Original Article

Why history matters for quantitative target setting: Long-term trends in socioeconomic and racial/ethnic inequities in US infant death rates (1960–2010)

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Abstract Policy-oriented population health targets, such as the Millennium Development Goals and national targets to address health inequities, are typically based on trends of a decade or less. To test whether expanded timeframes might be more apt, we analyzed 50-year trends in US infant death rates (1960–2010) jointly by income and race/ethnicity. The largest annual per cent changes in the infant death rate (between −4 and −10 per cent), for all racial/ethnic groups, in the lowest income quintile occurred between the mid-1960s and early 1980s, and in the second lowest income quintile between the mid-1960s and 1973. Since the 1990s, these numbers have hovered, in all groups, between −1 and −3 per cent. Hence, to look back only 15 years (in 2014, to 1999) would ignore gains achieved prior to the onset of neoliberal policies after 1980. Target setting should be informed by a deeper and longer-term appraisal of what is possible to achieve.

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To the extent that quantitative health data can contribute to guiding policy decisions for future targets, in conjunction with relevant qualitative, economic, and policy data,[1–6] a long-term perspective may be desirable. Yet, quantitative targets are typically based only on recent trends–a decade or less, in the case of the Millennium Development Goals (MDGs).[1] The use of limited time frames may be in part because current data may seem most immediately relevant and they are also most readily available. Such reliance on short-term data may, however, be problematic: looking back only 10 years, say from 2014 back to 2004, would ignore gains achieved, in relation to both improving population health and reducing health inequities, prior to the post-1980 onset of neoliberal policies, whose prioritization of private wealth over public investment and benefits has been associated with set-backs to reductions in health inequities.[7–10]

Accordingly, to explore the salience of history to policy-relevant quantitative target setting[11,12] for both on-average rates and health inequities, we present a novel analysis of long-term trends in US infant death rates (1960–2010), overall and jointly in relation to socioeconomic position and race/ethnicity. Infant mortality has long served as a key indicator of a population's well-being,[1–4,13] and socioeconomic and racial/ethnic inequalities in this outcome[4,13,14] warrant being conceptualized as health inequities. We use the term health inequities to mean unfair and avoidable differences in health outcomes across social groups who would otherwise have similar rates except for the embodied health consequences of injustice.[15–17]

Methods

Infant death data

We analyzed: (i) 1960–1967 US national mortality data from the National Center for Health Statistics (NCHS),[18] the earliest publicly available computerized US national mortality data (with death registration estimated to be >99 per cent complete), for which we manually located and identified the correct county code for each of the 3073 counties[8] (the primary legal division of most states, most of which are functioning governmental units[19]), and (ii) 1968–2010 data from the publicly available NCHS US compressed mortality file.[20] Together, these files encompass a longer span of time than the NCHS-linked birth cohort and period files, which go back only to 1983 and 1995, respectively.[21]

Records thus comprised individual-level mortality records and census denominator data, stratified by age, gender, and race/ ethnicity, and aggregated to the county level. Using these data, we computed the infant death rate ([deaths<age 1]/[population <age 1], in the same calendar year). This outcome is highly correlated with the infant mortality rate (deaths per liveborn infants).[20] Data limitations required that, for 1960–1967 only, we employ the NCHS algorithm for the infant death denominator which entails multiplying 'the population in the 1–4 age category by 0.25'[20].

County income data

To overcome the absence of socioeconomic data in the mortality records, we linked the mortality data to county median family income obtained from US census decennial 1960–2010 data (missingness<1 per cent), which we adjusted for inflation and regional cost of living.[8,22] We used linear interpolation between census years and then assigned counties to income quintiles, weighted by county population size because the range is high.[8] For 1960–1988, the lack of county data for one US state with a small population (Alaska) required the state's data to be analyzed as a single county.[8]

Racial/ethnic classification

Reflecting changing US race relations and conceptualizations of race/ethnicity,[8,17,21,23] available racial/ethnic categories were well documented,[8,20,21] for *1960–1967*, 'white' and 'non-white'; *1968–2010*: 'white', 'black', and 'other'; and since *1999*: 'non-Hispanic': 'white,' 'black,' 'American Indian and Alaska Native', 'Asian or Pacific Islander'; and 'Hispanic or Latino'.[20,23] For the 1960–1967 data, we followed standard practice by reclassifying 'non-white' persons as 'black'.[24] In 1960, 92 per cent of US 'non-white' persons were black, and the mortality rates of these two groups were almost identical.[24] This suggests that our approach is reasonable. One state (New Jersey) did not identify race/ethnicity in 1962 and 1963, precluding the use of these 2 years of data (<3 per cent of the US population).[18]

Statistical analysis

We first computed and plotted 3-year moving averages of infant death rates by county income quintile, for the total population and within each racial/ethnic group. We then computed the corresponding cross-sectional rate differences and rate ratios, and their 95 per cent confidence intervals, for (i) income quintile, for the total population and within racial/ethnic groups, setting as referent the highest income quintile (Q5), and (ii) race/ethnicity, within income quintiles, setting as referent, for 1960–2010, the white population, and for 1999–2010, the white non-Hispanic population.

To analyze time trends, we then employed *joinpoint* regression,[8,25,26] by specifying a Poisson model for the time series of annual infant death rates in each income and racial/ethnic stratum. To account for heteroscedasticity, each year's data is weighted by the inverse of the standard error of the rate for that year. To carry out these analyses, we used the National Cancer Institute's Joinpoint software,[25,26] which employs a grid search algorithm to identify statistically significant inflection points ($P<0.05$) in a series of data. The slope from the resulting regression function fit yields estimates of the annual percent change (APC) in rates.[25,26]

Findings

Between 1960 and 2010, in the United States there were ~2.5 million infant deaths and 189 million person-years at risk for persons< age 1 (Appendix Table A1). The only racial/ethnic groups for whom the percentage of infant deaths exceeded their per cent share of the population, in each and every income quintile, were the US black, American Indian, and Alaska Native populations. To illustrate, for 1960–2010, black infants comprised 15.4 per cent of all US infants and 27.8 per cent of all US infant deaths, and in the lowest income quintile, equaled 20.7 per cent of total infants and 35.4 per cent of infant deaths.

Figure 1 displays the 1960–2010 infant death rates (3-year moving average) by income quintile for the total US population, white population, black population, and populations of color, along with the rate difference and rate ratio, by income quintile, for each group. Also shown is the APC in infant death rates by income quintile. In the Appendix, Figure A1 presents, within each income quintile, the rate difference and rate ratio by race/ethnicity. Analogous data are shown, respectively, in

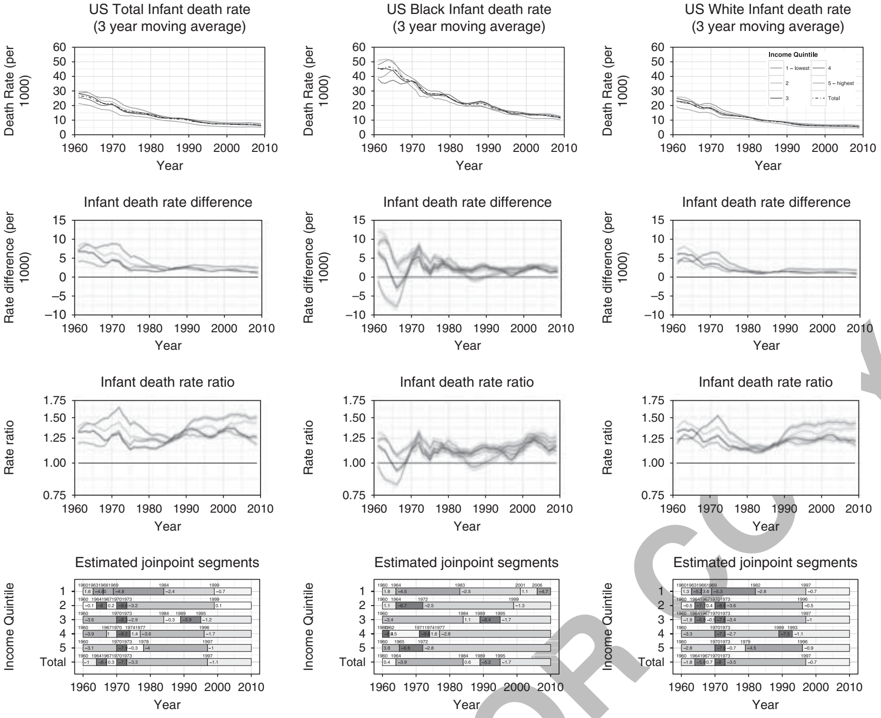

Figure 1: US infant death rates (3-year moving average), and rate difference and rate ratio by income quintile, for the total, black, and white population, 1960–2010.

Appendix Figures A2 and A3 for 1999–2010, using the more refined racial/ethnic categories.

Four primary findings stand out. First, the largest beneficial changes, in both rates and health inequities for the total population, by income quintile, primarily occurred between the mid-1960s and 1980 (Figure 1 and Appendix Figure A1). Second, although rate differences by race/ethnicity within all income quintiles shrank over time, the largest declines occurred in the two lowest income quintiles between 1960 and the early 1970s. Third, the largest APCs in the infant death rate (between −4 and −10 per cent) occurred, for all racial/ethnic groups, in the two lowest income quintiles between the mid-1960s and early 1980s; since the 1990s, they have hovered between −1 and −3 per cent, considered across all income quintiles (Figure 1). Fourth, analyses using the more refined racial/ethnic groups, available for 1999–2010, revealed smaller absolute and relative inequities and smaller changes in their magnitudes as compared with the longer-term analyses (Table 1; Appendix Figures A2 and A3).

Exemplifying these trends, among the US total and white population, infant death rates in the lower 4 income quintiles, which in 1960 ranged between 25 to 30/1000, dropped, by the mid-1980s, to ~9.5 to 11/1000, leading to convergence of their excess absolute and relative risks of infant death compared with the highest income quintile. Thereafter, their rates diverged, leading to re-emergence of differential risk by county income quintile (Figure 1). Among the US black population and populations of color, by contrast, socioeconomic gradients among the three lower compared with highest income quintiles that were evident in 1960 (when rates ranged between ~46 and 51/1000) more quickly converged by the early 1970s, after which they diverged, then re-converged in the early 1980s, and diverged again in the mid-2000s. (Figure 1).

The magnitude of the absolute gap in the infant death rate between the lowest and highest income quintile, in the total population and each racial/ethnic group, shrank by ~5/1000 (over 25 per cent of the total infant death rate), comparing 1970–1972 versus 1980–1982, whereas the size of the absolute gap remained unchanged comparing 1999–2001 versus 2008–2010 (Table 1).

Moreover, although the significantly elevated rate ratios comparing the lowest to highest income quintile increased between 1960 and 2010 for the total and white population (respectively, from 1.3 to 1.5 and from 1.2 to 1.4), they declined among the black population between 1960 and 1990 (from 1.2 to 2.0), and then rose again to 1.2 in 2010 (Table 1). None of the reductions in rates and inequities, using the more refined racial/ethnic categories available for 1999–2010, were as large as those observed between the mid-1960s and 1980 (Table 1; Appendix Figures A2 and A3).

Finally, the U.S. Department of Health and Human Services *Healthy People 2020* target of six infant deaths per 1000 livebirths[3] already was met (in relation to our results for the infant death rate), a decade in advance, by the US white non-Hispanic population in the top income quintiles and also overall and by Hispanics and Asian and Pacific Islanders in all income quintiles and overall (Table 1; Appendix Figure A2). The *Healthy People* 2020 target was not met by black non-Hispanics or American Indian and Alaska Natives in any income quintile (Table 1; Appendix Figure A2).

Table 1: US infant death rate: rate difference (RD) and rate ratio (RR), with 95per cent confidence interval (CI), for infant deaths per 1000 persons <age 1, comparing lowest county income quintile (Q1) to highest county income quintile (Q5, referent rate), by race/ethnicity and time period: (a) 1960–2010 (total, black, white) and (b) 1999–2010 (more refined racial/ethnic groups).

Race/ethnicity	Rate comparisons	Time period					
	a) 1960–2010	1960–1962	1970–1972	1980–1982	1990–1992	2000–2002	2008–2010
Total population	**Rate difference (95% CI):** Q1 vs Q5	**6.99 (6.72, 7.27)**	**8.74 (8.47, 9.02)**	**3.09 (2.87, 3.30)**	**3.06 (2.89, 3.23)**	**2.77 (2.62, 2.91)**	**2.59 (2.45, 2.74)**
	Rate ratio (95% CI): Q1 vs Q5	**1.33 (1.31, 1.34)**	**1.59 (1.57, 1.61)**	**1.28 (1.26, 1.30)**	**1.43 (1.40, 1.45)**	**1.52 (1.48, 1.55)**	**1.51 (1.47, 1.54)**
	Referent rate (Q5)	21.5	14.8	11.0	7.2	5.4	5.1
Black	**Rate difference (95% CI):** Q1 vs Q5	**8.67 (7.75, 9.60)**	**6.79 (5.68, 7.90)**	**1.72 (0.91, 2.54)**	0.36 (−0.29, 1.00)	**1.89 (1.36, 2.42)**	**2.20 (1.73, 2.67)**
	Rate ratio (95% CI): Q1 vs Q5	**1.22 (1.19, 1.25)**	**1.22 (1.18, 1.27)**	**1.08 (1.04, 1.12)**	1.02 (0.98, 1.06)	**1.16 (1.11, 1.22)**	**1.22 (1.17, 1.27)**
	Referent rate: (Q5)	39.2	30.4	21.5	17.2	11.5	10.1
White	**Rate difference (95% CI):** Q1 vs Q5	**3.53 (3.25, 3.81)**	**6.52 (6.24, 6.80)**	**1.66 (1.43, 1.88)**	**2.22 (2.05, 2.39)**	**2.07 (1.92, 2.23)**	**1.94 (1.78, 2.09)**
	Rate ratio (95% CI): Q1 vs Q5	**1.19 (1.17, 1.20)**	**1.48 (1.45, 1.50)**	**1.17 (1.14, 1.19)**	**1.36 (1.33, 1.39)**	**1.44 (1.40, 1.48)**	**1.43 (1.39, 1.47)**
	Referent rate (Q5)	19.0	13.6	10.0	6.2	4.7	4.5
	b) 1999–2010	**1999–2001**		**2004–2006**		**2008–2010**	
American Indian + Alaska Native	**Rate difference (95% CI):** Q1 vs Q5	1.06 (−0.89, 3.01)		−0.75 (−2.91, 1.41)		**2.70 (0.92, 4.48)**	
	Rate ratio (95% CI): Q1 vs Q5	1.14 (0.89, 1.48)		0.92 (0.73, 1.17)		**1.42 (1.09, 1.89)**	
	Referent rate: (Q5)	7.8		9.6		6.4	
Asian and Pacific Islander	**Rate difference (95% CI):** Q1 vs Q5	0.35 (−0.38, 1.08)		**0.84 (0.14, 1.53)**		**0.75 (0.06, 1.43)**	
	Rate ratio (95% CI): Q1 vs Q5	1.09 (0.91, 1.29)		**1.22 (1.04, 1.43)**		**1.20 (1.02, 1.40)**	
	Referent rate: (Q5)	4.0		3.8		3.8	

Table 1: *Continued*

Race/ethnicity	Rate comparisons	Time period					
	a) 1960–2010	1960–1962	1970–1972	1980–1982	1990–1992	2000–2002	2008–2010
Black non-Hispanic	**Rate difference (95% CI):** Q1 vs Q5	**1.48 (0.90, 2.06)**		**2.80 (2.23, 3.37)**		**1.99 (1.47, 2.51)**	
	Rate ratio (95% CI): Q1 vs Q5	**1.12 (1.07, 1.17)**		**1.23 (1.18, 1.29)**		**1.18 (1.13, 1.24)**	
	Referent rate: (Q5)	12.8		12.1		11.0	
Hispanic	**Rate difference (95% CI):** Q1 vs. Q5	0.21 (−0.09, 0.51)		**0.38 (0.10, 0.65)**		**0.44 (0.17, 0.71)**	
	Rate ratio (95% CI): Q1 vs Q5	1.04 (0.98, 1.10)		**1.07 (1.02, 1.13)**		**1.09 (1.03, 1.15)**	
	Referent rate: (Q5)	5.3		5.2		5.0	
White non-Hispanic	**Rate difference (95% CI):** Q1 vs Q5	**2.49 (2.31, 2.68)**		**2.60 (2.42, 2.79)**		**2.50 (2.31, 2.68)**	
	Rate ratio (95% CI): Q1 vs Q5	**1.55 (1.50, 1.60)**		**1.58 (1.53, 1.63)**		**1.60 (1.54, 1.66)**	
	Referent rate: (Q5)	4.5		4.5		4.2	

Bold font: Parameter estimates for which the 95per cent CI exclude 0 (for Rate Difference) or 1 (for Rate Ratio).

Interpretation

The case example here, long-term 50-year trends, spanning from 1960 to 2010, in US infant death rates and their economic and racial/ethnic inequities, reveals that today's comparative stagnation in, or worsening of, infant death rates and their socioeconomic and racial/ethnic inequities contrasts sharply with prior patterns, particularly before 1980. In this earlier period, pronounced beneficial change occurred, especially for infants in the lower income quintiles. A key implication is that the population health data that contribute to setting quantitative targets should extend beyond the recent past, especially when there are good grounds to believe that temporal dynamics reflect not only changing technology but also political priorities, whose implications for health cut across both the lifespan and generations.[5–14]

Well-known potential biases are unlikely to compromise our findings. Death registration was 99 per cent complete by 1960,[18] and the US census undercount (disproportionately affecting poor persons and/or persons of color) has also declined substantially over time,[27] thereby shrinking any inflation of recent estimates of social inequalities in mortality. Moreover, data indicate that racial/ethnic misclassification of 'black' and 'white' in the mortality data is <1 per cent,[31] and that the higher levels of misclassification for other racial/ethnic groups,[28] especially American Indians and Alaska Natives,[29] primarily results in underestimation, not inflation, of the magnitude of racial/ethnic inequities.[28,29] Furthermore, cross-sectional analysis of county income quintile data and infant death data is unlikely to be affected by issues of lag time and migration, because even if the mother/parents migrated prior to the infant's death, conditions at the time of death remain highly salient, as reflected by higher racial/ethnic and socioeconomic inequities for post-neonatal (⩾28 days) compared with neonatal (<28 days) mortality.[2,4,13,24]

Assuming our results are valid, the reported findings raise important questions regarding particular changes in political, legal, and social conditions and in health systems that over time likely contributed to the observed results.[8,14,24] Ascertaining both how and the extent to which these diverse phenomena have shaped US trends in infant mortality rates and inequities in these rates will require not only rich multi-level and longitudinal data on the etiologic drivers implicated by prior research,[4,8,13,14,17] but also quantitative and qualitative research attuned to investigating the impacts of actual interventions – in context.[11,12,30]

Our results raise provocative questions about reliance on short-term data to set quantitative targets, whether for on-average rates or for health inequities. As an example, the original MDG targets for 2015, including those for infant mortality, were announced in 2000 and set in relation to 1990 baseline data, with calls for disaggregation of data framed solely in relation to 'sex' and 'urban/rural' location. Only in the 2012 documentation is there reference to disaggregation by socioeconomic level and race/ethnicity.[1] The kinds of data that will contribute to target setting in the post-2015 era remain under active discussion.[1,2] The Report of the Secretary's Advisory Committee on Infant Mortality, in turn, relied on the average trend for 2007–2010 (4 years; −3.1 per cent decline) to formulate its proposed target of reducing the US infant mortality rate to 5.0 deaths/1000 livebirths by 2015 and to 4.5 by 2020 (that is, lower than the *Healthy People 2020* target of six)[4], p. 18. Setting of additional targets for reducing the excess rates among African American and American Indian/Alaska Native compared with white infants is a task recommended for a future panel, with no mention of socioeconomic inequities[4], p. 43.

The past 15 years, or past decade, or even past few years, as spans of time, are human inventions. They are based on a solar calendar and have no intrinsic social or biological meaning, even though they may feel like and function as a political eternity. Their relevance to population health and health targets is instead historically contingent, depending on societal conditions – and also the biological processes involved.[31,32] Although experiences of a decade or two may shape expectations, understanding possibilities for change requires a far deeper grasp of causal processes – both social and biological – that contribute to shaping long-term trends for not only on-average health but also health inequities.[7–13,17,31,32] Consider the example a fast-acting new vaccine or new policy mandating vaccination[33] that may dramatically shift on-average rates of the infectious disease at issue, and thus appear to render the need for knowledge of past (that is, pre-vaccine) trends moot. However, as suggested by the case of compulsory childhood vaccination in the United States and in other countries,[33,34] long-term data on trends in inequities in the disease distribution nevertheless remain salient for guiding contemporary interventions. They demonstrate which social groups have faced enduring obstacles to achieving rates of the outcome on par with the most privileged groups. The goal, after all, must be to do more than align with trends already under way (including improvements in technology) that would happen even without any concerted public health action.[5]

Although reliance on recent population health data may appear both pragmatic and cutting-edge, as our findings reveal, it can potentially – depending on historical circumstances –undercut the progressive objective of target setting. Data on long-term trends in on-average health and health inequities are thus a necessity, not a luxury. We suggest that initiatives to improve the availability of accurate and publicly accessible historical population health data – in which health records (and their denominators) can be used to monitor trends in both on-average health and health inequities – warrant support.[31,35–37] Support likewise is needed for efforts to obtain the pertinent long-term social, economic, legal, and policy data relevant to shaping the public's health,[6,11,12,30,31,35] and to improve statistical methods for analysis of large complex spatiotemporal data sets.[8,31,35–37] The goal should be to formulate quantitative targets, informed by principles that give priority to advancing both overall health and health equity[38], that will push beyond recent trends.[5]

In summary, adequate planning for the people's health requires reckoning with history. A focus only on the recent past will reflect only the scope of possibilities under current societal arrangements, as experienced by the relevant birth cohorts and the respective cumulative exposures that they have embodied.[8,31] Expanding the timeframe allows for new insights that expand understanding of what can be achieved.

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References

1. United Nations. (2014) We can end poverty: Millennium Development Goals and Beyond 2015, http://www.un.org/millenniumgoals/beyond2015.shtml, accessed 18 December 2014.
2. Bhutta, Z.A. *et al* (2010) Countdown to 2015 decade report (2000–10): Taking stock of maternal, newborn, and child survival. *Lancet* 375(9730): 2032–2044.
3. US Department of Health and Human Services. (2014) Healthy People 2020 leading health indicators: progress update, https://www.healthypeople.gov/2020/leading-health-indicators/Healthy-People-2020-Leading-Health-Indicators%3A-Progress-Update, accessed 18 December 2014.
4. Report of the Secretary's Advisory Committee on Infant Mortality. (2013) Recommendation for Department of Health and Human Services (HHS) Action and a Framework for National Strategy, http://www.hrsa.gov/advisorycommittees/mchbadvisory/InfantMortality/Correspondence/recommendationsjan2013.pdf, accessed 18 December 2014.
5. Ingledew, D. (1989) Target setting for health of populations: Some observations. *Health Promotion* 4(4): 357–369.
6. Pang, T., Sadana, R., Hanney, S., Bhutta, Z.A., Hyder, A.A.V and Simon, J. (2003) Knowledge for better health – a conceptual framework and foundation for health research systems. *Bull World Health Organisation* 81(11): 815–820.
7. Birn, A.-E., Pillay, Y. and Holtz, T.H. (2009) *Textbook of International Health: Global Health in a Dynamic World*, 3rd edn. New York: Oxford University Press.
8. Krieger, N., Rehkopf, D.H., Chen, J.T., Waterman, P.D., Marcelli, E. and Kennedy, M. (2008) The fall and rise of inequities in US premature mortality: 1960–2002. *PLoS Medicine* 5(2): e46, doi:10.1371/journal.pmed.0050046.
9. Piketty, T. (2014) *Capital in the Twenty-First Century*. Translated by A. Goldhammer. Cambridge, MA: Harvard University Press.

10. Oxfam. (2014) *Even It Up: Time to End Extreme Inequality*. Oxford, UK: Oxfam Great Britain, 2014, http://www.oxfam.org/even-it-up, accessed 18 December 2014.
11. Lieberman, E.S. (2001) Causal inference in historical institutional analysis: A specification of periodization strategies. *Comparative Political Studies* 34(9): 1011–1035.
12. Cartwright, N and Hardie, J. (2012) *Evidence-Based Policy: A Practical guide to Doing it Better*. New York: Oxford University Press.
13. Miller, C.A. (1985) Infant mortality in the U.S. *Scientific American* 253(1): 31–37.
14. David, R.J. and Collins, J.W. (2014) Layers of inequality: Power, policy, and health. *American Journal of Public Health 2014* 104(Suppl 1): S8–S10.
15. Whitehead, M. (1992) The concepts and principles of equity and health. *International Journal of Health Services* 22(3): 429–445.
16. Braveman, P. and Gruskin, S. (2003) Defining equity in health. *Jounal of Epidemiology Community Health* 57(4): 254–258.
17. Krieger, N. (2014) Discrimination and health inequities. In: L. Berkman, I. Kawachi and M. Glymour (eds.) *Social Epidemiology*, 2nd edn. New York: Oxford University Press, pp. 63–125.
18. National Office of Vital Statistics, Public Health Service, US Department of Health, Education and Welfare. (1969) Documentation of the detail mortality tape file (1959–1961, 1962–1967). Washington DC: US Department of Health, Education, and Welfare, 1969, http://www.nber.org/mortality/1965/mor59_67.pdf, accessed 18 December 2014.
19. US Census Bureau. (2014) Geographic terms and definitions, https://www.census.gov/popest/about/geo/terms.html, accessed 18 December 2014.
20. National Center for Health Statistics. (2014) Compressed Mortality File: Years 1968–1978 with ICD-8 Codes, 1979–1988 with ICD-9 Codes and 1999–2011 with ICD-10 Codes, http://wonder.cdc.gov/wonder/help/cmf.html, accessed 18 December 2014.
21. National Center for Health Statistics. (2014) Linked birth and infant death data, http://www.cdc.gov/nchs/linked.htm, accessed 18 December 2014.
22. US Department of Labor, Bureau of Labor Statistics. (2014) Consumer Price Indexes, http://www.bls.gov/cpi/home.htm, accessed 18 December 2014.
23. Office of Management and Budget. (1997) Revisions to the Standards for the Classification of Federal Data on Race and Ethnicity, Office of Management and Budget Directive 15, http://www.whitehouse.gov/omb/fedreg_1997standards, accessed 18 December 2014.
24. Kitagawa, E.M. and Hauser, P.M. (1973) *Differential Mortality in the United States: A Study in Socioeconomic Epidemiology*. Cambridge, MA: Harvard University Press.
25. Kim, H.J., Fay, M.P., Feuer, E.J. and Midthune, D.N. (2000) Permutation tests for joinpoint regression with applications to cancer rates. *Stat Med* 19(3): 335–351, erratum: *Stat Med* 2001; 20(4): 655.
26. National Cancer Institute. (2014) Joinpoint regression program (ver 4.1.1.1.; release date: October 7, 2014), http://surveillance.cancer.gov/joinpoint/, accessed 18 December 2014.
27. Clark, J.R. and Moul, D.A. (2004) *Census 2000 Testing, Experimentation, and Evaluation Program Topic Report no. 10, TR-10, Coverage and Improvement in Census 2000 Enumeration*. Washington DC: US Census Bureau.
28. Arias, E., Schauman, W.S., Eschbach, K., Sorlie, P.D. and Backlund, E. (2008) The validity of race and Hispanic origin reporting on death certificates in the United States. *Vital Health Stat 2* 148(2): 1–23.
29. Wong, C.A. *et al* (2014) American Indian and Alaska Native infant and pediatric mortality, United States, 1999–2009. *Am J Public Health* 104(Suppl 3): S320–S328.
30. Reiss, J. (2009) Causation in the social sciences: Evidence, inference, and purpose. *Phil Soc Sci* 39: 20–40.
31. Krieger, N., Chen, J.T., Waterman, P.D., Kosheleva, A. and Beckfield, J. (2013) History, haldanes, & health inequities: Exploring phenotypic changes in body size by generation and

income level among the US-born white and black non-Hispanic populations, 1959–1962 to 2005–2008. *International Journal of Epidemiology* 42: 281–295.

32. Gingerich, P.D. (1993) Quantification and comparison of evolutionary rates. *Am J Sci* 93A: 453–78.
33. Community Preventive Services Task Force. (2014) The Community Guide. Increasing appropriate vaccination: vaccination requirements for child care, school and college attendance, http://www.thecommunityguide.org/vaccines/RRrequirements_school.html, accessed 18 December 2014.
34. Mullholland, E., Smith, L., Carniero, I., Becher, H. and Lehmann, D. (2008) Equity and child-survival strategies. *Bull World Health Organisation* 86(5): 399–407.
35. Bengtsson, T. and van Poppel, F. (2011) Socioeconomic inequalities in death from past to present: An introduction. *Explorations Economic History* 48(3): 343–356.
36. Ruggles, S., Schroeder, M., Rivers, N., Alexander, J.R. and Gardner, T.K. (2011) Frozen film and FOSDIC forms: Restoring the 1960 U.S. Census of Population and Housing. *Historical Methods* 44(2): 69–78.
37. King, M.L. (2011) A half century of health data for the U.S. population: The integrated health interview series. *Historical Methods* 44(2): 87–93.
38. Tarantola, D. and Gruskin, S. (2003) Human rights approach to public policy. In: M.A. Grodin, D. Tarantola, G.J. Annas and S. Gruskin (eds.) *Health and Human Rights in a Changing World*. New York: Routledge, pp. 43–58.

Appendix

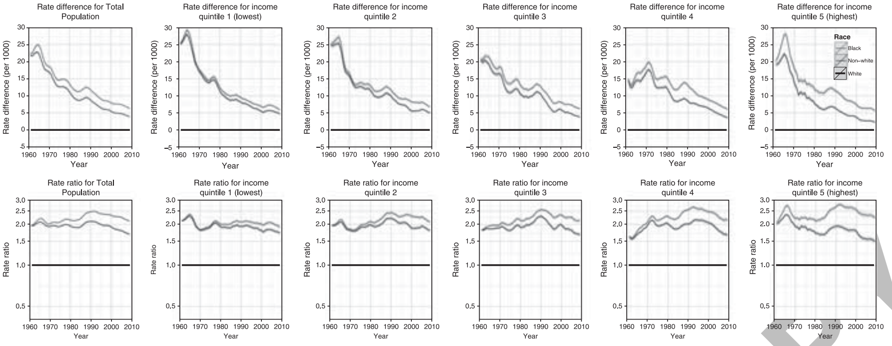

Figure A1: US infant death rates: rate difference and rate ratio, comparing black infants and infants of color to white infants, for the total population and by income quintile, 1960–2010.

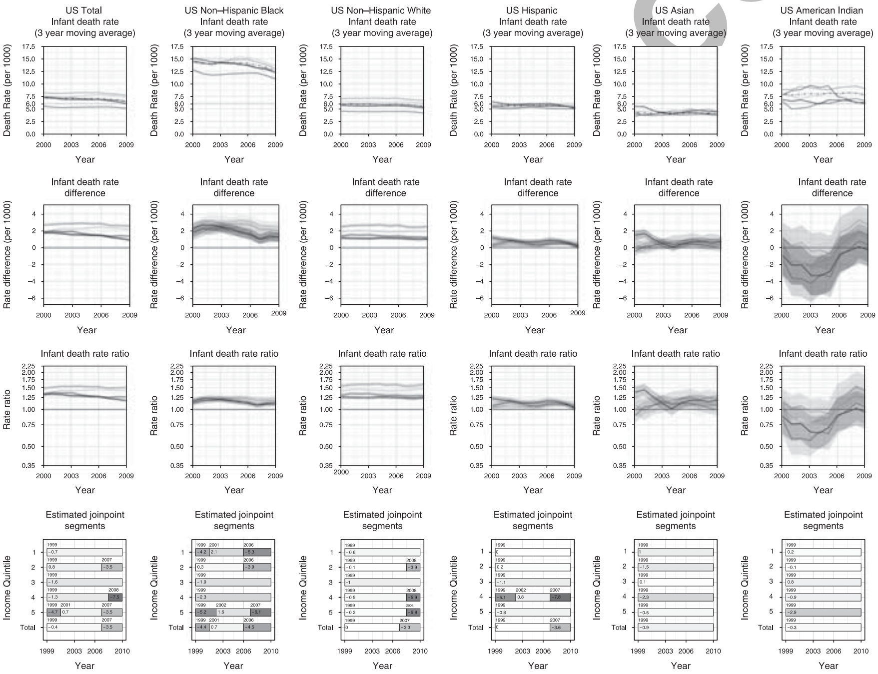

Figure A2: US infant death rates (3-year moving average), and rate difference and rate ratio by income quintile, for the total US population and by race/ethnicity (non-Hispanic black, non-Hispanic white, Hispanic, Asian and Pacific Islander, and American Indian and Alaska Native), 1999–2010.

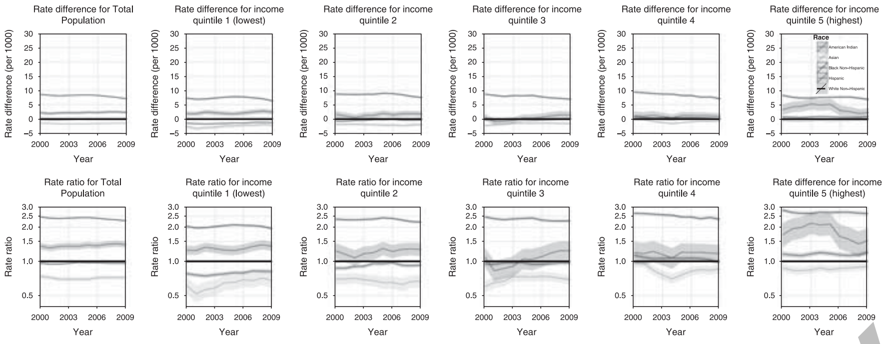

Figure A3: US infant death rates: rate difference and rate ratio, by race/ethnicity (comparing non-Hispanic black, Hispanic, Asian and Pacific Islander, and American Indian and Alaska Native infants to non-Hispanic white infants), for the total population and by income quintile, 1999–2010.

Table A1: US infant deaths and population under age 1, 1960–2010, by race/ethnicity and county income quintile (*N* in 1000s), and per cent distribution

Year	Race/ethnicity	Income Quintile											
		1 (lowest)		2		3		4		5 (highest)		All quintiles (total)	
		N (in 1000s) of deaths and persons<age1											
		Deaths	Persons	Deaths	Persons	Deaths	Persons	Deaths	Persons	Deaths	Persons	Deaths	Persons
1960–2010	Black	203.3	7920.7	150.1	5997.3	134.2	5788.3	134.2	5723.9	77.3	3586.6	699.1	29016.9
	White	359.3	29109.4	377.8	30453.0	370.8	31361.2	361.9	31310.8	291.5	30359.0	1761.3	152596.3
	Total population	573.8	38172.6	534.9	37441.6	513.7	38477.6	508.2	38602.7	383.6	36259.7	2514.2	188959.0
1999–2010	American Indian and Alaska Native non-Hispanic	2.0	215.9	0.8	104.5	0.4	66.3	0.4	64.8	0.3	37.4	3.9	489.7
	Asian and Pacific Islander non-Hispanic	0.7	160.9	1.2	288.4	1.8	449.9	2.2	462.9	3.5	910.3	9.4	2272.4
	Black non-Hispanic	26.1	1845.1	22.3	1513.2	21.3	1560.7	18.0	1292.4	11.1	934.2	98.7	7145.5
	Hispanic	13.0	2363.0	14.4	2464.6	14.3	2582.6	11.9	2048.2	9.7	1881.2	63.2	11339.6
	White non-Hispanic	35.6	5083.8	33.8	5318.4	29.6	5098.0	31.1	5643.1	24.1	5463.5	154.2	26608.0
	Total population	78.2	9668.7	73.0	9689.0	68.1	9757.4	64.2	9511.3	49.2	9226.6	332.7	47855.2
		Per cent distribution											
		%	%	%	%	%	%	%	%	%	%	%	%
1960–2010	Black	35.4	20.7	28.1	16.0	26.1	15.0	26.4	14.8	20.2	9.9	27.8	15.4
	White	62.6	76.3	70.6	81.3	72.2	81.5	71.2	81.1	76.0	83.7	70.1	80.8
	Total population	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1999–2010	American Indian and Alaska Native non-Hispanic	2.5	2.2	1.1	1.1	0.6	0.7	0.7	0.7	0.6	0.4	1.2	1.0
	Asian and Pacific Islander non-Hispanic	0.9	1.7	1.7	3.0	2.7	4.6	3.4	4.9	7.1	9.9	2.8	4.7
	Black non-Hispanic	33.3	19.1	30.5	15.6	31.3	16.0	28.0	13.6	22.6	10.1	29.7	14.9
	Hispanic	16.6	24.4	19.7	25.4	21.0	26.5	18.5	21.5	19.6	20.4	19.0	23.7
	White non-Hispanic	45.5	52.6	46.3	54.9	43.4	52.2	48.5	59.3	49.1	59.2	46.3	55.6
	Total population	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0