered likely for data gathered in government-controlled areas for a study of attacks on hospitals.<sup>19</sup> This study does not describe indirect deaths from this war, injuries, deaths of civilians taking refuge in other countries, disappeared persons, and detainees not recorded as killed such as concealed deaths by execution during government detention. Regarding the relative effects of weapons, we expect that deaths from wide-area explosive weapons were more likely to be under-recorded by the VDC than were deaths from shooting and executions because explosive forces are more likely to cause dismemberment and vapourisation of bodies, as well as bodies hidden by collapsed buildings. Thus, our findings of disproportionately high numbers of civilian deaths from wide-area explosives weapons might be an underestimate. However, we do not believe that such an underestimate would change our finding of a disproportionate effect on civilians compared with combatants in this war.

Strengths of this study include the minimisation of recall bias and possibility of verification afforded by the VDC's use of daily collated, detailed data. The VDC uses international standards for documentation of human

rights violations and has been recognised as a sound, detailed data source on Syrian conflict-related violent deaths over 6 years of the war.<sup>26,27</sup> The dataset distinguishes between civilians and combatants, which allows analysis for variable effects of different weapons and tactics on civilians compared with combatants. In addition, causes of death of child soldiers can be compared with child civilians and adult combatants. Data on geographic locations and times of deaths can be combined with victim and weapon characteristics to identify trends and patterns of violent deaths in the Syrian conflict.

In conclusion, Syrian civilians, and in particular children, have borne the brunt of violence by parties to the Syrian civil war. Aerial bombing and shelling rapidly became primary causes of direct deaths of women and children. Increased reliance on aerial bombing by the Syrian Government and international partners probably contributed to our findings that children were killed in increasing proportions over time. Our findings underscore the poor efficacy of shelling and aerial bombardments against combatants, and the disproportionate lethal impact on civilians. These findings call into question the use of wide-area weapons in populated urban areas and suggest possible indiscriminate weapons use contrary to international humanitarian law. The extreme disparity found between numbers of deaths of civilians compared with combatants from barrel bombs is consistent with direct targeting of civilians, which would be a violation of international humanitarian law and might constitute a war crime.

#### Declaration of interests

We declare no competing interests.

#### Contributors

DG-S, MH-RH, BS, JMR-L, and LL were responsible for the conception and design of the study. BS and JMR-L curated and statistically analysed the data. DG-S, MH-RH, LL, JMR-L, and BS contributed to interpretation of data, preparation of content, and critical revisions of drafts. JMR-L and MH-RH did the literature review. DG-S, MH-RH, JMR-L, BS, and LL contributed literature. DG-S, MH-RH, BS, JMR-L, and LL agreed to submit the final version.

#### Acknowledgments

We are grateful to the VDC for sharing the data with us and for providing methodological insights on the collection process. We also thank Abdo Beirekdar (Université catholique de Louvain, Brussels, Belgium) for preparing the dataset and translating and cross-checking records between Arabic and English.

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