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The Embodiment of War: Growth, Development, and Armed Conflict

Patrick F. Clarkin

Department of Anthropology, University of Massachusetts, Boston, Massachusetts 02125-3393, USA; email: patrick.clarkin@umb.edu

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Keywords

war, armed conflict, embodiment, growth, menarche, DOHaD

Abstract

Armed conflict regularly presents extremely adverse circumstances not only for combatants, but also for civilians. In fact, estimates from various wars over the past 70 years suggest that noncombatants comprise the majority of casualties. For survivors, war's effects are often embodied, leaving long-term effects on health and biology. Some of these effects, such as injuries and psychological trauma, are well known. Yet other effects may be subtle and may be elucidated by a developmental biological perspective. In early life, when growth rates are highest, conditions of war may have their greatest impact. Depending on local circumstances, a developing embryo, infant, or child growing in a place embroiled in armed conflict is likely to face—directly or indirectly—various stressors, including malnutrition, infectious disease, and/or psychological stress. Thus, the conditions of war and forced displacement may become embodied, getting under the skin for fundamental biological reasons.

INTRODUCTION

PTSD: post-traumatic stress disorder

The notion that armed conflicts can have lasting, deleterious effects on their participants is not new. In the last two centuries, various syndromes akin to post-traumatic stress disorder (PTSD) have been diagnosed in soldiers and veterans, at different times referred to as soldier's heart, war neurosis, battle fatigue, shell shock, or Vietnam syndrome (Shively & Perl 2012). Anecdotal evidence suggests that persistent effects of war-related psychological trauma may have been recognized in soldiers who fought in the French Revolution, in the Hundred Years' War of the fourteenth and fifteenth centuries, and during the Assyrian dynasty (Abdul-Hamid & Hughes 2014, Crocq & Crocq 2000). Of course, responses to trauma have not been consistent across all wars. Rather, people have long understood, at least occasionally, that armed conflicts can have enduring consequences for combatants.

Civilians can be affected as well. Yet, armed conflict is often framed primarily as a military endeavor, reducing the visibility of its impacts on civilians. For example, in a 2007 survey of US citizens, most respondents had an accurate perception of the number of US military personnel who had been killed in the contemporary war in Iraq, but they drastically underestimated the number of Iraqi civilians who died by that point in time, by a factor of at least 10 (Henderson et al. 2009).

Alternatively, war can be framed as a public health problem, with both immediate and long-term effects (Murray et al. 2002). In a national sample of more than 1,500 elderly Germans, those who were forcibly displaced from their homes as children or teenagers 60 years prior during the Second World War had significantly higher levels of anxiety and lower levels of resilience and life satisfaction than did those who were not displaced (Kuwert et al. 2009). However, Kuwert et al. (2009) observed that similar research on the long-term effects of war-related trauma was "scarce," suggesting that the effects of armed conflict on civilians may be underappreciated, not only in terms of casualties but also in terms of the myriad pathways through which the effects of conflict can become embodied.

Biological anthropologists have helped pave the way to understanding how the effects of various challenging social environments, including poverty, inequality, financial debt, and racism, can become embodied (Gravlee 2009, Leatherman & Goodman 1997, Sweet et al. 2013). Krieger (2005, p. 351) referred to embodiment as a process by which living organisms, including humans, "literally incorporate, biologically, the world in which we live, including our societal and ecological circumstances." This process continues unabated prenatally until death, as bodies interact with multiple levels of their environments: from available nutrients to interpersonal interactions to societal arrangements of power, resources, and status.

However, the discipline may have overlooked the biological effects of war, at least in modern human populations. For example, in a study of endemic warfare and health among rural pastoralists in Kenya, Pike et al. (2010, p. 50) wrote that "studies that directly link increased armed conflict and shifts in health experiences are exceedingly rare." Indeed, Brewis & McKenna (2015) reviewed a decade of articles in the *American Journal of Human Biology* (2004–2013) to estimate how well the articles addressed some of the most pressing global challenges. Only two articles explicitly mentioned armed conflict.

This review has two objectives. First, it frames armed conflict as an environment that presents challenges for human health and biology. Second, it explores some of the ways that conflict-related adversity can get under the skin, particularly in the earlier stages of the life course. Rather than going over the well-traversed ground of armed conflict and mental health, the focus is on how war-related disruption (economic, social, ecological, psychological, nutritional) consistently has deleterious effects on somatic development, including physical growth and physiological health

(Devakumar et al. 2014). Such disruption also pertains to the developmental origins of health and disease (DOHaD) paradigm, where early-life stressors may predispose an embryo, fetus, or infant to various chronic diseases later in life (Barker 1998). The aim is to look for patterns between armed conflict and health rather than to single out specific nations or political entities as aggressors. A preliminary, but safe, conclusion is that regardless of its participants or location, armed conflict consistently presents a suite of stressors that can impair health at the population level.

DOHaD: developmental origins of health and disease

ARMED CONFLICT AS AN ENVIRONMENT

It is necessary to find workable definitions of armed conflict and war, while acknowledging that these are not a dichotomous phenomenon. Rather, there is a continuum of severity; violence takes many forms that require an appreciation of local context (Martin & Harrod 2015). Anthropologists and archaeologists have offered various definitions; perhaps the most straightforward definition is proposed by Thorpe (2003, p. 146), who defined war as "organized aggression between autonomous political units." The Uppsala Conflict Data Program (UCDP 2018), by comparison, defines armed conflict as "at least 25 battle-related deaths per calendar year in one of the conflict's dyads." By extension, minor conflicts are defined as having 25–1,000 deaths, whereas wars entail at least 1,000 deaths. These can include various actors, including governments, rebel groups, militias, cartels, or informally organized interethnic violence. One-sided violence is defined as a formally organized group using armed force against civilians resulting in at least 25 deaths in a year. With those distinctions in mind, this review uses the umbrella term "armed conflict" for all wars, minor conflicts, and incidents of one-sided violence with more than 25 recorded deaths.

Recent and ongoing conflicts serve as reminders that, while all conflicts are unique, they have recurrent features and that one of the most extreme environments in which people can reside is one created by human agency. In a general sense, conflict can be conceptualized as an environment that can be as challenging to human biology and health as the most extreme ecological circumstances traditionally studied by biological anthropologists. For example, Pike (2004, p. 221) referred to the insecurity and frequent raiding of cattle faced by Turkana pastoralists of northwest Kenya "as disruptive as the worst drought" with regard to health. Although it is axiomatic that war and conflict can lead to death, injury, and psychological trauma among military personnel, some studies have suggested that civilians often bear the brunt of conflict. Casualties occurring among civilians are consistently above 50%, ranging from 40% in the case of Bosnia to 90% in the cases of Cambodia and Rwanda (Roberts 2010).

Direct and indirect casualties need to be distinguished (Hagopian et al. 2013). Direct casualties include deaths and injuries resulting from violent causes. Indirect casualties attributed to armed conflict result from heightened risks of malnutrition, infectious diseases (particularly diarrhea and acute respiratory infections), and complications from chronic diseases that would otherwise be treated under stable conditions (Degomme & Guha-Sapir 2010). These risks, in turn, can be caused by forced displacement or by a collapse in various aspects of infrastructure—either by their physical destruction or through the diversion of resources—including housing, health services (e.g., immunizations), food and water supplies, waste treatment, transportation, electricity, sanitation, or communication (Levy & Sidel 2007). Such disruptive forces can be pervasive, leading to an acute "complex emergency" with an accompanying spike in mortality (Salama et al. 2004).[1] Armed conflict, in short, has been referred to as "development in reverse" (Collier et al. 2003, p. ix).

[1]A "complex emergency" has been defined as an excessive crude mortality rate in a population, above the threshold of 1 death per 10,000 people per day in the acute phase (Toole & Waldman 1997).

Ecological Effects

Unexploded ordnance (UXO): remnants of explosive weapons (e.g., bombs, rockets, cluster munitions, mines) that did not detonate at the time they were utilized

Additionally, armed conflict can disturb local ecologies and economies in various ways, either through an intentional scorched earth strategy or as an incidental, albeit consistent, by-product (so-called collateral damage). As an example of the latter, Daskin & Pringle (2018) found that between 1946 and 2010, the frequency of military conflict was the most important predictor of declining population growth rates of wild herbivorous African mammal species. Several nations, including Laos, Cambodia, Vietnam, Bosnia, Chechnya, Kosovo, Afghanistan, Mozambique, Iraq, and Lebanon, have been saturated with land mines, cluster munitions, or other unexploded ordnance (UXO) during conflict (Andersson et al. 1995, Khamvongsa & Russell 2009, Parikh 2010). The effects of UXO can be extensive in some areas, to the point that Zani (2018) referred to these as "bomb ecologies," with the capacity to deter farming, impair economic development, and lead to casualties even decades after a conflict's official conclusion (Khamvongsa & Russell 2009). In fact, an estimated 98% of casualties caused by cluster submunition remnants occur among civilians (Handicap Int. 2007). Additionally, shelling and bombing can decrease soil quality and inhibit agriculture through "bombturbation" by disrupting topography, forming craters, and altering drainage patterns (Hupy & Schaetzl 2006). Weaponry can also pollute local environments. A century after the year-long Battle of Verdun during the First World War, the area known as *Place-à-Gaz* remains contaminated with lead, arsenic, copper, and mercury as a result of massive artillery shelling and subsequent disposal of ordnance (Thouin et al. 2016). These can be poisonous to certain plant species and continue to inhibit their growth in some areas of *Place-à-Gaz*, illustrating how long some ecological consequences of armed conflict can last.

Such contamination can become embodied. In a small sample of shed deciduous teeth from three Middle Eastern countries, levels of lead were 4 to 50 times higher in children from Basra, Iraq, than in Lebanon or Iran, pointing to the possible effects of early exposure to war-related pollution (Savabieasfahani et al. 2016). Among Vietnamese adults, Schecter et al. (1995) found that bodily concentrations of dioxin from the herbicide Agent Orange had declined between 1970 and 1992, yet still remained much higher among people living in formerly sprayed areas in the southern and central parts of the country compared with the north. Even the preparation for war can have deleterious effects. Marine vegetation near the island of Vieques, Puerto Rico, which was used for aerial and naval bombardment for 40 years until 2003, had higher levels of lead, copper, nickel, and cobalt than a site near the main island of Puerto Rico, likely the military by-products of ammunition, batteries, and paints (Massol-Deyá et al. 2005). In fact, concentrations of several of these metals declined substantially by 2004, after the cessation of bombing. Women on Vieques also had higher hair concentrations of mercury than did women in northeastern Puerto Rico, likely from consuming fish contaminated by military sources (Ortiz-Roque & López-Rivera 2004).

Conflict, Forced Displacement, and Malnutrition

Armed conflict and hunger are often intertwined, and their relationship may be bidirectional; hunger can lead to conflict and vice versa (Cohen & Pinstrup-Andersen 1999). Kelley et al. (2015) proposed that the severe 2007–2010 drought in Syria, which reduced livestock populations and wheat production in rural areas, created some of the conditions (massive migration, urban overcrowding, unemployment) that helped lead to the ongoing war. Conversely, conflict can lead to hunger and malnutrition via diverted resources, lowered food production, broken crop cycles, sieges and blockades, disrupted trade networks, and forced displacement.

The effects of forced displacement can be particularly pernicious. Shultz et al. (2014, p. 14) referred to massive forced displacement as "an intentional anthropogenic…armed-conflict disaster that escalates to a protracted complex emergency/humanitarian crisis." This is also germane to current global events. The United Nations High Commissioner for Refugees reported that, at the end of 2017, more than 68 million individuals were forcibly displaced worldwide, the highest that figure has ever been (UNHCR 2018). Refugees who cross international borders and internally displaced persons (IDPs) who remain in their country of origin often have little time to prepare for a strenuous journey; they also suffer from lost resources (property, social capital), a lack of access to humanitarian aid, resettlement in less fertile areas, overcrowding in camps, and restricted mobility due to fear of physical or sexual assault and are viewed as burdens by host countries (Al Gasseer et al. 2004, Hynes & Cardozo 2000, Salama et al. 2004). Breastfeeding rates decline among displaced women, putting infants and young children at risk for infection (Palmquist & Gribble 2018). All these factors may exacerbate a population's health and nutritional situation.

Internally displaced persons (IDPs): people who are displaced but have not crossed an international boundary and remain in their country of origin

Global acute malnutrition (GAM): the combined rate of moderate and severe acute malnutrition in a population, usually among children 0–59 months old

A systematic review of the relationship between conflict, displacement, and hunger is beyond the scope of this article. A few examples must suffice, which have been selected to illustrate the importance of local circumstances. In some instances, entire populations may face extreme hunger. During the Khmer Rouge era of 1975–1979, an estimated 1.7–1.9 million Cambodians were killed—up to a quarter of the population—by starvation, illness, execution, and overwork (Kiernan 2003). In a 2003–2005 survey of 490 Cambodian adult refugees living in California, 99% reported that they had experienced near-death due to starvation during the Khmer Rouge period (Marshall et al. 2005). In the current conflict in Yemen, up to 14 million people may be at risk of famine, owing in part to the Saudi-led blockade of its ports, which has curtailed the import of food, fuel, and medicine (Mohareb & Ivers 2019). By comparison, Sarajevo faced what was then the longest siege in the history of modern warfare from April 1992 to February 1995, yet it avoided widespread famine through a massive humanitarian airlift campaign, smuggling, and foraging of wild foods (Redžić 2010, Seybolt 2007).[2]

Many studies have used the World Health Organization definition of global acute malnutrition (GAM)[3] in young children to assess a population's nutritional status, defined as either a weight-for-height or an upper arm circumference of less than 2 standard deviations below the reference median or with the presence of edema (WHO 2000). Weight-for-height is the preferred anthropometric index in humanitarian evaluations because weight is more sensitive than height to rapid changes in food availability and because it is somewhat independent of a child's age, which is not always available. GAM rates of 5%, 10%, and 15% in a population are considered thresholds marking a population's nutritional status as poor, serious, or critical, respectively.

In general, IDPs tend to fare worse than refugees who have crossed an international border and made it to safer conditions with consistent humanitarian aid. For example, among various refugee populations, crude death rates were 5–12 times higher than baseline rates soon after arriving in their new host country; by comparison, rates for IDPs in northern Iraq, Somalia, and Sudan were 12–25 times above baseline, with children under age 5 being particularly vulnerable (Toole & Waldman 1993).

Furthermore, in the early 1990s, the prevalence of acute malnutrition in various conflict-affected populations ranged from 4% in Kurdish refugee children, to 48% in Mozambican refugees arriving in Zimbabwe, to 81% of internally displaced Sudanese children (Toole & Waldman 1993). In the following decade, 20.6% of internally displaced children under age 5 in Chad had acute malnutrition (Guerrier et al. 2009), whereas IDPs in neighboring Darfur had rates

[2]The Siege of Eastern Ghouta in Syria has since surpassed the one in Sarajevo in duration, lasting for more than five years between April 2013 and April 2018.

[3]GAM is a comprehensive term that includes both moderate acute malnutrition and severe acute malnutrition, marked by a weight-for-height < -2 z-score and < -3 z-score, respectively, for children 0–59 months old (WHO 2000). Strictly speaking, low weight-for-height need not be a result solely of malnutrition; it could also be due to infection, such as diarrheal disease, for example.

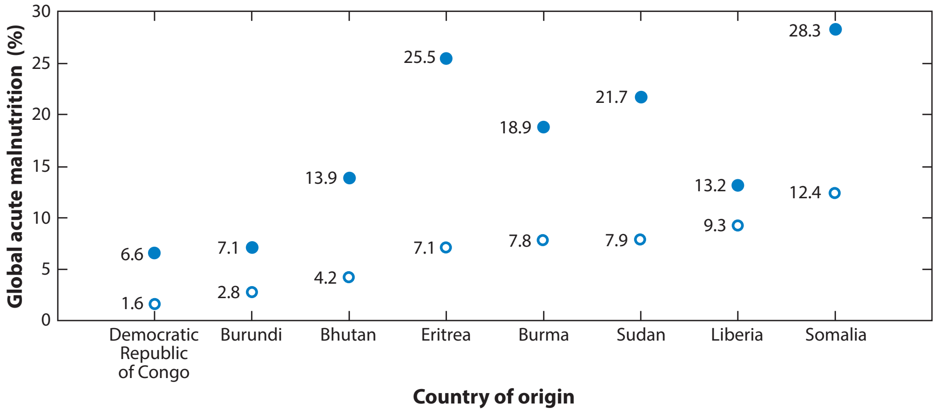

Figure 1

The highest and lowest rates of global acute malnutrition (GAM) found in children from various refugee groups. The data are from a review of 63 surveys from 22 camps housing refugees from 8 countries between 2004 and 2010 (Lutfy et al. 2014). For reference, GAM rates of 5%, 10%, and 15% in a population are considered thresholds marking a population's nutritional status as poor, serious, or critical, respectively.

between 11% and 24% (Grandesso et al. 2005). Among Rohingya refugees from Myanmar, known as "the most persecuted minority in the world," GAM was 18.2% for children living in a makeshift camp in Bangladesh (Phys. Hum. Rights 2010). In a review of 63 surveys from 22 camps housing refugees from 8 countries between 2004 and 2010, GAM rates ranged between 1.6% and 28.3%, illustrating the importance of local conditions (Lutfy et al. 2014) (**Figure 1**). More recently, there have been a few studies on the nutritional status of conflict-affected populations, such as Syrians in and outside of the country. However, it is obviously difficult to conduct surveys in Syria itself where intense fighting has displaced more than 12 million people since 2011 (UNHCR 2018). Among Syrian refugees in Jordan, Lebanon, and Iraq in 2013–2014, rates of GAM among young Syrian children were within acceptable levels, between 0.8% and 4.4% (Hossain et al. 2016). However, anemia was common and 10.5–21% of children were stunted, indicating chronic malnutrition. Data from health clinics and surveys in northern Syria have shown that while infections were frequent, rates of malnutrition were not excessive, although data are unavailable from the most devastated parts of the country, including Eastern Ghouta, Aleppo, Homs, and Raqqa; the health and nutritional situations there were likely to be far worse (Meiqari et al. 2018, van Berlaer et al. 2017).

EMBODIMENT OF ARMED CONFLICT

Armed conflicts consistently create a suite of stressors (economic, social, ecological, psychological, nutritional), albeit with local variation. Civilians will not experience all stressors equally or simultaneously, and it may be difficult to disentangle which stressors are most significant for a population. Given that conflict can be so disruptive, one can expect biology and health to be impacted beyond the well-known outcomes of injuries, mortality, and impaired psychological health and into other subtler aspects of physiology (**Figure 2**).

For example, in a study of more than 2,000 elderly Kuwaitis, a cumulative score of stressors experienced during the 1990 Iraqi invasion and occupation was correlated with subsequent development of asthma (Wright et al. 2010). Overall, 6.6% of men and 9.7% of women developed asthma at some point after Kuwait's liberation, and this measure had a dose–response relationship

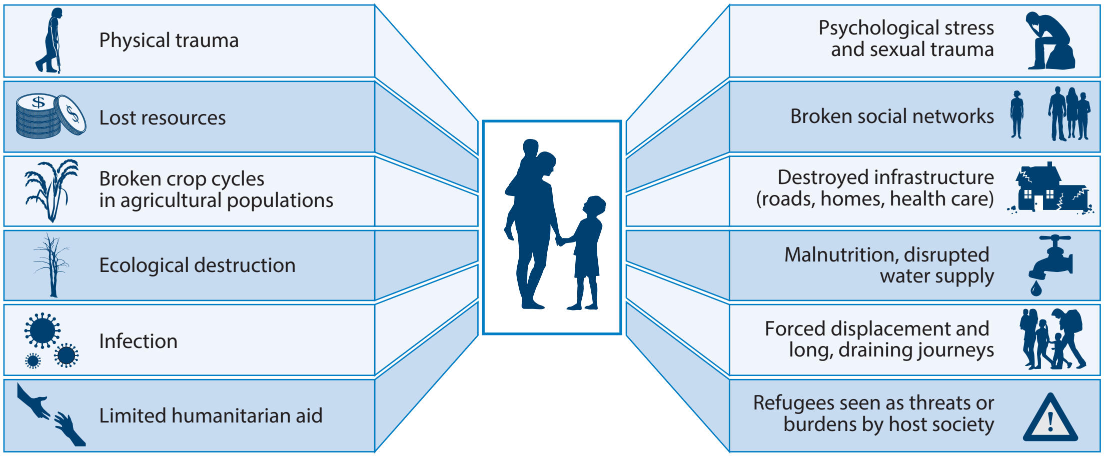

Figure 2

Some of the stressors encountered by populations affected by armed conflict. These stressors are particularly relevant in the earlier stages of life (prenatally, during infancy, and during childhood) when growth rates are most rapid and when the potential for environmental effects to become embodied is high.

with war-related trauma (e.g., fear of dying, loss of family members, or witnessing or experiencing torture, rape, or assault). After accounting for confounding variables, including exposure to air pollution from oil fires, people with the highest scores were more than twice as likely to have developed asthma than were those with no stressors, whereas those with in-between scores had an intermediate risk. Wright et al. (2010) speculated that psychological trauma from war could disrupt stress pathways, which might increase asthma risk. Although the mechanism is unclear, and this is the only study linking war trauma and asthma, the authors noted that "these findings implicate even broader health effects" stemming from armed conflict (Wright et al. 2010, p. 630). This study suggests, first, that the effects of traumatic experiences can be embodied and become manifest in many biological outcomes and, second, that this can take place throughout the life course, including at older ages.

Hertzman & Boyce (2010) observed that embodiment, or "biological embedding," can involve either mundane, cumulative experiences or extraordinary ones that "get under the skin." Like all species, humans are organisms with the capacity to respond to their environmental circumstances via short-term physiological changes and developmental plasticity (Frisancho 1993). Such responses may result in adaptations, pathologies, or compromises (accommodations) via developmental constraints, though it is not always easy to differentiate them (Ellison & Jasienska 2007). Previous research has explored how various forms of adversity early in the life course can become embodied, including racism (Novak et al. 2017), poverty and socioeconomic disadvantage (Kim et al. 2018, Lupien et al. 2001, Varela-Silva & Santinho 2016), and child abuse or severe neglect (McGowan & Szyf 2010, Shalev et al. 2013). A consideration of the embodiment of armed conflict follows suit. Conflict-related stressors likely fall along the extraordinary end of the spectrum (e.g., forced displacement, shelling, witnessing of atrocities) but may involve more mundane ones as well (e.g., minor food shortages).

While embodiment can take place throughout the life course, early experiences during critical or sensitive periods of development (e.g., prenatally or in infancy), when tissues are first forming and growth velocities are fastest, necessarily have a disproportionate effect on subsequent life stages. Early developmental trajectories—including organ development, physical growth, and timing of maturation—may be altered by various external factors, including malnutrition or infection. Chronic or acute psychosocial stress may limit early growth by impeding the secretion of growth hormone and inhibiting the effects of insulin-like growth factor 1 (IGF-1) on tissues (Charmandari et al. 2005, Chrousos & Gold 1992). Chronic stress may also increase an organism's allostatic load, incurring a "wear-and-tear" effect and leading to somatic damage (Edes & Crews 2017). Pollution, including heavy metals, polychlorinated biphenyls, and excessive noise, has also been linked to impaired prenatal growth (Schell et al. 2006). Several of these variables, including malnutrition, psychosocial stress, and environmental toxicants, may alter gene expression via epigenetic changes, such as DNA methylation (the attachment of a methyl group to DNA) or histone modifications, creating a "biological memory" of past experiences that can endure across the life course (Thayer & Kuzawa 2014). Finally, exposure to some of these stressors, such as malnutrition, during critical periods may increase the risk for developing various chronic diseases in adulthood (Barker 1998).

Armed Conflict and Physical Growth

At the population level, the physical growth of children is often viewed as a "mirror of the condition of society," as a gauge of the overall quality of socioeconomic and ecological conditions (Tanner 1987). The harmful effects of conflict on growth have been recognized for at least a century. A handful of studies of German and Austrian children after the First World War revealed growth deficits when compared with prewar samples (Keys et al. 1950). For example, 2- to 14-year-old children living in Berlin orphanages in 1919 had weight deficits of 10.5–25.2% compared with prewar figures, while deficits in height were between 2.0% and 11.0%. Many subsequent studies have found similar patterns, employing a range of methodologies, including geographic proximity to conflict, temporal (or secular) cohort effects over time, or exposure to specific traumatic experiences.

Several studies found negative secular trends for child height or weight as a result of the Second World War in many countries, including Belgium, the British Channel Islands, China, Finland, France, Germany, Hungary, Italy, Japan, Norway, Poland, and the Soviet Union (Angell-Andersen et al. 2004, Bodzsar et al. 2016, Ellison & Kelly 2005, Keys et al. 1950, Kimura 1984, Liczbińska et al. 2017, Markowitz 1955, Vlastovsky 1966). Among Nordic countries, reductions in the food supply were less severe in Denmark and Sweden, neither of which showed noticeable declines in child growth, indicating the importance of nutritional factors (Angell-Andersen et al. 2004). Markowitz (1955) suggested that in addition to nutritional deprivation, psychological factors could have also played a role in growth faltering.

Other conflicts have been associated with linear growth retardation as well, with some effects lasting into adulthood. The 1984 Ethiopia famine, which caused half a million deaths, resulted not only from drought, but also from years of conflict. In a sample of 550 young Ethiopian adults aged 17–27 who were measured in 2004, those who were 12–36 months old during the famine were significantly shorter than the older cohort by at least 5 cm (Dercon & Porter 2014). This significant difference is consistent with research showing that early postnatal growth through the first three years is a sensitive period for linear growth (Martorell 2010). In Guatemala, a negative secular trend in height was observed among 10–11-year-old children who were born between 1974 and 1985, an intense period of the Guatemalan Civil War (Bogin & Keep 1999). Similarly, adult height was lower among 21-year-old male military recruits who were born around the time of the Spanish Civil War (Varea et al. 2018). A different pattern was found in the 2000 Cambodia Demographic Health Survey. Women who were between 10 and 14 years old at the beginning of the Khmer Rouge period in 1975 had the highest rates of stunting as adults (below 150 cm), in comparison with women who were infants or younger children at that time (de Walque 2006). Adolescence is another sensitive period for growth (Reiches et al. 2013), likely contributing to the pattern. In addition, de Walque noted that the extreme rates of malnutrition in Cambodia between 1975 and 1979 led to a much higher child mortality rate, with smaller children being less likely to survive to adulthood.

Other studies have found correlations between geographic proximity to armed conflict with reduced linear growth in several locations, including the 1969 Nigerian Civil War (Davis 1971), the 1990 Civil War in northern Rwanda (Akresh et al. 2011), the 1998–2000 Eritrean/ Ethiopian border war (Akresh et al. 2012), the Zapatista rebellion in Chiapas, Mexico, in 2001 (Sánchez-Pérez et al. 2007), and the 2003 US invasion of Iraq (Guerrero Serdan 2009). In the Netherlands, men and women who were exposed as infants to the Nazi-imposed famine (the Dutch Hunger Winter) were shorter as adults (Portrait et al. 2017). In a 2006–2007 sample of 9,051 Palestinian children, rates of stunting in children younger than 5 years old were 8.2% and 14.2% in the West Bank and Gaza, respectively (Gordon & Halileh 2013). Compared with data from earlier nutritional surveys, rates of food insecurity and stunting had worsened considerably in Gaza after the Second Intifada in 2000.

Exposure to specific conflict-related traumas have been linked to growth retardation as well. In May 2009, Ghazi et al. (2013) measured 3–5-year-old children in Baghdad, six years after the invasion of Iraq. Children who had a family member killed, or whose parents felt their neighborhood was unsafe, were more than twice as likely to be underweight. Other studies have found that forced displacement was a predictor of anthropometric variables. Young Afghan children who were displaced in the previous five years were significantly more likely to be shorter, lighter, and wasted than nondisplaced children (Mashal et al. 2008). Similarly, internally displaced children in eastern Burma were three times as likely to be malnourished (Mullany et al. 2007), whereas refugees from El Salvador and Guatemala living in Belize were more likely to be wasted than local children (Moss et al. 1992). These effects can be enduring. In a sample of 365 Laotian (Hmong and Lao) adult refugees living in the United States and French Guiana, the number of times a person was displaced as a child was negatively correlated with adult height (Clarkin 2012). Interviews revealed that several people who lived in regions of Laos where conflict was most intense, such as the northeast, had been displaced six times or more as a child during the First and Second Indochina Wars.

Other studies have found a correlation between adult height and exposure to aerial bombings during early life. Akbulut-Yuksel & Yuksel (2017) employed a creative method to assess the effects of the Second World War on height in Germany. Utilizing rubble in m^3 per capita—largely the result of aerial bombing by Allied forces that destroyed 40% of German homes—as a proxy for wartime devastation, they found that adults who resided in the most heavily destroyed districts in utero or during childhood were an average of 3 cm shorter than a control group, a substantial difference. Two studies considered whether the atomic bombs detonated on Hiroshima and Nagasaki impacted long-term physical growth, including Japanese teenagers who were exposed prenatally (Wood et al. 1967) and adults who were exposed as children (Belsky & Blot 1975). In the teenage sample, males and females whose mothers were closest to the hypocenter (<1500 m) at the time of the bombings were shortest. Among adults, postnatal exposure to the bombs before age 5 was associated with significantly shorter height in Hiroshima, but this measure failed to reach statistical significance in Nagasaki. Belsky & Blot (1975) suggested that this discrepancy could be due to a number of variables, including exposure to different types of radiation from the two bombs. Some evidence supports the notion that radiation alone can impair growth. Boys younger than 5 years old who lived on three atolls in the Marshall Islands who were accidentally exposed to fallout radiation from a 1954 thermonuclear test were shorter than an unexposed control group

(Sutow et al. 1965). Residents of the atolls later experienced an array of other health problems, including cancers, which were likely at least partially attributable to the fallout (Land et al. 2010).

Mean menarcheal age (MMA): the average age at first menstruation in a population

Maturation and the Timing of Menarche

Several studies have found associations between conflict-related adversity and maturation events such as menarche (first menstruation), although the relationship is complex. While the twentieth century saw a downward secular trend in the mean menarcheal age (MMA) in many populations, a number of studies have found that periods of conflict have interrupted, or even reversed, this trend. The timing, and severity, of exposure to stressors may be critical; exposure in early childhood and shortly before puberty has generally been associated with earlier and later menarche, respectively (Mishra et al. 2009). In a sample of 16,853 Dutch women, exposure to the Hunger Winter led to an increase in MMA of about 8 months in the cohort born in 1930 (van Noord & Kaaks 1991). Similar delays for women born in the 1930s were also observed in Poland (Liczbińska et al. 2018), among Japanese survivors of the atomic bombs (Hoel et al. 1983), in the British Channel Islands under Nazi occupation (Fentiman et al. 2007), and among rural ethnic Chuvashian women in Russia (Kalichman et al. 2006).

Similar patterns have been found in other conflicts. Citing the role of the Mozambican Civil War (1976–1990), Padez (2003) found an increase in MMA for girls in Maputo between 1963 (13.6 years) and 2000 (13.9 years). A few studies from the 1990s wars in the Balkans are also relevant here. In a highly distressed cohort of Bosnian girls who lived under siege in Srebrenica and who were later deported to a refugee camp, MMA was 14.4 years, compared with 13.0 years for a control group living in more peaceful areas (Tahirović 1998). Srebrenica girls experienced multiple severe traumas, including fear that they might be killed, death of close family members, extended separation from family, and inadequate food supply, which may have contributed to the delay (**Figure 3**). Also, MMA was found to increase by about three months in the Croatian town of Šibenik between 1985 and 1996 (Prebeg & Bralic 2000). Girls who were absent from the city during the war years had a MMA of 13.00 years, compared with those whose homes were destroyed (13.53 years) or who had a family member killed (13.76 years). In Zagreb, MMA increased slightly between surveys conducted in 1990 and 1997, but not significantly so, and thereafter declined substantially by 2010 (Veček et al. 2012). However, there was a delay of MMA for prepubertal

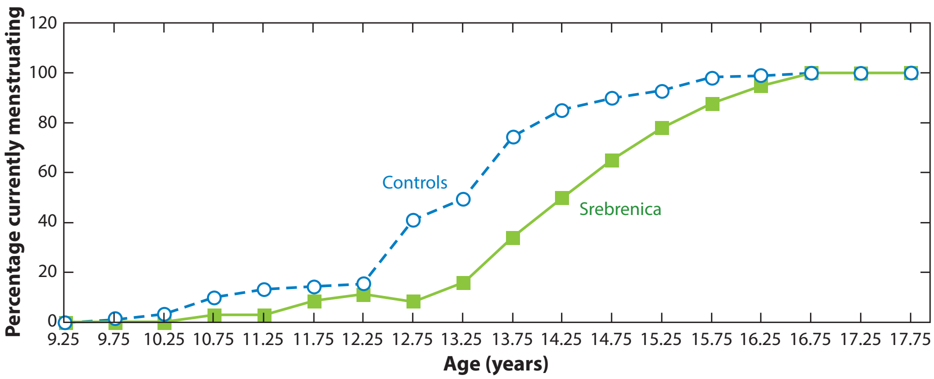

Figure 3

The percentages of girls menstruating at each age for a highly stressed sample from Srebrenica and a control group from safer areas of Bosnia in August through December 1995. Here it is apparent that menarche was delayed significantly in the Srebrenica sample. Data from Tahirović (1998).

girls who were 10–12 years old in 1991–1992, the most intensive part of the war, pointing to the role of stressors in late childhood.

Different patterns have been found elsewhere. For example, data from Liestøl (1982) showed no effect of the Second World War on MMA in Norway. For South Korean women born in the 1930s—a period of instability under Japanese occupation followed by liberation and the Korean War—a previously downward secular trend for menarche stagnated then declined thereafter for later cohorts (Hwang et al. 2003). In Colombia, which experienced fluctuations in irregular violence and civil war, MMA declined each decade for women born between 1941 and 1989 (Villamor et al. 2009). However, the rate of decline stagnated in more violent periods, using homicide rate at age 5 as a proxy for stressful conditions during childhood. Among Ugandan girls, MMA was not significantly associated with conflict trauma, such as being kidnapped by the Lord's Resistance Army or loss of a relative (Odongkara Mpora et al. 2014). These predictors fit the expected pattern (i.e., later menarche for girls who lost a relative), but the study likely lacked statistical power owing to the relatively small sample size ($n = 271$). Menarche occurred earlier among Finnish girls who were sent to temporary foster homes in Sweden or Denmark, unaccompanied by their parents, to escape the conflict with the Soviet Union during the Second World War (Pesonen et al. 2008). This measure was interpreted within the framework of life history theory as an example of accelerated puberty under conditions of early psychosocial stress in order to increase the chances of reaching reproductive maturity. However, altogether, it appears that the majority of studies point to conflict having a delaying effect on menarche, which has been associated with health risks later in adulthood, including low bone mineral density and increased risk of fractures (Eastell 2005).

CVD: cardiovascular disease

The DOHaD and Armed Conflict

As is true of postnatal growth, prenatal development is also likely to be impaired during periods of armed conflict. For example, average birth weight and/or infant mortality rates worsened in the Soviet city of Kursk during the Second World War (Vlastovsky 1966), in the Palestinian territories after the Second Intifada (Mansour & Rees 2012), and in the provinces that experienced the most intense fighting during the Vietnam War (Savitz et al. 1993). These experiences are pertinent to the developmental origins of health and disease (DOHaD) paradigm, which proposes that stressors in early life (prenatally but possibly through infancy or early childhood) induce physiological shifts at critical developmental periods. These shifts may confer short-term adaptive benefits but also increase the risk for various chronic diseases in adulthood, including cardiovascular disease (CVD), elevated cholesterol, insulin resistance, type 2 diabetes, central obesity, and osteoporosis (Barker 1998, Kuzawa & Quinn 2009). The relationship between prenatal deprivation and later chronic disease risk is often continuous rather than dichotomous (Gluckman & Hanson 2005). Therefore, there may be a dose–effect association between early exposure to conflict-related stressors and later health outcomes, and such biological memories may extend beyond the period of conflict itself.

The Dutch Hunger Winter is the best-known example of conflict predisposing a population to later chronic disease, though this is not the only case (**Figure 4**). At the nadir of the Dutch Hunger Winter, official daily rations in Amsterdam were between 400 and 800 calories prior to liberation in May 1945. The historically well-defined period of the famine has allowed researchers to test how the timing of early exposure to severe deprivation may be associated with later health outcomes. In a sample of 741 Dutch adults aged 50, those who were exposed to famine in early gestation had a higher risk for coronary heart disease, elevated lipids, altered clotting (factor VII), and obesity compared with those born before the famine or conceived afterward, whereas exposure in late gestation was associated with impaired glucose tolerance (Painter et al. 2005). Other studies found that prenatal exposure to the Dutch famine has been associated with earlier natural menopause

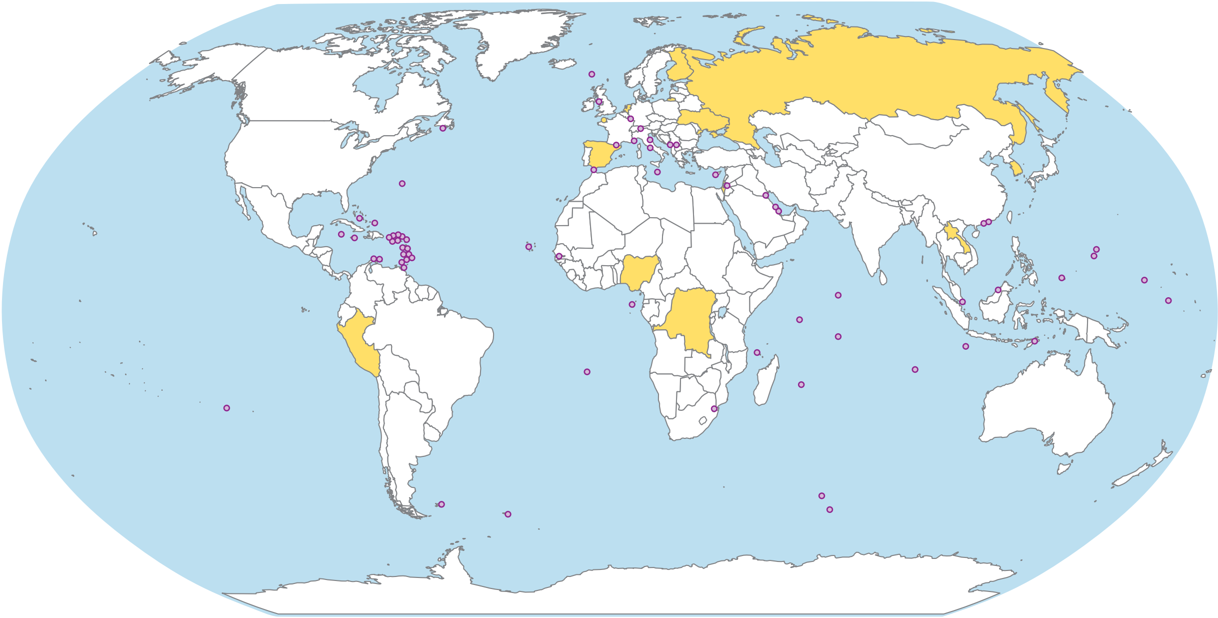

Figure 4

Countries where an association has been found between conflict-related deprivation early in life and later compromises to adult health thus far. This phenomenon is pertinent to the developmental origins of health and disease (DOHaD) paradigm. Future research will likely reveal more examples. This map includes adults from the British Channel Islands and Israel (who were exposed prenatally to the Holocaust in Europe).

(Yarde et al. 2013), elevated overall mortality risk and mortality from breast cancer in women (van Abeelen et al. 2012), and obesity in men (Ravelli et al. 1976). Postnatal exposure between the ages of 2 and 9 was also associated with an increased risk of breast cancer (Elias et al. 2004).

As a potential mechanism linking prenatal adversity and later health status, researchers have observed epigenetic changes in methylation for a number of loci related to growth and metabolism among Dutch adults who were prenatally exposed to the famine (Tobi et al. 2018). These effects can be long-lasting. Heijmans et al. (2008) found that six decades after the famine, individuals who were exposed in early gestation had reduced DNA methylation of the imprinted insulin-like growth factor 2 (*IGF2*) gene compared with their unexposed, same-sex siblings. *IGF2* plays an important role in early growth, and Heijmans et al. (2008) suggested that their findings could be a possible mechanism linking early deprivation and later health outcomes. In another study of 25 mother–infant dyads in the Democratic Republic of Congo, conflict-related stress experienced by mothers was associated with decreased birth weight and increased methylation at the gene *NR3C1* in their newborns (Mulligan et al. 2012, Rodney & Mulligan 2014). Furthermore, conflict-related stress experienced by mothers explained 35% of the variance in offspring birth weight and was a better predictor than other, more mundane, stressors. The *NR3C1* gene encodes for the glucocorticoid receptor, giving it an important role in the hypothalamic-pituitary-adrenocortical axis response to stress. Mulligan et al. suggested that increased methylation at this site, and others, could reduce plasticity in the stress response and predispose an individual to chronic disease later in life.

While the specific mechanisms (epigenetic and others) linking early stressors and later disease are still being elucidated, comparable epidemiologic patterns have been found in other studies from the Second World War, though there are differences in study designs as well as in the timing, severity, and nature of early stressors. In a study of 1,086 Israeli adults (mean age 69), those born in Nazi-occupied countries in Europe between 1940 and 1945 were more likely to have dyslipidemia, type 2 diabetes, hypertension, and CVD than those born in Israel, pointing to the possible effects of prenatal exposure to the Holocaust (Keinan-Boker et al. 2015). In a sample of 549 men and women 52–53 years old, there were no significant differences between those who were exposed to the Siege of Leningrad (1941–1944) in utero or during infancy for blood pressure, glucose tolerance, insulin concentration, lipid concentration, or coagulation factors (Stanner & Yudkin 2001). However, when compared with an unexposed control group born outside the city limits, the combined in utero/infant group had higher blood pressure and glucose concentrations, pointing to the importance of early postnatal life in the development of later health (Stanner et al. 1997). A larger study of 5,634 adults from Leningrad found that exposure to the Siege during childhood was associated with higher blood pressure and higher mortality from ischemic heart disease and stroke in men (Koupil et al. 2007). In the British Channel Islands, postnatal exposure in childhood and adolescence to a nine-month food shortage during Nazi occupation was a significant predictor of CVD in later adulthood (Head et al. 2008). Older children may have fared worse during the occupation because they were expected to work yet did not receive extra rations. Finally, Alastalo et al. (2009) found that Finnish children who were evacuated to Sweden or Denmark and experienced traumatic family separation had significantly higher odds ratios for CVD and type 2 diabetes as adults.

Compromised adult health has been associated with early exposure to other armed conflicts as well, including elevated mortality from coronary heart disease among people who were born during the Spanish Civil War (1936–1939); elevated risk for hypertension, impaired glucose tolerance, and centralized obesity among people born around the time of the Biafran famine during the Nigerian Civil War (1967–1970); shorter stature and higher adiposity for Hmong adults born in war-zone villages of Laos during the First and Second Indochina Wars (1945–1975); and greater disability among adults born during the Korean War (1950–1953) (Clarkin 2008, González Zapata et al. 2006, Hult et al. 2010, Lee 2014). Grimard & Laszlo (2014) found that early exposure to periods of elevated violence in the Peruvian civil conflict from 1980 to 2000 was associated with shorter stature and anemia in women. Finally, using a national data set, Lumey et al. (2015) found a dose–response relationship between prenatal exposure to the Great Ukrainian Famine of 1932–1933 and type 2 diabetes in adulthood. The famine, known as the Holodomor, was largely the result of a Soviet policy of forced collectivization of agriculture and resulted in millions of deaths. The European Parliament recognized the famine as a crime against humanity and can be considered an act of one-sided violence by a government against civilians.

CONCLUSIONS

The studies described above, while not exhaustive, span a range of time periods, conflicts, and geographic locations. Collectively, they make the case that armed conflict contributes to an environment that is consistently disruptive to human health and biology in both the immediate and long terms. Furthermore, these effects extend beyond the well-known outcomes of injuries and compromised psychological health into other subtler aspects of biology. Thus, these effects can become embodied, creating biological memories that can endure long after a conflict has officially concluded. Future research will likely produce more examples of this phenomenon, unfortunately. Pettersson & Eck (2018) reported that there have been more than 1,000 armed conflicts since the end of the Cold War in 1989, and their full effects on health have likely been underestimated. Research in this area will help contribute to our understanding of how traumatic experiences become embodied in other features of biology and health, including their mechanisms and sensitive periods. Such research may also help validate the experiences of affected populations, making invisible conflicts more visible (Scheper-Hughes 1996) by documenting how these effects leave an enduring mark on bodies. Finally, an effort should be made to avoid framing such effects of conflict trauma as natural experiments. While studies of conflict and embodiment are almost necessarily retrospective and the products of history, it seems important not to overlook that one of the most extreme environments in which people can reside is one created by human agency. Of course, the most pressing concern is the enormous immediate suffering caused by conflicts (loss of life, injury, psychological trauma, food insecurity, displacement). Yet the effects of such biological memories have been overlooked and should be considered when calculating the overall costs of war and armed conflict, as they are likely to reverberate for years or decades, contributing to future deficits in health.

SUMMARY POINTS

1. The effects of war and armed conflicts on long-term civilian health may be underappreciated. While it is widely recognized that conflict leads to injuries, mortality, and impaired psychological health, evidence suggests that other aspects of biology and health may also be affected.
2. Armed conflict may be considered an anthropogenic environment that consistently generates a suite of stressors that may compromise human biology and health. The effects of these stressors may be particularly relevant for civilians exposed early in life (prenatally or during infancy or childhood).
3. Results from a number of studies suggest that exposure to armed conflict early in life is consistently linked with both short- and long-term impacts on biology, including reduced birth weight, physical growth retardation, changes in timing of maturation (e.g., age at menarche), and the development of chronic diseases during adulthood. These impacts may be mediated by diverse mechanisms, including epigenetic modifications.
4. Such findings indicate that the effects of armed conflict can get under the skin and become embodied, creating long-term biological memories that can leave an enduring mark on bodies long after a conflict has officially concluded.

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