

# Florida State University Libraries

---

2017

## Annual War Deaths in Small-Scale versus State Societies Scale with Population Size Rather than Violence

Dean Falk and Charles Hildebot



## Reports

### Annual War Deaths in Small-Scale versus State Societies Scale with Population Size Rather than Violence

Dean Falk and Charles Hildebolt

Department of Anthropology, Florida State University, Tallahassee, Florida 32310, USA (dfalk@fsu.edu), and School for Advanced Research, Santa Fe, New Mexico 87505, USA/Mallinckrodt Institute of Radiology, Washington University School of Medicine, St. Louis, Missouri 63110, USA. This paper was submitted 6 III 17, accepted 29 VI 17 and electronically published 13 X 17.

**Online enhancement: appendix**

In *The Better Angels of Our Nature: Why Violence has Declined*, psychologist Steven Pinker cites mean ratios of war (battle) deaths suffered annually per 100,000 individuals as evidence for concluding that people who live in states are less violent than those who live or lived in “hunting, gathering, and horticultural societies in which our species spent most of its evolutionary history.” Because such ratios are blind to actual population sizes, it remains to be seen whether the apparent decrease in contemporary violence is an artifact of scaling factors. Here scaling of war deaths is quantified relative to actual population sizes for 11 chimpanzee communities, 24 human nonstates, and 19 and 22 countries that fought in World War I and World War II, respectively. Mean annual battle deaths expressed as percentages of population sizes scale inversely with population sizes in chimpanzees and humans, indicating increased vulnerability rather than increased violence in smaller populations. However, the absolute number of mean annual war deaths increases exponentially (superlinearly) and nearly identically with population sizes across human groups but not chimpanzees. These findings suggest that people evolved to be more violent than chimpanzees and that humans from nonstates are neither more nor less violent than those from states.

Although it has long been known that biological variables (e.g., brain sizes) scale exponentially (allometrically) with body sizes in animals ranging from insects to humans (Huxley and Teissier 1936; Mirth, Frankino, and Shingleton 2016), it is less appreciated that some human behaviors scale as power functions with population sizes (Bettencourt et al. 2007). Bi-

ological allometry is driven by physiological phenomena, but scaling of cultural variables is likely due to increased “productive social opportunities” that lead to “changes in individual behavior across the full complexity of human expression, including those with negative consequences, such as costs, crime rates, and disease incidence” (Bettencourt et al. 2007: 7303). Because of allometry, biologists do not use simple ratios like relative brain size (RBS; brain size/body size) to make comparative inferences about species (Jerison 1973, 1991). For example, the average RBS of .03 for squirrel monkeys does not imply this primate has greater intelligence than humans, who have a smaller average RBS of .02 (Stephan, Bauchot, and Andy 1970), because the larger RBS of the former is largely a reflection of their comparatively small mean body size rather than superior intelligence. Below, we show that mean annual war deaths scale exponentially with human population sizes and that the assertion that people living in small-scale societies are more violent than those living in state societies (Pinker 2011) is based on comparisons of annual war death ratios that are opaque to actual population sizes, just as simple RBS ratios for squirrel monkeys and humans are blind to actual body sizes.

Psychologist Steven Pinker suggests that humans “started off nasty and . . . the artifices of civilization have moved us in a noble direction” (Pinker 2011:xxii). Figure 1, reproduced from Pinker, illustrates his main evidence for asserting that states are less violent than small-scale “hunting, gathering, and horticultural societies in which our species spent most of its evolutionary history” (Pinker 2011:xxiv); however, because this figure depicts annual rates of war deaths suffered per 100,000 people, these ratios are blind to actual population sizes. (Pinker also invoked percentage of warfare deaths from data for prehistoric archaeological sites that he provided in another figure, but this part of his argument has been thoroughly critiqued and refuted elsewhere; Ferguson 2013.) Unlike other studies (Gat 2006; Gómez et al. 2016; Keeley 1996; Pinker 2011), we explore whether scaling with population sizes rather than different inclinations for violence accounts for different war rates in nonstates and states. We do this within a comparative evolutionary context by analyzing mean annual deaths caused by aggressors from external communities relative to actual population sizes for 11 chimpanzee communities, 24 nonstates, and 19 and 22 countries that fought in World War I and World War II.

### Results

The closest living relatives of humans are chimpanzees (*Pan troglodytes*) and bonobos (*Pan paniscus*; Prüfer et al. 2012). Unlike bonobos, chimpanzees and people share the derived trait of regularly engaging in lethal violence against conspecifics from other communities (Goodall 1986). For 11 chimpanzee communities (fig. 2A, table S1; tables S1–S3 available online), we used data from the literature (Wilson et al. 2014)

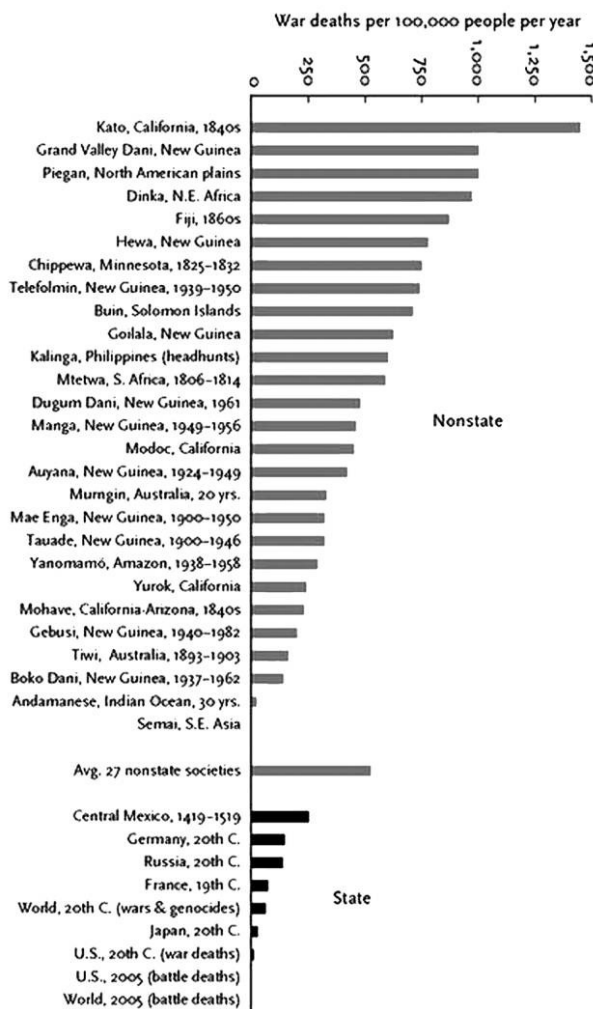


Figure 1. Annual war deaths per 100,000 people in 27 nonstate and nine state societies. Data for 25 of the 27 nonstates from Keeley (Keeley 1996); data for the Hewa and Goilala from Gat (Gat 2006). Figure reproduced from Pinker (2011). Used by permission of Viking Books, an imprint of Penguin Publishing Group, a division of Penguin Random House LLC.

to calculate mean annual deaths from external aggressors divided by population sizes. It is important to stress that the chimpanzee bar chart (fig. 2A) reflects communities' relative vulnerabilities to lethal intercommunity violence rather than their predispositions for violence—the smaller the population, the greater its susceptibility to lethal deaths from outsiders.

A Cochran-Armitage trend test indicates that, as mean chimpanzee population sizes increase, the percentages of mean annual deaths from external aggressors that are observed, inferred, or suspected decrease (Monte Carlo sample size = 50,000; two-sided  $P = .03$ ; bar chart in fig. 2A). A reduced major axis regression (fig. 2A) shows that the absolute number of annual deaths suffered by a population is unrelated to its size ( $P = .57$ ; tables 1, S1).

As is the case for chimpanzees, battle/war deaths for small-scale societies sometimes include deaths of females and non-adults from raids but exclude intragroup killings (homicides), which is consistent with definitions proposed by Pinker (Pinker 2011), Keeley (Keeley 1996), and others (Lacina and Gleditsch 2005). We were able to obtain actual population sizes and mean annual battle deaths recorded during years of lethal conflict for 18 of the 27 nonstates in figure 1 from the literature cited by Pinker, Keeley, and their sources (appendix, available online). These population sizes were used to estimate rates of battle deaths suffered by populations (table 2). Nine of the 27 nonstates were excluded because the cited sources lacked data for computing these rates; however, these sources yielded six other comparable societies that, for unknown reasons, were not included in figure 1. Our final sample of 24 small-scale societies (1825–1966) approximates that of figure 1, which represents 26 rather than 27 nonstates, because the Goilala are identical to the Tauade (appendix).

The Cochran-Armitage trend test indicates that, as population sizes increase in nonstates, their proportions of mean annual battle deaths decrease (Monte Carlo sample size = 50,000; two-sided  $P < .01$ ; fig. 2B). Although the ratios of mean annual battle deaths to population sizes decrease with increased population sizes (box plots), a reduced major axis linear regression of mean annual battle deaths versus mean population sizes (table 2) for 23 nonstates (excluding Semai, log 0; appendix) shows that the absolute number of mean annual battle deaths increases with population size ( $P < .01$ ; table 1).

Data for 19 and 22 countries that fought during World War I (1914–1918) and World War II (1939–1945) are provided in tables S2 and S3. Military deaths for both wars include soldiers and officers killed in combat or dead from wounds, accidents, disease, captivity, and, in the case of World War I, poison gas (Urlanis 1971) but not collateral civilian deaths caused by war (Lacina and Gleditsch 2005). Because the data exclude collateral civilian deaths, such as those from the World War II bombing of Hiroshima (140,000) and Nagasaki (70,000) and the deaths of 6 million Jews during the Holocaust (Ready 1995), the ~10,000,000 military deaths in World War I and ~22,000,000 in World War II (Urlanis 1971) do not represent the total human costs of these wars.

Separate Cochran-Armitage trend tests for both world wars indicate that, as population sizes of countries increase, their proportions of mean annual military deaths decrease (for both sets, Monte Carlo sample size = 50,000; two-sided  $P < .01$ ; box plots in fig. 2C, 2D). Although, for the 19 countries from World War I and the 22 countries for World War II, the ratios of battle deaths to population sizes decrease with increased country population sizes, reduced major axis linear regressions of mean annual military deaths versus population sizes demonstrate that the absolute numbers of mean annual war deaths increase as a power function with population sizes ( $P < .01$ ; table 1). Because the trend in the World War II box plot is not as visually obvious as it is for the other three groups (fig. 2), we performed a Cauchy regression analysis and superimposed the

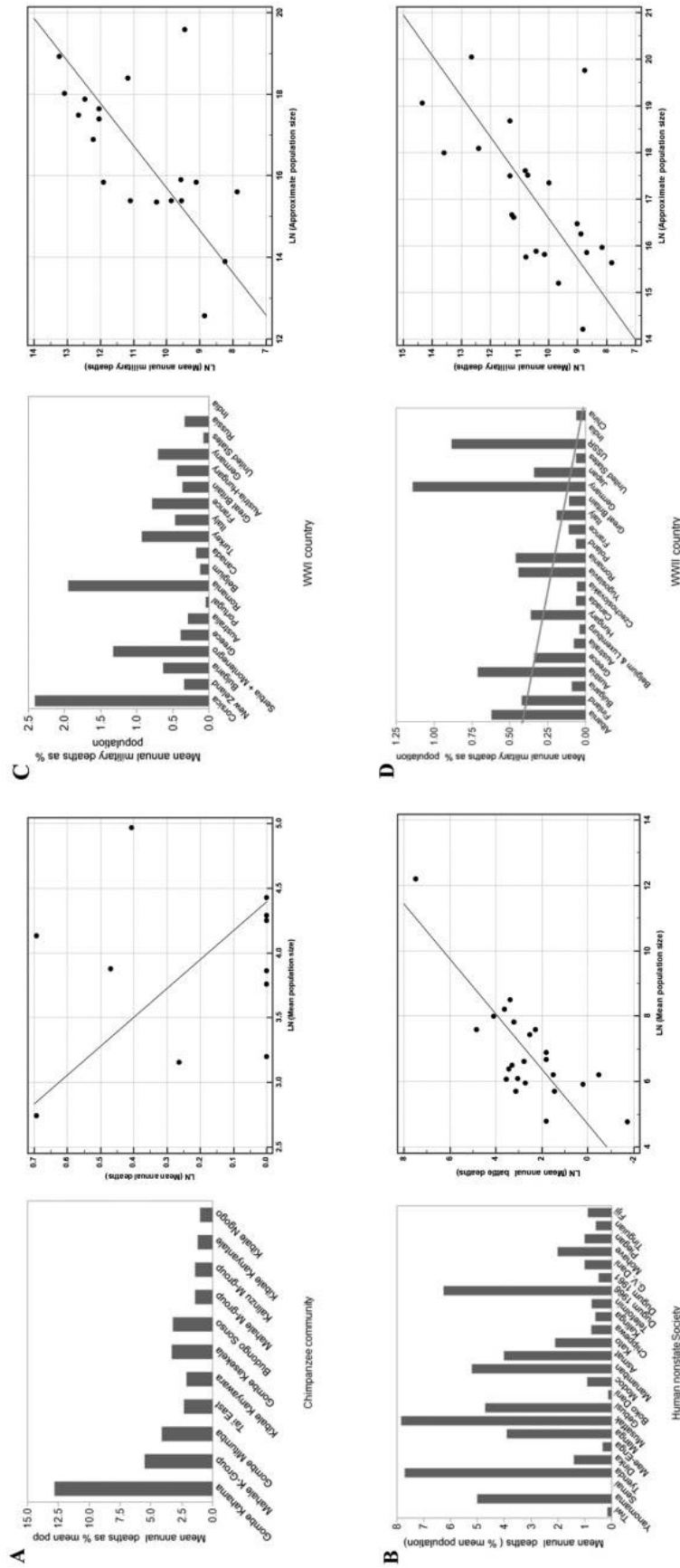


Figure 2. Annual deaths from external aggressors for chimpanzees, small-scale human societies, and countries that fought in World War I and World War II. *Left*, box plots represent ratios of mean annual battle deaths suffered from external aggressors relative to population sizes arranged left to right in order of increasing population sizes. *Right*, reduced major axis regressions of natural logs of actual number of mean annual battle/war deaths against natural logs of mean population sizes. *A*, Eleven communities of chimpanzees, box plots arranged left to right from Gombe Kahama ( $n = 16$ ) to Kibale Ngogo ( $n = 144$ ; Wilson et al. 2014). *B*, Twenty-four human nonstate societies arranged from Tiwi population ( $n = 118$ ) to Fiji ( $n = 200,000$ ; table 2). The reduced major axis regression is for 23 of the 24 nonstates (excluding Semai, log 0; appendix). *C*, Nineteen countries that fought in World War I from Corsica ( $n = 291,000$ ) to India ( $n = 321,800,000$ ; Uhlmanis 1971). *D*, Twenty-two countries that fought in World War II from Albania ( $n = 1,081,000$ ) to China ( $n = 511,078,000$ ; Uhlmanis 1971). The line superimposed on the bar chart (to help visualize the trend) is the Cauchy regression line for mean annual military deaths as percentages of population sizes regressed on rank of population sizes (from 1 to 22;  $P < .01$ ). A color version of this figure is available online.

Table 1. Reduced major axis regressions of mean annual battle deaths on population size

Group	No.	Intercept (95% CI)	Slope (95% CI)	<i>P</i>	<i>r</i> <sup>2</sup>
Chimpanzees	11	.86 (.29, 1.42)	-.45 (-.78, -.12)	.57	.04
Nonstates	23	-5.57 (-8.06, -3.09)	1.19 (.84, 1.54)	<.01*	.57
World War I	19	-5.14 (-11.49, 1.22)	.96 (.58, 1.35)	<.01*	.40
World War II	22	-9.07 (-16.42, -1.72)	1.15 (.72, 1.58)	<.01*	.35

Note. Bivariate fit of natural logs of mean annual battle deaths on natural logs of mean population size for chimpanzees and humans. CI = confidence interval.

\* Statistically significant.

resulting red regression line on the box plot for World War II (figure 2D).

## Discussion

Despite the disparate types of societies studied, results for three sets of human battles/wars (small-scale societies, World War I, and World War II) reveal that mean annual war deaths expressed as percentages of population sizes decrease with increasing population sizes, like the trend for deaths from external aggressors among chimpanzees. Unlike chimpanzees, however, the absolute numbers of mean annual war

deaths scale positively as power functions of population sizes, with exponents of 1.19, 0.96, and 1.15 for nonstates, World War I, and World War II, respectively (table 1; fig. 2). These exponents are all significantly different ( $P < .01$ ) from the exponent (-0.45) for chimpanzees but are not significantly different from each other ( $P \geq .38$ ) and have a mean slope of 1.1. The finding that mean annual war deaths scale equivalently and superlinearly (mean slope:  $>1.0$ ) with population sizes for humans living in nonstate and state societies but not for chimpanzees strongly suggests that, when it comes to intercommunity lethal aggression, people evolved to be more violent than the common ancestor that gave rise to *Pan* (in-

Table 2. Mean annual battle deaths relative to known population sizes for 24 nonstate societies

Nonstate society	Type of affected community, years	Mean population size	Mean annual battle deaths	Mean annual deaths, % of mean population
Fiji	South Pacific chiefdom, 1860s	200,000	1,750.0	.88
Tinguian	Philippines headhunters tribe, 1889	5,000	29.0	.58
Piegian	North American Plains tribe, pre-1885	3,700	37.0	1.00
Mohave	North American tribe, 1857 or 1858	3,000	60.0	2.00
Grand Valley Dani	Grand Valley, New Guinea Aso-Logobal confederacy, 1954-1956	2,500	25.0	1.00
Dugum 1961	New Guinea Dugum Dani, two combined confederations, 1961	2,000	9.6	.48
Dugum 1966	New Guinea Dugum Dani, three combined confederations, 1966	2,000	125.0	6.25
Telefolmin	New Guinea Eliptaman Telefolmin subtribe, 1939-1950	1,700	12.55	.74
Kalinga	Philippines headhunters, Bolo subregion tribe, precontact	1,000	6.0	.60
Chippewa	North American tribe, 1825-1832	800	6.0	.75
Kato	North American, California tribe, 1857	750	16.0	2.10
Asmat	New Guinea Sjur Asmat village, 1945-1947	675	27.0	4.00
Manamban	New Guinea clan cluster, 1956	600	31.0	5.20
Modoc	North American, California tribe, 1850s	500	4.5	.90
Boko Dani	New Guinea parish, 1937-1962	500	.62	.12
Gebusi	New Guinea small-scale society, precontact	450	21.0	4.70
Musatfak	New Guinea Grand Valley Dani community of 12 compounds, 1959	434	34.0	7.83
Manga	New Guinea clan cluster, 1955-1956	387	15.0	3.90
Mae-Enga	New Guinea clan parish, 1900-1950	375	1.24	.33
Dinka	Northeast Africa village, 1916 and 1928	300	4.2	1.40
Tyenda	New Guinea clan cluster, 1955	300	23.0	7.70
Semai	Southeast Asia, two settlements, 1962	300	.0	.00
Yanomama	Brazil Ninan Yanomama group, 1938	121	6.0	5.00
Tiwi	Australia band, 1893-1903	118	.18	.15

Note. See appendix for details and references.



cluding bonobos) and *Homo*. On the other hand, nonstates should be viewed as neither more nor less fundamentally violent than the countries that fought in World War I and World War II, because severity of war deaths scales nearly identically with population sizes in all three groups. (This does not suggest that all human societies are victims of intercommunity lethal violence to the same degree. The  $r^2$  values in table 1 indicate the percentages of the total variances in values for mean annual battle deaths that are explained by values for population sizes.)

The scaling of war deaths with population sizes reported here is consistent with the findings that superlinear power scaling of social indicators with population sizes is common for phenomena ranging from serious crimes to new patents, signifying “increasing returns with population size . . . manifested by quantities related to social currencies, such as information, innovation or wealth. . . . These indicators reflect unique social characteristics with no equivalent in biology and are the quantitative expression that knowledge spillovers drive growth” (Bettencourt et al. 2007:7303).

In the case of war, increased “returns” in battle/military deaths with increased population sizes in humans was/is likely driven partly by “knowledge spillovers” in the development of new military technology or logistical techniques (Cederman 2003:138). This hypothesis accords with accretion in the weapons/tactics across the four groups studied here. While chimpanzees use teeth, hands, and feet to bite, hit, and stamp enemies, in addition to brandishing sticks and throwing rocks during intimidation displays (Goodall 1986), individuals in nonstates (1825–1966) also use (depending on the culture) slings, bows and arrows (including iron-headed and poison-tipped arrows), stone adzes, stone axes, headaxes, fire, spears, lances, shields, bamboo and metal knives, machetes, poison, and rifles, which are transported by foot, horseback, or canoe (appendix). Weapons available during World War I (1914–1918) expanded to include improved rifles, bayonets, machine-guns, howitzers, grenades, flamethrowers, long-range artillery, armored tanks, and poison gas (Haythornthwaite 1992). Tactics included trench warfare, line fighting on battlefields, war at sea using battleships and destroyers, and aerial bombing. Weapons of World War II (1939–1945) were similar but more developed, with a vast increase in aerial warfare, including the addition of aerial suicide attacks and atomic bombs (Ulanis 1971). This progression in weaponry echoes the trend for inventing increasingly complex tools that began prehistorically (Falk 2016).

The fact that the absolute numbers of war deaths power scale with population sizes (as documented here) is relevant when one considers that the probabilities of different-sized wars occurring also power scale with the severity of wars (i.e., their absolute numbers of war deaths); thus, in 97 interstate wars that occurred between 1820 and 1997, “a 10-fold increase in war severity [war casualties] decrease[d] the probability of war by a factor of 2.6” (Cederman 2003:136; fig. 3). Importantly, wars causing relatively few absolute numbers of

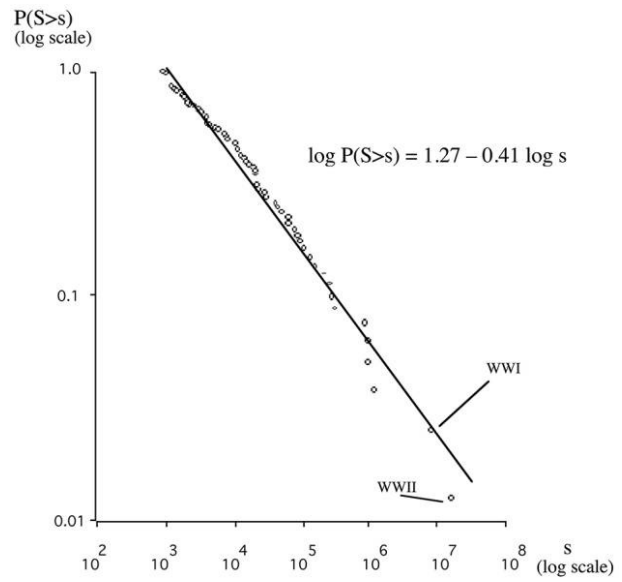


Figure 3. Cumulative frequency distribution of severity of 97 interstate wars, 1820–1997.  $P(S > s)$  represents the cumulative frequency (Y-axis) of wars as a function of their severity in casualties ( $s$ );  $S$  is the random variable of war sizes; double logarithmic scales. The probability of more severe wars occurring decreases with increasing severity. Reproduced from Cederman (2003), with permission of the author and the publisher (American Political Science Association).

deaths occurred frequently; those with moderate deaths occurred less often; and highly disastrous wars (e.g., World War I and World War II) occurred rarely (fig. 3). Furthermore, this finding generalizes beyond the two last centuries—for example, to the European great power wars from 1495 to 1965 (Cederman 2003)—and it is notable that “given these strong results, it may seem surprising that so few scholars have attempted to account for what seems to be an important empirical law” (Cederman 2003:136).

Cederman employed an agent-based model that sought explanations for the power distribution in figure 3, and by using concepts of scaling and self-organized criticality, he found that stochastic decisions of states to wage wars depended largely on innovations in military technology and logistics and alterations in contextual conditions (Cederman 2003). His conclusions are consistent with the findings of Bettencourt et al. (2007) and the analysis regarding the progressive development of weapons, military technology, and logistical techniques presented above. An implication of the probability distribution for the 97 wars in figure 3 is that, regardless of whether the totality of war in the post–World War II era has decreased, stabilized, or increased (Lacina and Gleditsch 2005; Sarkees, Wayman, and Singer 2003), the eventual occurrence of a third “rare” world war is a distinct possibility. This is especially so because the onerous liability of weapons of mass destruction has failed to obviate further developments in war technology (Gusterson 2016) and

because population size is projected to increase by 1.1 billion people by 2030 in parts of the world, mostly dense African and Asian cities (Forman and Wu 2016), that are the primary drivers of current battle deaths (Lacina and Gleditsch 2005).

Together, the findings documented by Bettencourt et al. (2007) and Cederman (2003) and the findings presented here have implications for how one interprets the so-called long peaces, including that among the “great powers” after 1945 (Gat 2013). To the extent that “great” powers are characterized by relatively large populations, the finding that absolute numbers of war deaths scale strongly and nearly identically with population sizes for both nonstates and states (table 1) predicts that great powers would suffer relatively large absolute numbers of military deaths when they engage in war, putting them at the bottom-right (low probability) end of the distribution in figure 3. Rather than being manifestations of less violent societies, however, these kinds of wars are extremely severe. Furthermore, “long” is a relative term—the approximately 70 years that have transpired since the end of World War II are a proverbial drop in the bucket compared with the 5–7 million years that hominins have been around. The uneasy suspicion to be gleaned from figure 3, despite so-called long peaces, is that, like a missed bus—keep waiting and another large war may eventually come along.

Pinker is aware that the absolute number of war deaths increased with population sizes but nonetheless opted for the interpretation that smaller ratios of war deaths relative to population sizes in states indicate that they were less violent than nonstates.

In absolute numbers, of course, civilized societies are matchless in the destruction they have wreaked. But should we look at absolute numbers, or at *relative* numbers, calculated as a proportion of the populations? . . . Another way of expressing this frame of mind is to ask, “If I were one of the people who were alive in a particular era, what would be the chances that I would be a victim of violence?” The reasoning in this second frame of mind, whether it appeals to the proportion of a population or the risk to an individual, ends in the conclusion that in comparing the harmfulness of violence across societies, we should focus on the rate, rather than the number, of violent acts. (Pinker 2011:47)

As documented in this paper, however, the rates of war deaths decrease with increasing population sizes, not only among people living in both small-scale and state societies but also across chimpanzees. Because the absolute numbers of war deaths scale up with population sizes in humans but not chimpanzees, our interpretation for the pervasive trend in war death ratios is not that larger populations are less prone to violence than smaller ones; rather, larger communities are less vulnerable to having large portions of their populations killed by (or entirely wiped out by) external enemies compared with smaller ones (i.e., there is safety in numbers). The existence of this trend in chimpanzees suggests that it is phylogenetically old, consistent with findings that have long been known for terrestrial Old World

primates (including certain macaques and baboons) that are relatively close to humans phylogenetically and that became adapted to terrestrial habitats that were full of dangerous predators. As primatologists like to quip, “a lone baboon is a dead baboon.” Indeed, anthropologists have speculated that one of the main reasons primates became larger-bodied and formed large social groups after they shifted from arboreal to ground living was precisely because it afforded such security (Falk 2000:204).

Other factors are, of course, associated with the reduction of war death ratios in increasingly large human populations. These factors include lower mobilization rates of military, industrialization, commercial interdependence, and rocketing economic growth (Gat 2013); however, these variables do not apply to chimpanzees, and many of them are just the kinds of social indicators that scale superlinearly with increasing population sizes (Bettencourt et al. 2007) and thus are correlated with increasing absolute numbers of war deaths.

As documented above, when it comes to lethal intercommunity interactions, the thing that is unique (i.e., derived) in humans is that larger human populations are associated with increasingly larger numbers of military deaths. To paraphrase Pinker (2011:xxii), this paper uses numbers gleaned from data sets and depicted in graphs to make the case that people living in small-scale societies are not inherently more violent than those living in “civilized” states. Our analyses demonstrate that war deaths scale similarly with population sizes across all levels of human society. Although similar scaling of social variables with population sizes is familiar to theoretical physicists (West 2017), it is less so to social scientists. To come full circle, assertions that humans living in states have become less violent than those living in nonstates, with the assertions being based on blind ratios of annual war deaths relative to population sizes (e.g., war deaths per 100,000 people), are parallel to the untenable assertion that squirrel monkeys are smarter than humans because they have relatively large (blind) ratios of brain sizes divided by body sizes.

It is important to stress that the analyses presented above for humans focus on figure 1 and, as such, only address intercommunity lethal violence (war) in past and recent nonstate and state societies. Although analyses of other forms of violence discussed in Pinker’s comprehensive book (such as homicide, genocide, and terrorism) are beyond the scope of this paper, we hope that future scholars will examine these variables in light of the above discussions about power law distributions (scaling factors). We also note important observations made by Gat, namely that different societies at all levels have engaged in varying levels of violence and that “people can cooperate, peacefully compete, or use violence in order to achieve their objectives” (Gat 2015:123).

## Conclusion

Optimists naturally hope that “better angels” (such as reason, moral sense, and empathy) associated with “civilized” humans

will prevent a third massive war from happening (Pinker 2011). Although these qualities are as much a product of hominin biocultural evolution as are increasingly dangerous weapons, it remains to be seen whether such angels constrain the development of biological, chemical, and nuclear weapons enough to prevent their spread and eventual use (Dhanapala 2015; Eden et al. 2017). Meanwhile, the assertion that people who lived/live in small-scale societies were/are generally more violent than denizens of states should be abandoned, because severity of war deaths appears to be a function of population sizes in *H. sapiens* rather than a manifestation of greater violence in smaller, more vulnerable societies.

### Materials, Methods, and Their Potential Weaknesses

The ratios of mean number of deaths experienced annually from external aggressors (battle or war deaths) relative to mean population sizes of warring communities were obtained for four data sets representing chimpanzees (table S1) and people living in nonstates (table 2) and state societies that participated in World War I (table S2) and World War II (table S3). Chimpanzees were included for comparative context, and the world wars were included because they occurred at different times and involved many state societies with highly varying population sizes.

Battle (war) deaths were averaged across the actual number of years during which deaths from external enemies were recorded (table 2; tables S1–S3). For example, although the Gombe Kasekela chimpanzee community was studied for 53 years, deaths from external aggressors were reported during only seven of those years (Wilson et al. 2014; table S1). The average number of annual battle deaths was, therefore, calculated across 7 years rather than 53 years. As far as can be determined (see appendix), Keeley (Keeley 1996) applied the same standard to most, but not all, of the calculations that provided most of the data for nonstates in figure 1 (Pinker 2011). On the other hand, Pinker noted that twentieth-century annual war death rates for Germany, Russia, France, and Japan (fig. 1) were from Keeley (1996) and were “pro-rated for missing years” (Pinker 2011:700, n. 63). If by this he meant that the recorded war deaths were averaged over 100 years, and war did not take place during some of those years, the effect would have been to dilute the average annual war deaths rates and therefore the average rates of warfare deaths for all states compared with all nonstates—a bias that would have favored his claim that states are less violent than nonstates. This interpretation is consistent with Keeley’s remark that “if these rates were calculated for only the bloodier period from 1900 to 1950, they would more or less double” (Keeley 1996:195, n. k).

Population sizes represent the specific societies and countries that sustained the recorded battle deaths (table 2; tables S1–S3). For example, the 3.3% ratio of mean annual battle deaths to population size of the Gombe Kasekela chimpanzees (table S1) was calculated by dividing that group’s

mean annual battle deaths (1.6) by its mean population size (48.5), rather than by dividing the battle deaths by a larger estimate for population size that encompassed individuals in other communities. As far as can be determined (see appendix), the same standard was used for most but not all of the population sizes used by Keeley (or his sources) to calculate the warfare death rates that provided data for all but two of the bars for nonstates in figure 1 (Pinker 2011).

The Cochran-Armitage trend test, which tests the null hypothesis that there is neither an increasing nor decreasing trend in response rates for a group of binomial populations (Armitage 1955; Cochran 1954) was used to compare the relationship between the percentages of mean number of deaths experienced annually during years of lethal conflict relative to the mean population sizes for the four data sets. Because some of the sample sizes for World War I and World War II countries were in the millions, exact *P* value computations could not be performed for World War I and World War II; therefore, the Monte-Carlo method was used with a Monte-Carlo sample size of 50,000. With this method, 99% confidence intervals were calculated for exact *P* values—that is, there is 99% confidence that the exact *P* value is contained within the 99% confidence interval. Two-sided testing was used. For all groups, the Monte-Carlo method was used to calculate *P* values. In addition, asymptotic *P* values were calculated for all groups, and exact *P* values were calculated for chimpanzee communities and human nonstates. *P* values with the various methods agreed. These analyses were performed with StatXact 11.1.0 Statistical Software for Exact Nonparametric Inference (Cytel, Cambridge, MA). To visualize the data, variable bar plots of percentage mean annual deaths relative to increasing population sizes were created (fig. 2). Because the statistically significant trend was not as visually apparent on the bar plot for World War II as it was for the other groups, we performed a Cauchy regression analysis in which the mean annual military deaths as percentages of the population sizes were regressed on the ranks of the populations from the smallest population (rank = 1, Albania) to the largest population (rank = 22, China), and the resulting regression line was superimposed on the bar plots (fig. 2D). Bar plots and Cauchy regression analysis were performed with JMP Pro Statistical Software, release 12.0.1 (SAS Institute, Cary, NC).

This report also examined the relationship between the number of mean annual war deaths sustained by chimpanzee and human societies relative to the mean population sizes of the societies that engaged in the battles (rather than per 100,000 individuals) for the four data sets. We performed reduced major axis regressions of natural logs of the number of mean annual battle/war deaths against natural logs of mean population sizes. The reasons we selected reduced major axis regressions are as follows: (1) we wished to “define some mutual, codependent, biological ‘law’ underlying the interaction between X and Y” (Smith 2009:482), and (2) we wished to use the slope of the line to interpret the pattern of change (Smith 2009). We created



our reduced major axis regression plots and determined  $P$  values and  $r^2$  values with MedCalc Statistics for Biomedical Research, version 16.2.0 (MedCalc, Mariakerke, Belgium). We determined 95% confidence intervals of the intercepts and slopes and standard errors with Software for Reduced Major Axis regression (Bohonak and van der Linde 2004). Differences in slopes were determined (Soper 2016). Residuals were calculated with Statistica, release 12.5 (StatSoft, Tulsa, OK), and were assessed for normality with the Kolmogorov-Smirnov test available with MedCalc. According to the Kolmogorov-Smirnov test, reduced major axis regression residuals were normally distributed for the groups ( $P \geq .07$ ) except for chimpanzees ( $P = .03$ ).

#### *Potential Weaknesses of the Materials and Methods*

First, there is a narrow focus on one aspect of violence. This report focuses exclusively on mean annual battle/war deaths because Pinker's assessment of this variable is the main evidence offered to support his assertion that smaller populations (nonstates) are more violent than larger ones (states; fig. 1; Pinker 2011). Although Pinker separately compares annual homicide rates per 100,000 people in four nonstate and four state societies (Pinker 2011), he does not include homicide rates in figure 1. Exploring scaling of homicides with population size is beyond the scope of this report. The focus on battle/war deaths is especially appropriate for investigating possible universal trends related to violence, because "the concept of battle deaths is readily applied across a variety of types of conflicts" and "measuring battle deaths . . . is the best measure of the scale, scope, and nature of the military engagement that has taken place" (Lacina and Gleditsch 2005:148).

Second, there are limited sample sizes and data for nonstates. Because relevant data for nonstate societies are scarce, the number included in this report is 24, which approximates the 26 included in Pinker's analysis (rather than 27; see appendix). For Keeley's data (thus the bars in fig. 1), as well as those reported here, battle deaths may be conservative because of unreported cases or because relatively few battles/wars were used to estimate warfare death rates for a particular year. Nonetheless, the surprising and nearly identical statistically significant reduced major axis regressions of mean annual battle deaths during years of conflict on mean population sizes for nonstates and World War I and World War II state societies (table 1) suggest that this report's data set for nonstates (table 2) is reasonably comparable to the other sets.

Third, the report for states focuses on only two "rare" world wars; however, each world war entailed many states of varying population sizes, was associated with consistently defined mean annual war deaths, and represented many millions of military deaths, rendering them especially suitable for a study of the impact of population size on war deaths. Because the world wars occurred at different times, their inclusion adds some time depth to the analysis. This report also incorporates

findings from a study of 97 interstate wars that occurred from 1820 to 1997 (Cederman 2003); this sheds light on the scaling of the frequency of common, less-severe wars versus rare, more-severe wars and has implications for the likely consequences of a future "rare" war.

Fourth, data for the world wars include only deaths of military personnel, while the data for prestate warfare encompasses overall mortality, including deaths of nonwarriors (women and children) who were sometimes killed during raids. The criteria used here to identify war deaths for nonstate and state societies are comparable to those used to identify war deaths for both types of society in Pinker's table (fig. 1). For example, the reference that Pinker cites for war deaths for Germany, Russia, France, and Japan (Keeley 1996) relied heavily on Wright, who included "soldiers killed and died of wounds" (Wright 1942:664) but not civilians. Similarly, Pinker's source for US twentieth century (war deaths) and US 2005 (battle deaths) were the "total deaths" columns from tables in Leland and Oboroceanu (2010) and encompassed military deaths from "accidents, diseases and infections" but not civilian deaths (Leland and Oboroceanu 2010: 1). Our criteria for identifying war deaths in the world wars—namely, military killed in battle from (1) wounds, (2) disease, (3) accidents, and (4) as prisoners of war, and, in the case of World War I, (5) poison gas (tables S2, S3)—are comparable to Pinker's data for war deaths in states, which, like our data, also exclude civilian deaths. Of course, this does not minimize the importance of civilian deaths during the world wars. For example, as Gat observes, "it is all too often forgotten that the vast majority of the many millions of non-combatants killed by Germany during World War II . . . fell victim to intentional starvation, exposure to the elements, and mass executions rather than to any sophisticated military technology" (Gat 2013:153); however, not only would incorporating civilian deaths in our analyses for states depart from the criteria used by Pinker's sources for the states in table 1, but also the resulting increase in war deaths for World War I and World War II would unfairly bias our analyses against Pinker's hypothesis that states are less violent than nonstates.

It is also worth noting that at least one small-scale society (the Tiwi) considered it improper to kill women during sneak attacks, and the warfare deaths for various North American tribes often involved only male warriors (see appendix for details). Unlike many small-scale societies, theaters of military operations in states were commonly distanced from general populations, thus decreasing the vulnerability of women and children during combat, which helps account for the lack of "civilian" deaths from direct combat in states (Gat 2013).

Fifth, chimpanzees and humans represent different genera of primates (*Pan* and *Homo*, respectively), and intercommunity lethal violence in the former is not as influenced by cultural factors as it is in the latter. Data from chimpanzees allow comparison of humans with their genetically closest nonhuman cousins that engage in intercommunity lethal violence—a standard comparison for exploring evolutionary

hypotheses (such as the suggestion that humans “started off nasty and . . . the artifices of civilization have moved us in a noble direction” (Pinker 2011:xxii). The data for chimpanzees are from one authoritative source (Wilson et al. 2014), and the largest population of chimpanzees (table S1) exceeds the population sizes of the two smallest nonstates (table 2). Nonstates, however, include a wider variety of population types, such as clans, tribes, and so on (table 2). Such diverse data sets are likely to reflect general trends that depend on population sizes rather than a particular level of social organization. Importantly, the analysis of chimpanzees demonstrates that average ratios of annual deaths from intercommunity lethal conflicts divided by mean population sizes, computed according to the same criteria used for humans living in nonstates (fig. 2A, 2B), reflect communities’ relative vulnerabilities to lethal intercommunity violence—not their predispositions for violence. This finding for chimpanzees casts serious doubts on the interpretation that reduced war death ratios in states compared with nonstates is indicative of relatively reduced violence in the former despite their comparatively (and strikingly) increased absolute numbers of military deaths. The information gleaned from comparing chimpanzees and humans is also relevant for discussions about the relative influences of cultural versus biological variables on the development of human warfare (Ferguson 2013; Gat 2015).

## Acknowledgments

Financial support for figure licenses was provided by the School for Advanced Research in Santa Fe, New Mexico.

## References Cited

- Armitage, Peter. 1955. Tests for linear trends in proportions and frequencies. *Biometrics* 11(3):375–386.
- Bettencourt, Luis M. A., José Lobo, Dirk Helbing, Christian Kühnert, and Geoffrey B. West. 2007. Growth, innovation, scaling, and the pace of life in cities. *Proceedings of the National Academy of Sciences of the USA* 104(17):7301–7306.
- Bohonak, Andrew J., and Kim van der Linde. 2004. RMA: software for reduced major axis regression, Java version 2004.
- Cederman, Lars-Erik. 2003. Modeling the size of wars: from billiard balls to sandpiles. *American Political Science Review* 97(01):135–150.
- Cochran, William G. 1954. Some methods for strengthening the common  $\chi^2$  tests. *Biometrics* 10(4):417–451.
- Dhanapala, Jayantha. 2015. The 2015 Review Conference for the Treaty on the Non-Proliferation of Nuclear Weapons: a review or a requiem? *Global Governance* 21(1):1–7.
- Eden, Lynn, Rod Ewing, Sivan Kartha, Lawrence M. Krauss, Herb Lin, Suzet McKinney, Steve Miller, et al. 2017. It is two and a half minutes to midnight, 2017 doomsday clock statement. *Bulletin of the Atomic Scientists* 73(1):2–8.
- Falk, Dean. 2000. *Primate diversity*. New York: Norton.
- . 2016. Evolution of brain and culture: the neurological and cognitive journey from *Australopithecus* to Albert Einstein. *Journal of Anthropological Sciences* 94:1–14.
- Ferguson, R. Brian. 2013. Pinker’s list: exaggerating prehistoric war mortality. In *War, peace, and human nature: the convergence of evolutionary and cultural views*. Douglas P. Fry, ed. Pp. 112–150. New York: Oxford University Press.
- Forman, R. T., and J. Wu. 2016. Where to put the next billion people. *Nature* 537(7622):608–611.
- Gat, Azar. 2006. *War in human civilization*. New York: Oxford University Press.
- . 2013. Is war declining—and why? *Journal of Peace Research* 50(2):149–157.
- . 2015. Proving communal warfare among hunter-gatherers: the quasi-Rousseauian error. *Evolutionary Anthropology: Issues, News, and Reviews* 24(3):111–126.
- Gómez, José María, Miguel Verdú, Adela González-Megias, and Marcos Méndez. 2016. The phylogenetic roots of human lethal violence. *Nature* 538:233–257.
- Goodall, Jane. 1986. *The chimpanzees of Gombe: patterns of behavior*. Cambridge, MA: Harvard University Press.
- Gusterson, Hugh. 2016. *Drone: remote control warfare*. Cambridge, MA: MIT Press.
- Haythornthwaite, Philip. 1992. *The World War I source book*. London: Arms & Armour.
- Huxley, Julian S., and Georges Teissier. 1936. Terminology of relative growth. *Nature* 137(3471):780–781.
- Jerison, Harry J. 1973. *Evolution of the brain and intelligence*. New York: Academic Press.
- . 1991. *Brain size and the evolution of mind: 59th James Arthur lecture on the evolution of the human brain*. New York: American Museum of Natural History.
- Keeley, Lawrence H. 1996. *War before civilization*. New York: Oxford University Press.
- Lacina, Bethany, and Nils Petter Gleditsch. 2005. Monitoring trends in global combat: a new dataset of battle deaths. *European Journal of Population/Revue européenne de Démographie* 21(2–3):145–166.
- Leland, Anne, and M.-J. Oboroceanu. 2010. *American war and military operations casualties: lists and statistics*. Collingdale, PA: DIANE.
- Mirth, Christen K., W. Anthony Frankino, and Alexander W. Shingleton. 2016. Allometry and size control: what can studies of body size regulation teach us about the evolution of morphological scaling relationships? *Current Opinion in Insect Science* 13:93–98.
- Pinker, Steven. 2011. *The better angels of our nature: why violence has declined*. New York: Viking.
- Prüfer, Kay, Kasper Munch, Ines Hellmann, Keiko Akagi, Jason R. Miller, Brian Walenz, Sergey Koren, Granger Sutton, Chinnappa Kodira, and Roger Winer. 2012. The bonobo genome compared with the chimpanzee and human genomes. *Nature* 486(7404):527–531.
- Ready, J. Lee. 1995. *World War Two: nation by nation*. London: Arms & Armour.
- Sarkees, Meredith Reid, Frank Whelon Wayman, and J. David Singer. 2003. Inter-state, intra-state, and extra-state wars: a comprehensive look at their distribution over time, 1816–1997. *International Studies Quarterly* 47(1):49–70.
- Smith, Richard J. 2009. Use and misuse of the reduced major axis for line-fitting. *American Journal of Physical Anthropology* 140(3):476–486.
- Soper, D. S. 2016. Significance of the difference between two slopes calculator. <http://www.danielsoper.com/statcalc/calculator.aspx?id=103>.
- Stephan, H., R. Bauchot, and O. J. Andy. 1970. Data on size of the brain and of various brain parts in insectivores and primates. In *Advances in primatology, vol 1: the primate brain*. C. R. Noback and W. Montagna, eds. Pp. 289–297. New York: Appleton-Century-Crofts.
- Ulanis, B. T. S. 1971. *Wars and population*. Moscow: Progress.
- West, Geoffrey. 2017. *Scale: the universal laws of growth, innovation, sustainability, and the pace of life in organisms, cities, economies, and companies*. New York: Penguin.
- Wilson, Michael L., Christophe Boesch, Barbara Fruth, Takeshi Furuichi, Ian C. Gilby, Chie Hashimoto, Catherine L. Hobaiter, Gottfried Hohmann, Noriko Itoh, and Kathelijne Koops. 2014. Lethal aggression in *Pan* is better explained by adaptive strategies than human impacts. *Nature* 513(7518):414–417.
- Wright, Quincy. 1942. *A study of war*. Chicago: University of Chicago Press.