Published in final edited form as:
JAMA. 2012 May 16; 307(19): 2060–2067. doi:10.1001/jama.2012.2001.

HIV Development Assistance and Adult Mortality in Africa

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Abstract

Context—The effect of global health initiatives on population health is uncertain. Between 2003 and 2008, the US Emergency Plan for AIDS Relief (PEPFAR), the largest initiative ever devoted to a single disease, operated intensively in twelve African focus countries. The initiative's impact on all-cause adult mortality is unknown.

Objective—To determine whether PEPFAR was associated with relative changes in adult mortality in the countries and districts where it operated most intensively.

Design, Settings, and Patients—Using person-level data from the Demographic and Health Surveys, we conducted cross-country and within-country analyses of adult mortality (annual probability of death per 1,000 adults between 15 and 59 years old) and PEPFAR's activities. Across countries, we compared adult mortality in nine focus countries (Ethiopia, Kenya, Mozambique, Namibia, Nigeria, Rwanda, Tanzania, Uganda, and Zambia) with eighteen non-focus African countries from 1998 to 2008. We performed sub-national analyses using information on PEPFAR's programmatic intensity in Tanzania and Rwanda. We employed difference-in-difference analyses with fixed effects for countries and years as well as personal and time-varying area characteristics.

Main Outcome Measure—Adult mortality.

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Author Contributions: Dr. Bendavid had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Study concept and design: Bendavid, Miller
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Analysis and interpretation of data: Bendavid, Holmes, Bhattacharya, Miller
Drafting of the manuscript: Bendavid, Miller
Critical revision of the manuscript for important intellectual content: Bendavid, Holmes, Bhattacharya, Miller
Statistical analysis: Bendavid, Bhattacharya, Miller
Obtained funding: NA
Administrative, technical, or material support: NA
Study supervision: Bendavid, Miller
The findings and conclusions of this paper are those of the authors and do not necessarily represent the views of the U.S. Department of State.

Financial Disclosures We the authors (Bendavid, Holmes, Bhattacharya, Miller) declare that we have no conflicts of interest.

Previous Presentations This work was presented at the Global Health Conference (November 15, 2011) in Montreal, Canada

Online-only Material Supplementary Appendix and Technical Appendix available at XXX

Results—We analyzed information on 1,538,612 adults, including 60,303 deaths, from 41 surveys in 27 countries, 9 of them focus countries. In 2003, age-adjusted adult mortality was 8.3 per 1,000 adults in the focus countries (95% CI 8.0–8.6) and 8.5 per 1,000 adults (95% CI 8.3–8.7) in the non-focus countries. In 2008, mortality was 4.1 per 1,000 (95% CI 3.6–4.6) in the focus countries, and 6.9 per 1,000 (95% CI 6.3–7.5) in the non-focus countries. We estimate that the odds ratio of mortality among adults living in focus countries compared with non-focus between 2004 and 2008 was 0.84 (95% CI 0.72–0.99, p=0.03). Within Tanzania, the odds ratio of mortality for adults living in districts where PEPFAR operated more intensively was 0.83 (95% CI 0.72–0.97, p=0.02) compared with districts where it operated less intensively..

Conclusions—Between 2004 and 2008, all-cause adult mortality declined more in PEPFAR focus countries relative to non-focus countries. It was not possible to determine whether PEPFAR was associated with mortality effects separate from reductions in HIV-specific deaths. These findings could inform decisions about resource allocation for future development assistance programs.

Introduction

The United States' financial commitment to health improvement in poor countries is at an all-time high. From just over $1 billion dollars in 2000, the US budget for global health in 2009 topped $8.3 billion.[1–3] The majority of this increase was directed assistance for disease-specific initiatives such as the President's Emergency Plan for AIDS Relief (PEPFAR), the President's Malaria Initiative (PMI), and the Global Fund to Fight AIDS, Tuberculosis, and Malaria.[1,3] The largest among these, PEPFAR, targeted the rapidly expanding HIV epidemic with a coordinated effort to increase HIV treatment, prevention, and care in 15 focus countries, mostly in sub-Saharan Africa. PEPFAR scaled-up the delivery of expanded antiretroviral therapy (ART) and supported large scale prevention efforts.[4–7]

While PEPFAR ushered a new era of support for HIV programs in Africa, its impact on population health has been associated with uncertainty. Some argue that assistance for Africa's HIV sector, led by PEPFAR, has siphoned resources and attention from other health priorities, possibly resulting in worsening health outcomes.[8] One prior analysis found that PEPFAR was associated with a reduction in HIV-specific mortality.[9] Beyond HIV, however, PEPFAR's impact remains mostly unknown. Some found evidence to suggest that HIV development assistance displaced funding for other health priorities[10]; other studies failed to find evidence to support the view that PEPFAR's investments crowded out other health measures such as child health or antenatal care.[11–13] Whether or not the unprecedented influx of funds for scaling-up HIV treatment and prevention programs was associated with changes in all-cause adult mortality has not been demonstrated.

The relationship between PEPFAR's activities and population health has important policy implications. Limited global health budgets, PEPFAR's expansion to more than a dozen additional countries, and reorganization of US global health aid may signal important changes in the funding environment for HIV programs.[3,14,15] Understanding the association between PEPFAR and population health outcomes is therefore an important input to the policy-making process with implications for the health of many in sub-Saharan Africa. We study the relationship between PEPFAR's implementation and differential trends in adult mortality, and further explore whether or not these trends suggest spillover benefits or unintended harms beyond HIV-related mortality.

Methods

We performed two parallel analyses of changes in adult mortality in areas that received more compared with less PEPFAR support: a cross-country analysis, and sub-national analyses within Tanzania and Rwanda. Sub-national analyses complemented the cross-country analysis by removing some unobserved differences.[16] We chose adult mortality because of its broad importance to population health and because it allowed a comparison with HIV-specific mortality.[17] Methodological and data advances allowed us to analyze adult mortality using individual and household information.[18]

Adult Mortality Data

We created a longitudinal dataset using person-level information from the Demographic and Health Surveys (DHS). These nationally representative surveys are conducted approximately every five years in many low- and middle-income countries by IFC Macro in collaborations with in-country partners. Survey households are chosen using a 2-stage sampling process where representative clusters are selected from a national sampling frame, and a random sample of households is selected within each cluster. In each household, women between 15 and 49 years old who consented were interviewed. Sampling was independently repeated in each survey wave. Response rates were greater than 90% in 36 of the 41 surveys, and never lower than 85%.[19,20] We used information on sibling survival provided in the “Maternal Mortality” module. In this module, index women respondents were asked about all children born to their biological mother, including the age of each living sibling and the date and age at death for each deceased sibling. Using this information we constructed a longitudinal cohort with repeated observations for each adult sibling (excluding the respondent), indicating whether or not they died during each year that he or she lived between ages 15 and 59. We omitted survey years because of their incomplete observations period. The Technical Appendix includes additional information about the data structure and manipulation.

We used information from all but one African DHS surveys conducted after 1998 with maternal mortality modules, yielding a sample from 27 countries, 9 of them (italicized) PEPFAR focus countries: Benin, Burkina Faso, Cameroon, Chad, Congo, Democratic Republic of the Congo, *Ethiopia*, Gabon, Guinea, *Kenya*, Lesotho, Liberia, Madagascar, Malawi, Mali, *Mozambique, Namibia*, Niger, *Nigeria, Rwanda*, Senegal, Sierra Leone, Swaziland, *Tanzania, Uganda, Zambia*, and Zimbabwe. We excluded Nigeria's 1999 survey because of questionable data validity.[21] Fieldwork for the surveys used was conducted between November, 1998 and May, 2010. We included information on all siblings with complete survival information between 1998 and 2008, inclusive (Table 1). Sibling survival information for Tanzania and Rwanda were also used in sub-national analyses.

PEPFAR Program Intensity

PEPFAR's selection criteria for focus countries were not explicit, but appeared to be related to HIV prevalence, the focus countries' governmental commitment to fighting HIV, administrative capacity, and a willingness to partner with the U.S. government and non-governmental implementers. Country choice, however, is only partially explained by observed factors. For example, Ethiopia was selected despite a low HIV prevalence compared with many African countries (2%), while Malawi was not selected despite a high burden and responsive government. Thus, selection as a focus country, while not random, did not, ex ante, suggest straightforward differential trends in mortality among the focus countries. In the cross-country analyses, we compared focus countries with non-focus African countries.

Within-countries, we obtained information on the location of PEPFAR-supported clinics and the number of patients receiving PEPFAR-supported ART by clinic (available by request). This information was only available for Rwanda and Tanzania. We analyzed information for both countries' major administrative divisions, 22 regions in Tanzania and 30 districts in Rwanda (we use “district” throughout in this context). Using this information, we calculated two measures of district-level program intensity: the annual number of people newly starting ART per capita in the district, and the annual number of people starting ART per PEPFAR-supported clinic in the district. We then evaluated mortality in districts with above-median PEPFAR-supported programmatic activity compared with below-median districts.

Statistical Analysis

We used logistic regression and a difference-in-difference study design to estimate how the odds of death for adults (defined as men and women ages 15 to 59) living in focus countries changed during PEPFAR's implementation relative to those who lived in non-focus sub-Saharan countries.[22,23] The difference-in-difference design estimates the relative change in mortality over time associated with PEPFAR as the difference of two differences: the mortality difference between the focus and non-focus groups of countries, and the difference in mortality before and after PEPFAR's implementation within each group. This design is well-suited for policy evaluations by isolating effects where the policy was implemented compared to “controls” (non-focus countries) and to pre-existing trends. Additional details are available in the Technical Appendix.

We used a parallel analytic framework within Tanzania and Rwanda. We identified PEPFAR's programmatic intensity at a district level, and compared those districts with above-median programmatic intensity to those with below-median intensity. Throughout, we considered calendar year 2004 to be the first full year of PEPFAR activities.

The main outcome variable was a binary indicator of whether or not an adult who was alive for any part of a year died during the year of observation. The main parameter of interest was the coefficient on an indicator of whether the person lived in a focus country during PEPFAR's implementation. All models included year and country (or district) fixed effects, which control for fixed unobserved differences across countries (or districts) and for changes over time that are common to all countries (or districts). Adjusted analyses also included individual characteristics (sibling age in years, recall period between the year of survey and year of observation, and the index woman's education and place of residence) and time-varying country characteristics (HIV prevalence,[24] per-capita development assistance for health from all sources other than PEPFAR,[2] gross domestic product (GDP) per capita,[25] and an index of government effectiveness from the World Governance Indicators[26]). Our specified threshold of significance was $p<0.05$, and all tests were 2-sided. We calculated robust standard errors clustered by country to relax the assumption of independent and identically-distributed errors within countries.[22]

Adult and HIV-specific Deaths Averted

To examine the possibility of mortality spillovers associated with PEPFAR, we computed the implied number of all-cause adult deaths averted from 2004 to 2008 and an estimate of HIV-specific deaths averted in the same focus countries over the same time period obtained from modeled data. The number of all-cause adult deaths averted was estimated using a 3-step process. First, we predicted the probability of death for all individuals in the focus countries between 2004 and 2008 (inclusive) using the main adjusted regression coefficients for two scenarios: an “actual” scenario where PEPFAR was implemented, and a “counterfactual” scenario where it was not implemented. We then calculated the mortality benefit associated with PEPFAR as the mean of the difference between the two scenarios for

each focus country between 2004 and 2008. Finally, we estimated the number of deaths averted by multiplying that difference by the size of the adult population. This approach relies on the regression parameters to estimate the mortality counterfactual in the absence of PEPFAR.

We calculated the number of HIV-specific deaths averted using previous estimates of PEPFAR's HIV-specific mortality benefits.[9] This approach relied on estimates of HIV-specific deaths provided by epidemiologic models developed by the Joint United Nations Programme on HIV/AIDS (UNAIDS). The annual reduction in HIV-specific deaths of 10.5% (95% CI 4.4–16.6%) was used to calculate the counterfactual estimate of HIV-specific deaths among adults 15 and older. Additional details are available in the Technical Appendix.

Additional sensitivity analyses are available in the Supplementary Appendix. These include repeating the analysis while leaving out each country in turn, with only those countries whose data spans the year 2004 (the first full year of PEPFAR's implementation), with only the most recent survey for each country, with only those countries whose data extends at least through 2007, and using linear time trends. The study was deemed Exempt by Stanford's Institutional Review Board. All analyses were done using STATA 11.2 (Statacorp, College Station, TX).

Results

Cross-country Analyses

We assembled data on 1,538,612 adult Africans collected from 41 surveys conducted in 27 countries between 1998 and 2008 (8,943,676 person-years of observation). During this time period, 60,303 deaths were captured in the DHS surveys used in this study. Table 1 shows the survey dates, number of adults, and number of deaths by country. Group comparisons (Table 2) show that in 1998, mean HIV prevalence was 8.1% in the focus countries and 6.5% in the non-focus countries (p=0.62); mean HIV development assistance per person living with HIV was $3.8 in focus counties and $6.3 in non-focus countries (p=0.55). By 2008, mean assistance was $171.0 per person living with HIV in focus countries and $76.9 in non-focus countries (p=0.007). Trends in HIV assistance per country, shown in Figure 1, exhibit an accelerating separation between the focus and non-focus countries from 2004 to 2008.

Annual age-adjusted all-cause adult mortality aggregated for the focus and non-focus countries is shown in Figure 2. The figure shows relatively greater mortality declines among adults living in focus countries between 2004 and 2008. The figure shows that adult mortality in the focus countries declined from 8.30 per 1,000 adults (95% CI 8.04–8.57) in 2003 to 4.10 per 1,000 (95% CI 3.60–4.61) in 2008. The mortality trends in non-focus countries did not show a similar decline during the study period.

These divergent trends under PEPFAR are also reflected in the regression analyses. Our unadjusted analyses suggest that between 2004 and 2008 (under PEPFAR), the odds ratio of death among adults living in focus countries was 0.80 (95% CI 0.68–0.95, p=0.01) compared with adults living in non-focus countries (Table 3). After adjustments for country-level and personal characteristics, the mortality odds ratio was 0.84 (95% CI 0.72–0.99, p=0.03). Each 1% increase in HIV prevalence was associated with an odds ratio for death of 1.07 (95% CI 1.01–1.14, p=0.03), and each 1-point increase in the government effectiveness index was associated with an odds ratio for death of 0.58 (95% CI 0.38–0.89, p=0.01). Age of the observed sibling showed a positive association with mortality (OR 1.05 per year, 95% CI 1.04–1.05, p<0.001), while the index woman's education and residence in an urban

environment were negatively associated with mortality (OR 0.98 per year of education, 95% CI 0.98–0.99, p=0.01; and OR 0.94 for living in urban environment, 95% CI 0.89–0.99, p=0.05). GDP per capita and non-PEPFAR development assistance for health were not associated with adult mortality.

To explore the possibility that pre-existing trends account for the differential decline among the focus countries, we interacted year dummies with the focus country indicator. We observed higher odds of death in the focus countries (relative to non-focus countries) prior to PEPFAR. The onset of the program, however, was associated with a decline in mortality relative to the pre-existing trend (Figure A1: Odds of death when using year relative to program initiation as the main predictor variable), consistent with an increasing treatment availability over time in these countries.

Sub-national Analyses

District-level data for Tanzania and Rwanda is shown in the Supplementary Appendix (Table A1: Baseline characteristics of administrative regions in Tanzania and Rwanda). High and low PEPFAR activity districts had similar populations, but program intensity was significantly different between the groups. We examined district-level changes in adult mortality in areas with low and high programmatic activity using the same framework employed in the cross-country analysis. Figure 3 shows adult mortality in Tanzania by two groups of districts: above-median and below-median PEPFAR-supported ART per capita. The mortality odds ratios among adults living in the regions with above-median PEPFAR intensity compared with adults living in regions with below-median intensity between 2004 and 2008 were 0.83 (95% CI 0.72–0.97, p=0.02) in Tanzania and 0.75 (95% CI 0.56–0.99, p=0.04) in Rwanda (Table A2: Odds ratios of mortality within Tanzania and Rwanda).

Spillover Mortality Effects

Using the results for each focus country and generalizing to the size of each country's adult population, we estimate a total of 740,914 all-cause adult deaths were averted (95% CI 443,318–1,808,601) between 2004 and 2008 in association with PEPFAR. In comparison, PEPFAR was associated with an estimated 631,338 (95% CI 249,026–1,060,253) HIV-specific deaths averted during the same period.[9]

Sensitivity Analyses

We re-analyzed the data to explore the results' robustness. The Supplementary Appendix shows that leaving out any one country, analyzing only those countries with data both before and after the implementation of PEPFAR, restricting the sample to only the most recent survey, and limiting the analysis to only those countries with data up to 2007 resulted in some loss of power but consistent direction and magnitude of the main effect.

Comment

We provide robust evidence that PEPFAR has been associated with a decline in all-cause adult mortality in the African countries where it operated most intensively. Our study utilizes direct evidence from surveys and individual-level reports of mortality. Sub-national analyses in Tanzania and Rwanda yield broadly consistent findings. Although the evidence for positive, negative, or no spillovers with respect to adult mortality is inconclusive, we note that overall, PEPFAR had been associated with improvements in adult mortality. As discussions about the role of US involvement in global health activities evolve, the implications and limitations of these findings deserve further consideration.

Several possible factors may have contributed to PEPFAR's apparent success. First, PEPFAR's investment has been larger than any previous commitment for a single disease. Development assistance for health has grown from about 4% of US development assistance in 1999 to over 20% by 2008, and PEPFAR accounts for a large share of this growth.[1] Second, PEPFAR's structure was unusual, with its implementation relying on experienced non-governmental organizations and academic centers that were rewarded for reaching aggressive coverage targets. Finally, PEPFAR's comprehensive approach to scaling up treatment programs enabled a cogent set of related activities such as antiretroviral procurement processes and supply chain management.

Our estimates of all-cause adult deaths averted and HIV-specific deaths averted are consistent with either positive, negative, or no spillovers mortality effects associated with PEPFAR. Although the point estimate of the reduction in all-cause adult deaths is larger than the estimated reduction in HIV-related deaths, the confidence limits overlap broadly. The HIV-specific mortality benefits associated with PEPFAR were obtained from modeled estimates, making their direct comparison to all-cause mortality benefits uncertain.

The study's measurements and findings uniquely strengthen the topic's evidence base. A previous study concluded that PEPFAR was not associated with changes in adult mortality.[12] That study, however, relied on more aggregated data from the years 2000 and 2006, limiting its ability to detect relative changes within the study period and not studying benefits that evolved more slowly over time (emerging after 2006, for example). Another study relied on modeled data to estimate mortality benefits, with lingering concerns about data validity.[9,27] Our use of individual-level data over a longer period of time improves upon these limitations and advances the understanding of factors associated with adult mortality. We find that education of the index woman is associated with lower adult mortality. While the literature on the health benefits of personal education is extensive, we show that this effect is additionally present in siblings.[28,29] We also find that a measure of government effectiveness suggests mortality is lower in countries with better governance. While the association between governance and indicators of population health such as child mortality has been previously demonstrated, its association with adult mortality has not been well established.[30]

Our findings are also notable for the consistent association between HIV development assistance and improvements in population health when many studies of development assistance programs fail to find meaningful changes in targeted outcomes.[31,32] Other examples where assistance was associated with its intended goals have also been in the health arena, including smallpox eradication and control of polio.[33,34] PEPFAR's success with HIV, however, may be the clearest demonstration of aid's effectiveness in recent years.

Our study has several limitations. First, other factors that coincide with PEPFAR's timing and geographic activity may confound the analysis. Notably, a different epidemic phase between the focus and non-focus countries could lead to earlier mortality declines in focus countries unrelated to PEPFAR. Our range of sensitivity analyses investigate this possibility, but we cannot fully rule out the possibility of phase offset. A successful treatment campaign, however, can alter the epidemic phase, maintaining the possible role played by PEPFAR in adult mortality improvements. Second, past work has shown that adult mortality estimation from surveys is biased by imperfect recall and under-representation of high-mortality families.[18,35] Bias could also be introduced if adult mortality is underestimated in countries with high HIV mortality because of selection against sibships with HIV-infected index women. However, previous analyses suggest that the bias is approximately constant over time, limiting its role in this analysis.[18] Third, not all the focus countries were included in this study. Botswana, South Africa, and Côte d'Ivoire did not have suitable data for this

analysis – and the conclusions cannot therefore be generalized to all focus countries. Botswana and South Africa, in particular, carry a heavy HIV burden, and their omission could change PEPFAR's overall effect, though the direction of change is unclear. Fourth, our sub-national analyses cannot fully overcome the concern over unobserved confounders. Finally, we assumed that all siblings live within the same urban/rural environment as the index woman, as well as the same country (for cross-country analysis) or district (for sub-national analyses). We do not have evidence for or against this assumption's validity.

Overall, we provide new evidence suggesting that reductions in all-cause adult mortality were greater in PEPFAR's focus countries relative to the non-focus countries over the time period between 2004 and 2008. Our analysis suggests an association of PEPFAR with these improvements in population health. These benefits could have important implications for other domains of human welfare.[36–39]

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Funding/Support Dr. Bendavid is supported by the National Institute of Allergy and Infectious Diseases (K01-AI084582) and by the Dr. George Rosenkranz Prize for Health Care Research in Developing Countries. Dr. Miller receives support from the National Institute of Child Health and Development, the National Institute of Aging. Both received support from the Center on the Demography and Economics of Health and Aging (P30-AG17253).

Role of the Funding Organization or Sponsor The funding agencies had no part in the design and conduct of the study; collection, management, analysis, and interpretation of the data; and preparation, review, or approval of the manuscript.

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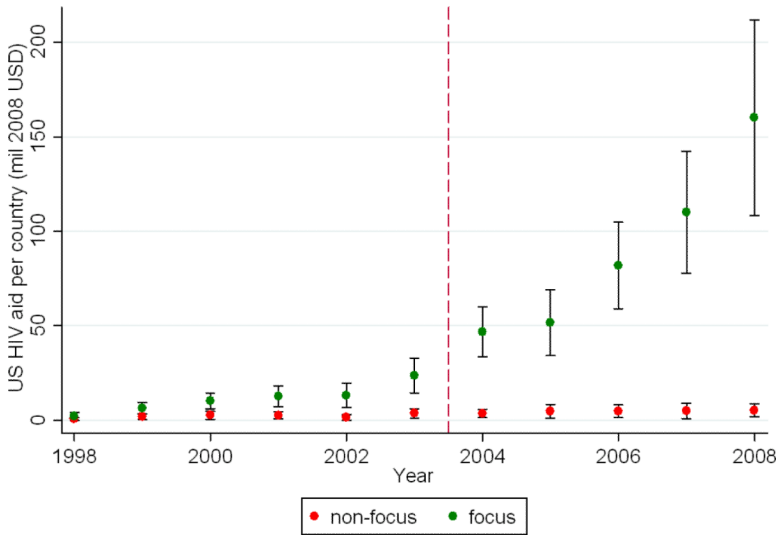

Figure 1.

Average annual development assistance for HIV (and 95% confidence intervals) from the Institute for Health Metrics and Evaluation database to the focus countries (green) and non-focus countries (red) in 2008 USD, 1998–2008. A preferential rise in assistance to the focus countries is seen between 2003 and 2004. The year 2004 was PEPFAR's first year of implementation, indicated by the dashed vertical line.

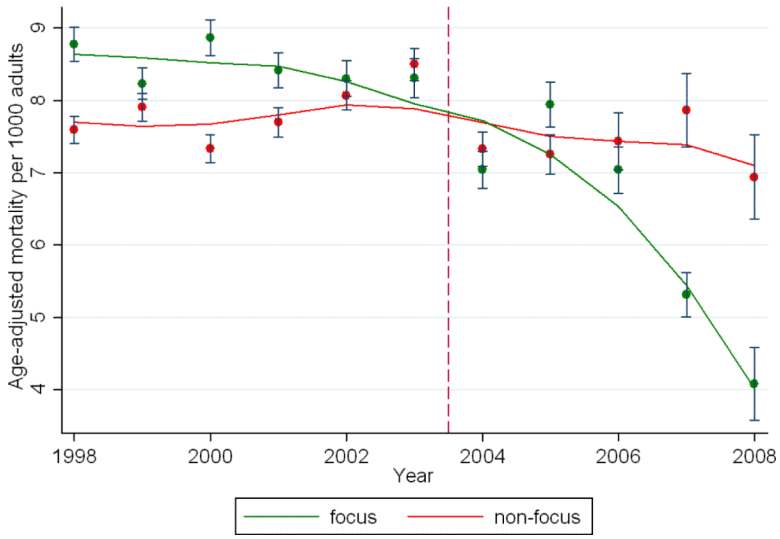

Figure 2.

Age-adjusted adult mortality trends in the study countries, separated by country group, 1998–2008. Each point represents the probability that an adult between 15 and 59 years old died during the year per 1,000 adults alive for any part of the year. UN Population Division age-structured population estimates for each country were used for age-adjustments. Age weights were calculated in 5-year age categories from 15–59 (9 age categories). These weights were then used to adjust the crude mortality for each country-year-age group, and the point estimates represent the adjusted total. The Figure shows mortality declines were greater in the focus countries starting in 2004. A narrow-bandwidth (0.6) lowess curve is used to fit the trend, and 95% confidence interval bars are shown around each annual estimate. Lowess (locally weighted scatterplot smoothing) is a non-parametric method of fitting a curve using local regressions for each point. The dashed vertical line divides the time period into a baseline period prior to PEPFAR, and a period of implementation starting in 2004.

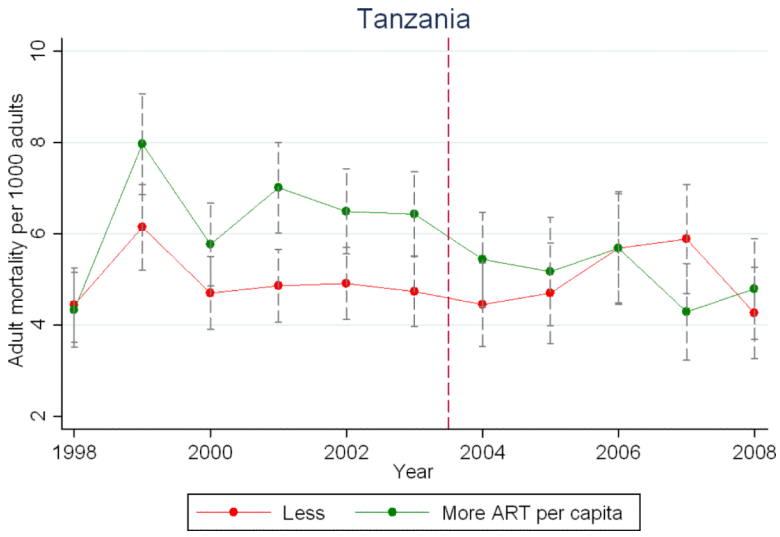

Figure 3.

Adult mortality trends within Tanzania, separated by PEPFAR activity from 1998 to 2008. Intensity of PEPFAR's activities is measured as the number of people receiving PEPFAR-supported ART per capita in the region (above and below median ART per capita are represented as More and Less in the figure, respectively). 95% confidence interval bars are shown around each annual estimate. Additional figures showing trends by clinic size (number on ART per clinic) for Tanzania and Rwanda are in the Supplementary Appendix. The dashed vertical line divides the time period into a baseline period prior to PEPFAR, and a period of implementation starting in 2004.

Table 1

Study countries, participants, and group designation

Country	Survey fieldwork dates	# of unique adults	Observations	# of deaths
Focus Countries				
Ethiopia	2–5/2000, 4–8/2005	96,980	391,835	2,596
Kenya	4–9/2003, ll/2008–2/2009[a]	73,580	491,521	2,971
Mozambique	8/2003–1/2004	41,103	189,752	1,367
Namibia	9–12/2000, 10/2006–3/2007	64,382	340,338	3,303
Nigeria[b]	6/10/2008	122,815	1,020,435	4,590
Rwanda	6–8/2000, 2–7/2005	74,818	316,179	2,943
Tanzania	10/2004–2/2005, 12/2009–5//2010[a]	83.992	615,367	2.993
Uganda	9/2000–3/2001,4–10/2006	62,132	301,234	2,856
Zambia	11/2001–5/2002, 4/2007–1/2008	60,014	328,837	4,228
Non-focus countries				
Benin	8/11/2006	64,463	449,155	1,703
Burkina Faso	11/1998–3/1999,6/2003	55,416	206,068	1,123
Cameroon	2/8/2004	41,422	222,637	1,550
Chad	7/12/2004	20,891	111,943	736
Congo	1/11/2005	28,305	175,576	1,323
Congo Dem Rep	1/8/2007	38,637	295,800	1,887
Gabon	7/2000–1/2001	22,083	43,671	210
Guinea	5–7/1999, 2–6/2005	44,848	177,877	977
Lesotho	9/2004–1/2005,10/ 2009–l/2010[a]	47,185	334,908	4,428
Liberia	12/2006–4/2007	23,052	178,489	842
Madagascar	11/2003–3/2004, 11/2008–8/2009[a]	107,869	844,146	3,509
Malawi	7–11/2000, 10/2004–1/2005	84,041	305,436	3,945
Mali	1–5/2001,5–12/2006	92,775	470,612	2,161
Niger	1/5/2006	34,858	243442	942
Senegal	2/5/2005	55,881	347,114	1,096
Sierra Leone	4/6/2008	19,675	165,810	891
Swaziland	7/2006–2/2007	18,458	128,135	1,739
Zimbabwe	9–12/1999,8/2005–2/2006	58,937	247,359	3,394

[a]The fieldwork for these surveys was carried out after the end of the study period at the end of 2008. However, no data more recent than the end of 2008 is used in this study.

[b]Another DHS survey with data on adult mortality was conducted in Nigeria in 1999. However, the survey's data quality was shown to be poor, and we did not include the survey in the analysis.

Table 2

Comparison of focus countries and non-focus countries with each other and with non-study Sub-Saharan countries

Parameter		Focus countries, mean (95% CI)	Non-focus countries, mean (95% CI)	p-value[a]	Other Sub-Saharan Countries[b], mean (95% CI)	p-value[c]
Population (millions)[40]						
	1998	33.6(5.1–62.1)	9.8(4.5–15.0)	**0.02**	10.3(2.9–17.7)	0.35
	2008	43.4(7.8–79.0)	12.8(5.9–19.8)	**0.01**	13.6(4.8–22.4)	0.30
HIV prevalence among adults 15–49 years old (%)[24]						
	1998	8.1(5.0–11.2)	6.5(2.0–11.0)	0.62	5.0(1.1–8.9)	0.41
	2008	7.5(3.9–11.0)	5.8(1.9–9.8)	0.57	5.0(1.0–9.1)	0.56
GDP per capita (constant $)[25]						
	1998	471.3(98.6–844.1)	641.8(98.7–1,184.8)	0.67	767.2(152.6–1,381.9)	0.58
	2008	629.1(115.1–1,143.1)	654.5 (180.3–1,128.8)	0.95	995.1(148.4–1,841.8)	0.34
HIV aid per country (mil $)[2]						
	1998	6.3(0.0–14.6)	2.0 (−0.1–4.2)	0.16	1.8(0.9–2.7)	0.25
	2008	240.4(168.7–312.3)	24.6(10.2–39.1)	**<0.001**	63.1 (−6.1–132.4)	0.37
HIV aid per adult with HIV ($)[2,24]						
	1998	3.8(1.8–5.7)	6.3(0.2–12.3)	0.55	18.4(0.6–35.1)	0.11
	2008	171.0(75.8–266.3)	76.9 (54.9–98.9)	**0.007**	113.1(40.7–185.6)	0.89
Antiretroviral coverage (%)[24]						
	2003	2.6 (−2.1–7.4)	1.9 (−3.1–7.2)	0.46	1.9 (−2.6–6.5)	0.68
	2008	55.6(38.3–73.6)	28.6(16.1–41.2)	**0.04**	39.6(26.6–52.5)	0.51
Urban residence (%)[25]						
	1998	24.0(15.8–32.2)	33.7(25.4–42.0)	0.13	38.1(29.6–46.5)	0.45
	2008	28.1(19.0–37.2)	38.0(29.1–46.9)	0.15	42.4(33.5–51.3)	0.43

[a] p-values provided from 2-tailed t-tests on data for the specified year in the focus countries compared with the non-focus countries.

[b] Sub-Saharan countries not included in this study are: Angola, Central African Republic, Burundi, Djibouti, Eritrea, Somalia,Sudan, Botswana, South Africa, Cote d'Ivoire, Ghana, Guinea-Bissau, The Gambia, and Togo

[c] p-values provided for the comparison between the aggregated estimates for all 27 study countries (focus and non-focus countries) and the sub-Saharan countries not included in the study (listed above). This comparison provides a comparison between the counties excluded from the study and those included along the observed metrics.

Table 3

Regression models estimating the odds ratio of death among study adults

	Unadjusted (95%CI, p-value)[a]	Adjusted with country covariates (95% CI, p-value)	Adjusted with country and personal covariates (95% CI, p-value)
Adult death[b]	0.80(0.68–0.95, 0.01)	0.83(0.72–0.95, 0.01)	0.84(0.72–0.99, 0.03)
HIV prevalence (per additional 1%)		1.07(1.01–1.14, 0.03)	1.07(1.01–1.14, 0.03)
Non-PEPFAR assistance[c]		0.99(0.96–1.01, 0.24)	0.99(0.96–1.02, 0.61)
GDP per capita (per additional $1)		1.00(1.00–1.00, 0.65)	1.00(0.99–1.01, 0.58)
Government effectiveness (per 1-point increase)[d]		0.62 (0.41–0.95, 0.03)	0.58(0.38–0.89, 0.01)
Sibling age (per year)			1.05 (1.04–1.05, <0.001)
Residence in urban area[e]			0.94(0.89–0.99, 0.05)
Education (per additional year)[e]			0.98(0.98–0.99, 0.01)
Recall (interval between survey and observation, per year)			0.97(0.95–0.99, 0.006)

[a] All results are exponentiated coefficients on parameters in logistic regression models. Unadjusted model includes the main effect as well as country and year fixed effects. All confidence intervals are calculated using robust standard errors clustered by country.

[b] These odds ratios represent the relative reduction in mortality among adults living in the focus countries while PEPFAR was implemented compared with adults living in non-focus countries.

[c] All development assistance for health from all donors minus US-funded HIV development assistance, per capita[2]

[d] The Index is centered at 0 and each 1-point represents 1 standard deviation, with higher numbers representing greater government effectiveness.[26]

[e] These variables are characteristics of the index woman rather than the sibling. The residence status and educational status of the sibling are not known.