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Article

The socio-economic distribution of exposure to Ebola: Survey evidence from Liberia and Sierra Leone

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A B S T R A C T

Socio-economic factors are widely believed to have been an important driver of the transmission of Ebola Virus Disease (EVD) during the West African outbreak of 2014–16, however, studies that have investigated the relationship between socio-economic status (SES) and EVD have found inconsistent results. Using nationally representative household survey data on whether respondents knew a close friend or family member with Ebola, we explore the SES determinants of EVD exposure along individual, household, and community lines in Liberia and Sierra Leone. While we find no overall association between household wealth and EVD exposure, we find that pooled data mask important differences observed within countries with higher wealth households more likely to have been exposed to EVD in Sierra Leone and the opposite relationship in Liberia. Finally, we also generally find a positive association between education and EVD exposure both at the individual and the community levels in the full sample. There is an urgent need to better understand these relationships to examine both why the outbreak spread and to help prepare for future outbreaks.

1. Introduction

The West African outbreak of Ebola Virus Disease (EVD) of 2014-16 was the most devastating outbreak of the virus on record with more than 28,000 cases and 11,000 deaths (World Health Organization, 2016). It is believed that the outbreak began with a single case in a boy in rural Guinea in late 2013, but due to a slow initial response (Grépin, 2015; International Ebola Response Team et al., 2016), the virus spread quickly to both rural and urban communities throughout Guinea, Liberia, and Sierra Leone. While the outbreak was largely contained by early 2015, it was not before it had significant economic and social effects in the heavily affected countries (Bowles, Hjort, Melvin, & Werker, 2015; World Health Organization, 2016).

Many lessons have been learned about EVD as a result of the West African outbreak, including a much better understanding of the zoonotic origins of the disease and the development of vaccines against the virus. But while biology may help to explain why EVD emerged in Guinea, it is ultimately the social, behavioral, and environmental factors that explain why outbreaks spread and become epidemics (Heymann, 2005). Ebola has been described as a “disease of social intimacy”, in that it is mainly transmitted from infected patients to others through intimate social interactions (Richards et al., 2015): to loved ones who are tasked for caring for the sick, to front line health workers that have been tasked with saving those fighting for their lives, and to community members when tasked with burying the remains of those that they have lost. Poverty has also been implicated as an important determinant of EVD (Fallah, Skrip, Gertler, Yamin, & Galvani, 2015). However, many factors likely contributed to the transmission of the virus in West Africa and to date there has been little formal evaluation of these relationships. Since the West African outbreak, three Ebola outbreaks have already been reported in the Democratic Republic of the Congo (DRC), including one outbreak that at the time of the writing of this article had already become the second largest outbreak of the disease in history. A better understanding of the determinants of EVD exposure is therefore important not just to understand why the outbreak spread so widely and so quickly throughout West Africa but also from the perspective of preparing for future epidemics (Phua & Lee, 2005).

A sizeable literature has established that SES, whether it is measured as wealth, income, or related indicators, is an important determinant of health (Feinstein, 1993; Marmot, 2007a). In almost all cases, people or populations of higher SES enjoy longer and healthier lives, both through lower levels of exposure to risk factors and better ability to recover when ill. Although the bulk of the literature has focused on high-income countries, similar associations have also been documented in low and

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middle-income countries (LMICs), including countries in Africa (Amouzou & Hill, 2004; Marmot, 2007b). Social epidemiologists usually distinguish between diseases associated with relative poverty, which has to do with a person's comparative economic position in society, and absolute poverty, which has to do with a person being deprived of basic needs such as running water, sanitation systems, and adequate nutrition (Marmot, 2005). Infectious diseases, especially those that contribute to higher rates of child mortality in LMICs, and which help to explain much of the gap in life expectancy observed between high-income and LMICs, are largely believed to be associated with conditions of absolute poverty (Marmot, 2005). Non-communicable diseases (NCDs), which are believed to be largely caused by behavioral factors, also form along SES gradients such that lower SES groups also develop a higher burden of disease relative to higher SES groups. By contrast, these health gradients are theorized to form as a consequence of greater knowledge, prestige and power being concentrated among higher SES groups allowing them to reduce their exposure to risk factors and to gain access to more effective health services when ill (Link & Phelan, 1995).

However, less is known about the association between SES and the so called emerging infectious diseases (EIDs) with epidemic potential, including EVD but also Zika, SARS, and MERS. At the country level, poorer countries are generally thought to have higher rates of these diseases. EVD and Zika seem to follow this pattern as they first emerged in low-income countries (DRC and Uganda respectively) thus supporting the view that absolute poverty may be an important determinant of exposure to these viruses. However, SARS and MERS were both first detected in relatively well-off countries, Hong Kong and Saudi Arabia respectively, suggesting a more complex relationship may exist between SES and infectious disease exposure the population level.

One pathway that may lead to increased exposure to these diseases is proximity to the sources of the viruses. In the case of EVD, bats are the likely zoonotic reservoirs, which are common in sparsely populated, forested areas of Africa (Pigott et al., 2014). For SARS, civets and bats have been identified as likely reservoirs of the virus (Shi & Hu, 2008). For MERS, bats and camels have been identified as zoonotic reservoirs (Mohd, Al-Tawfiq, & Memish, 2016). Therefore, for EVD and other EIDs, exposure is likely related to ecological factors, such as vegetation, elevation, temperature that bring communities into contact with the zoonotic reservoirs and vectors of the viruses. For EVD, exposure would likely be higher in populations and communities located poorer parts of Africa. We illustrate this pathway, as well as additional pathways we discuss below in a conceptual model to help conceptualize how various SES determinants may lead to EVD exposure in Fig. 1. Increased exposure may also be due to higher rates of international travel among some relatively higher income countries, or some communities (Bogoch et al., 2014). This explanation may help to explain why EVD eventually spread to countries in Europe and the United States and may have played some role in the spread of the outbreak within West Africa, including the spread to Nigeria.

A number of studies have also explored determinants of EIDs at the sub-national level. For example, a study from Brazil found that cases of Zika were more common in neighborhoods in Rio that were less likely to be connected to the municipal water source (Fuller et al., 2017). A study of the spread of SARS in Hong Kong found a negative relationship between income and incidence rates across estates in the special administrative region (Bucchianeri, 2010). We posit that these associations may be due to access to infrastructure or compositional effects, in which lower wealth communities due to poorer infrastructure and overcrowding within urban centers may be at higher risk of being exposed to disease. In the case of EVD in West Africa, a number of studies have found evidence to support these associations. For example, one study in Montserrado County, a largely urban county where the Liberian capital of Monrovia is located, found that infected individuals from low SES areas were more likely to have more contacts and were more likely to have been linked to secondary cases of EVD (Fallah et al., 2015). Another study that classified sub-districts in Liberia in terms of their social vulnerability found the sub-districts with the highest measures of social vulnerability also had the highest number of reported cases of EVD (Stanturf, Goodrick, Warren, Charnley, & Stegall, 2015). However, the capital Montserrado county, which also scored low in terms of social vulnerability, was an exception as it also had a large number of cases, perhaps due to its larger urban population. In addition, another study

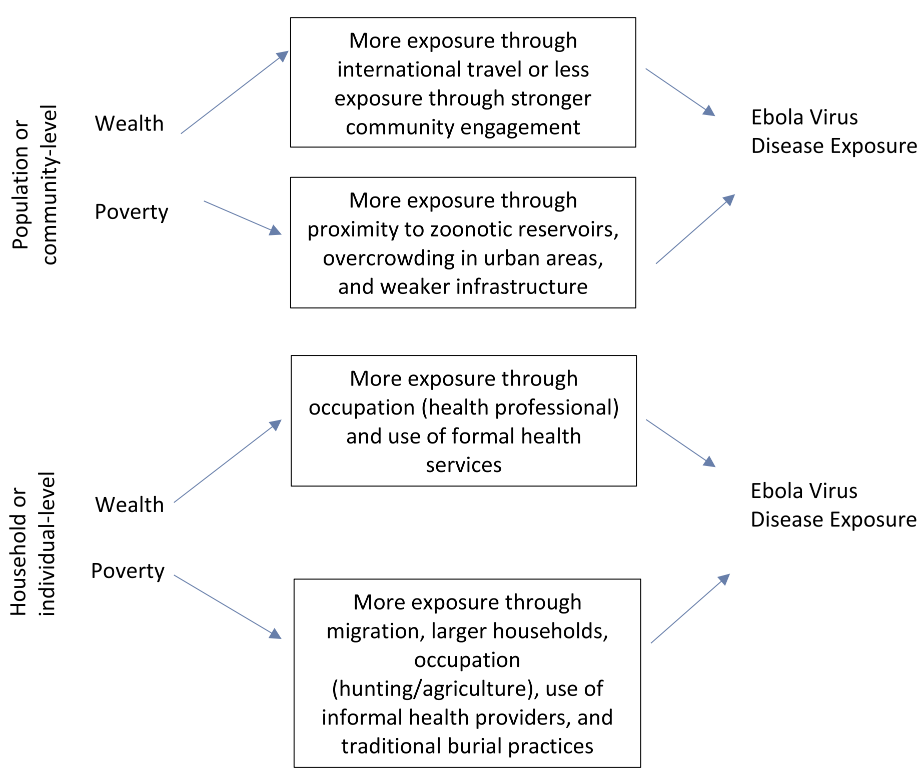

Fig. 1. Conceptual model of pathways between SES and increased EVD exposure.

that compared measures of population density and wealth index found that both were positively associated with the transmission rate of the virus at the district-level across West Africa (Krauer, Gsteiger, Low, Hansen, & Althaus, 2016). Similarly, another study found that population density and education, both measured at the regional-level, were also both positively associated with epidemic size and spread across West Africa (Valeri et al., 2016).

On the other hand, studies have also shown that communities played an important role in the prevention, transmission and response to the outbreak effectively containing EVD in spite of resource constraints (Abramowitz et al., 2015). The availability of health infrastructure at the community-level was associated with the amplification of EVD but also played an essential role in containing the outbreak (Chowell & Nishiura, 2014; International Ebola Response Team et al., 2016). Many communities adopted innovative coping strategies to help contain the outbreak in Liberia (Abramowitz et al., 2015). The influence or power of chieftaincies and other local authorities may also help to explain why communities in Sierra Leone were faster to take up public health control efforts, such as bans on unsafe funeral practices and implementing local quarantines, than in Guinea (Wilkinson & Fairhead, 2016). Therefore, community-level factors also likely influenced why some people living in certain areas may have had more or less exposure to the virus, however, it is less clear how these factors would vary along SES lines.

Another strand of the literature has investigated how individual or household-level risk factors were associated with exposure to EVD during the West African outbreak. Early in the outbreak, funerals and transmission to health workers were important sources of exposure to EVD, but their importance declined markedly over time, likely due to public health efforts to improve safe burial practices and provide access to personal protective equipment (International Ebola Response Team et al., 2016). We might expect poorer households within communities to be those most likely to have these more traditional practices. Studies have also shown that the bulk of reported exposures occurred from one family member to another, or from a close friend or neighbor (International Ebola Response Team et al., 2016). Therefore, people living in larger households might be expected to be more likely to be exposed to the virus, which is also likely associated with lower SES. Other individual behaviors may have also influenced exposure to the illness. For example, people in Monrovia with higher trust in government were more likely use public health services during and immediately after the peak of the outbreak and were more likely to comply with public health directives (Blair, Morse, & Tsai, 2017; Morse, Grépin, Blair, & Tsai, 2016). However, it is unclear how these determinants are likely to be associated with SES.

There is evidence that occupation may have also led some people to be more or less exposed the virus. For example, health workers represented a disproportionately large share of total cases in the West African outbreak, likely due to increased contact with EVD patients (Evans, Goldstein, & Popova, 2015). Migration, especially migration from rural to urban areas, has also been implicated in the transmission of the virus and was also likely linked to occupation (Alexander et al., 2015). Some of these occupations might be associated with higher SES groups while others may be associated with lower SES, but occupation is an important variable that should be explored as a determinant of exposure to the virus.

Gender, which is also likely confounded by SES, also likely played an important role in the transmission of the outbreak since gendered roles, for example the fact that women were more likely to provide care to sick household members than men, likely shaped exposure and care seeking patterns (Harman, 2016). However, there is less evidence available to substantiate gendered differences in either exposure or transmission according to gender, during previous outbreaks of EVD, mostly due to limited ability of gender disaggregated data on EVD cases (Nkangu, Olatunde, & Yaya, 2017). However, it may be an important variable to investigate in the context of EVD exposure.

There is also evidence that we might expect the relationship between SES and disease transmission to change as epidemics spread or mature. Similar changes have been observed, for example, in the SES determinants of HIV since it first recognized approximately 40 years ago. While early studies of risk factors of HIV in sub-Saharan Africa initially found a positive relationship between wealth and education and HIV (Fox, 2012; Hargreaves et al., 2002), over time, the relationship appears to have changed as the epidemic matured (Grépin & Bharadwaj, 2015; Hargreaves et al., 2008; Parkhurst, 2010). There is also evidence of a "crossover" in the relationship between SES and mortality outcomes during the Spanish Flu outbreak in Norway during the early 20th century (Mamelund, 2018). Taken together, these studies suggest that the inverse relationship between SES and infectious disease outcomes in outbreaks should not always be taken as a given and that the relationship may actually be a dynamic one. We illustrate how this may happen over time in Fig. 2. As our data were collected towards the end of the outbreak, these dynamic relationships may shape the patterns we observe in our data.

A common challenge plaguing all studies to date of EVD in West Africa is the lack of population-based data on either individuals exposed to EVD or with the virus as well as the risk factors likely associated with EVD. Previous studies were limited to patient-level data that was collected on cases during the outbreak, but which were only collected from people with the diseases and only collected very limited individual-level data on SES. In addition, data from patient-level databases have not been made widely available to the research community, making it challenging to even use those data to study the socio-economic determinants of EVD (Helleringer, Grépin, & Noymer, 2015). Another common challenge that faced previous studies was the lack of data on either income or wealth of individuals exposed to EVD, and therefore either had to rely upon geographic level estimates of wealth, which could mask important differences in relative wealth of individuals even within absolutely poor areas (de Alencar Ximenes et al., 2009). Even if commonly used measures of household SES, such as the wealth index, were available on patients, such measures are themselves only relative measures based on distributions in a given country, which could mask important differences in absolute wealth that may exists across countries (Poirier, Grignon, Grépin, & Dion, 2018).

In an attempt to address the gap in the literature, this paper explores the distribution of exposure to EVD during the outbreak in West Africa relative to individual, household, and community measures of SES. We use a measure of EVD exposure that is different than those explored in previous studies, namely whether or not an individual knew a close friend or family member who were infected by Ebola, which was

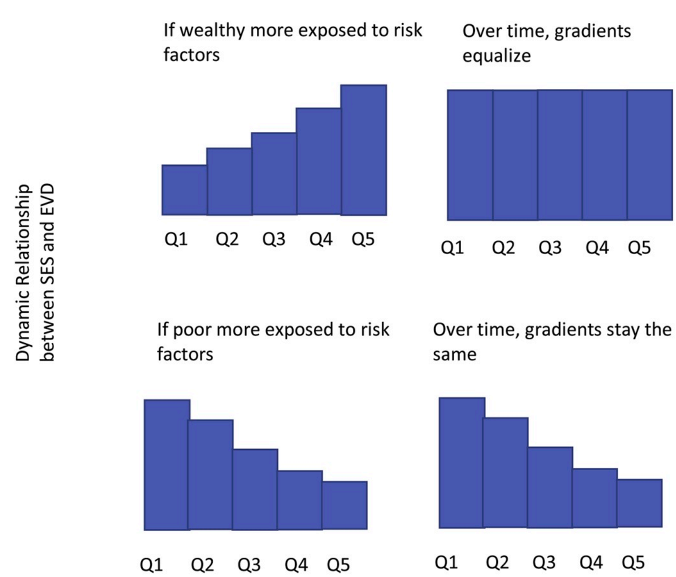

Fig. 2. Dynamic relationship between SES and EVD gradients.

collected in nationally representative public opinion polls conducted in Liberia and Sierra Leone in early 2015. The findings of this study will hopefully be able to contribute to planning against future outbreaks of EVD and potentially inform ongoing outbreaks as well.

2. Material and methods

2.1. Data

Data on exposure to EVD, individual, household, and community characteristics were all drawn from the 6th wave of the Afrobarometer survey, a nationally representative household survey of public attitudes towards governance, economic and other issues that has been conducted in more than 30 African countries since 1999 ("Afrobarometer," 2016). Afrobarometer uses a clustered, stratified, multi-stage proportion probability sampling procedure that is designed to generate samples that are nationally representative of voting age citizens. Sampling units are first randomly selected from national surveys, usually censuses, and then within sampling units, households are randomly selected for participation into the survey. In sampled households, enumerators alternate between interviewing a voting age male or female adult within each household in order to generate gender balance among survey respondents. In the 6th round, Afrobarometer interviewed 1199 respondents in Liberia and 1191 respondents in Sierra Leone, for a total of 2390 respondents.

Surveys had been planned for all three of the heavily affected countries prior to the Ebola outbreak, but were not fielded until the outbreaks had largely been controlled in 2015. In Sierra Leone and Liberia, additional questions were added to the survey to ask respondents about their experiences during the Ebola outbreak. Specifically, in both countries the survey asked respondents "Do you know a close friend or relative who was infected with Ebola?" with yes, no, refused, and don't know as potential answers. Regardless of their answer the first question, the survey then also asked "Do you know a close friend who died of Ebola?" with the same set of potential answers. Similar questions were not included in Guinea and thus data from that country were not included in this study. Field dates for the survey were May 6-22, 2015 in Liberia and May 22- June 10, 2015 in Sierra Leone. By May 6, 2015 in Liberia almost 98% of eventual cases were already reported (10,564 of 10,675) while by May 27, 2015 in Sierra Leone almost 90% of eventual cases had already been reported (12,706 of 14,124) therefore these represent time periods towards the tail end of the outbreaks in both countries. We acknowledge that this measure of exposure to the virus is less than ideal for the broad measurement of EVD exposure. For example, the survey does not ask how many people the respondent knew with the virus, or of cases of people who are not considered close friends or family members, or ask questions on network size, all which could allow for network-based modeling or the calculation of exposure in additional groups of the population. We believe, however, that nonetheless the measure is useful for an exploration of the determinants of EVD the population level given that the question was asked in the same way across areas.

Individual-level characteristics drawn from the survey included the age of the respondent, whether the respondent was male or female, and the level of education completed (no formal education, some primary education, some secondary education, and some post-secondary education). Household-level variables were constructed in terms of whether or not the household was located in an urban area and the number of adults in the respondent's household. We also used data from the Afrobarometer to construct household and community-level wealth indices at the sampling unit level as described below. Data on the administrative level unit or region of the household were also obtained from the Afrobarometer survey. There were 15 second-level administrative units in Liberia and 5 second-level administrative units in Sierra Leone. We refer to these as regions in the rest of the paper.

3. Methods

Dependent variable. We defined two EVD exposure variables, both binary variables, which were defined as 1 if the survey respondent reported knowing one or more close friends or family members who had Ebola or 0 otherwise, and the second which was coded as 1 if the respondent knew a friend who died of Ebola or 0 otherwise.

Independent variables. We constructed two measures of wealth-related SES, one at the household-level, and the other at the community-level, using principal component analysis (PCA) of available assets or resources. At the household-level, the wealth index was built based on ownership of the following assets or goods: shelter type, roofing material, water source, toilet location, radio, television, vehicle, mobile phone, receive remittance, always have food, always have water, always have medications, always have fuel, and always have cash. We first calculated the wealth index using pooled data from all households in both Sierra Leone and Liberia after ensuring all data were coded uniformly and then calculated the wealth index quintiles for the full sample as well as for country-specific samples. A separate community-level index was also constructed using the same methods and data sources with binary (yes/no) sampling unit-level resources only, which included: passable roads, paved roads, electricity grid, piped water, mobile phone service, post office, school, police station, health clinic, market stalls, bank, and public transportation. Only the first principal component was used, and separate factor analyses of urban and rural households were then regressed against the pooled results to obtain a common score (Filmer & Pritchett, 2001; Rutstein & Johnson, 2004). As a robustness check, a household index was also created using a weighted average approach after selecting variables using Cronbach's alpha and item-response correlation (Anderson, 2012) but since the estimates were similar we use the measures of SES constructed PCA methodology. In addition, to wealth, we also examined the relationship between educational attainment and Ebola exposure at an individual and community level. Respondents were recoded into categories of having received no formal, at least some primary, at least some secondary, or at least some post-secondary education. Community-level education is measured by taking the average education level in the province or county and dividing into three groups of equivalent size.

We also adjusted models for demographics (urban residence, age of the respondent, the number of adults in the respondent's household, and gender of the respondent) as well as the region of the household. Given that the size of the units may vary across countries, we include one specification that includes dummy variables to control for these regions, and one that does not. The main results are based on logistic regression using STATA 14 (College Station, TX, USA), using survey weights, population-weighted post-stratification across countries, and jackknife variance estimation. The logistic regressions were run on both the full-sample with data pooled across both countries and then separately for each country individually.

4. Results

The summary statistics for our sample are presented in Table 1, both for the full sample as well as for Liberia and Sierra Leone separately. Overall, approximately 41% of the respondents in the pooled sample knew a close friend or family member who had been infected with Ebola and only slightly lower percentage reported knowing a close friend who had died of Ebola (38%). A slightly higher percentage of people had been exposed to cases of Ebola in Liberia than in Sierra Leone. Almost exactly half of the respondents were male, which is not surprising given the sampling strategy of the Afrobarometer survey. The sample was well distributed in terms of ages, but was slightly older in Sierra Leone. About half of the sample had more than a primary education, but the Liberian sample was slightly more educated than in Sierra Leone. Households in both countries were large (mean 6.5–6.7 adults per household). Based on the full-sample pooled common asset score, we find that households

Table 1
Sample summary statistics.

	Pooled		Sierra Leone		Liberia	
	mean	n	mean	n	mean	n
Exposure variables: Knew people						
Infected with Ebola	0.41	958	0.36	416	0.46	542
Died from Ebola	0.38	874	0.34	388	0.41	486
Male respondent	0.50	1189	0.49	589	0.50	600
Age Groups						
18–24	0.16	378	0.13	159	0.18	219
25–34	0.32	760	0.26	311	0.37	449
35–44	0.27	649	0.27	319	0.28	330
45+	0.25	603	0.34	402	0.17	201
Education						
No formal education	0.26	626	0.38	452	0.15	174
Some primary	0.25	251	0.21	251	0.29	353
Some secondary	0.31	328	0.28	328	0.35	416
Some post-secondary	0.17	157	0.13	157	0.20	244
Adults in household (n)	6.62	2390	6.62	1191	6.61	1199
Household asset score	0.00	2372	−0.01	1190	0.01	1182
Community Education						
Avg. some primary	0.30	708	0.43	516	0.16	192
Avg. some secondary	0.49	533	0.45	533	0.53	631
Avg. some post-secondary	0.22	142	0.12	142	0.31	376
Community asset score	0.00	2278	−0.52	1191	0.56	1087
Urban	0.43	1019	0.37	443	0.48	578
Regional units						
East	0.13	301	0.25	301		
North	0.16	392	0.33	392		
South	0.11	260	0.22	260		
Western	0.10	238	0.20	238		
Bomi	0.01	32			0.03	32
Bong	0.05	112			0.09	112
Gbarpolu	0.01	32			0.03	32
Grand Bassa	0.03	80			0.07	80
Grand Cape Mount	0.02	40			0.03	40
Grand Gedeh	0.02	48			0.04	48
Grand Kru	0.01	16			0.01	16
Lofa	0.04	95			0.08	95
Margibi	0.03	72			0.06	72
Maryland	0.02	40			0.03	40
Montserrado	0.17	400			0.33	400
Nimba	0.06	152			0.13	152
River Gee	0.01	24			0.02	24
Rivercess	0.01	24			0.02	24
Sinoe	0.01	32			0.03	32

in both countries were similar in terms of overall wealth, but that communities in Liberia fared better in terms of access to community-level resources than in Sierra Leone.

In Table 2, we present our regression results which explore the determinants of Ebola exposure along individual, household, and community lines. The dependent variable in all of the specifications is a binary variable reporting knowing at least one close friend or family member with Ebola and the models are all estimated using logistic regression. The first set of columns correspond to the results for the pooled sample, while the second and third sets of columns present the same analysis for Sierra Leone and Liberia separately. In columns 1,4, and 7, we regress knowing a close friend or family member with Ebola with individual and household-level factors alone. In columns 2, 5, and 8 we add community-level factors while in the last set columns in each set we also control for region-level fixed effects.

In the full sample, we find that after controlling for all other variables, individual-level education as well as an indicator that the household lives in an urban area are both positively and significantly associated with knowing a close friend or family member with Ebola. When we use the same specification in the country-specific models, controlling for all other variables, we find that the individual-level educational effect is only significant in Sierra Leone and the urban effect is only significant in Liberia, although the patterns observed were consistent across countries, but were just not significant. We also find that the pooled sample masks important differences in the association between household wealth and exposure at the country-level. While there is no measurable effect in the pooled sample, after controlling for other variables, in Sierra Leone, higher wealth index quintile households were more likely to report knowing a close friend or family member with Ebola, while in Liberia we get the opposite finding with higher SES households less likely to report knowing someone with Ebola. Whether or not the respondent was male or the number of adults in the household had little impact on exposure in any sample. Overall age had little impact, with the exception of older respondents in Liberia being more likely to report knowing someone with Ebola.

We then explore whether controlling for community and region-level factors influence these relationships by adding the average educational levels and socio-economic status measured at the community-levels. We find that community-level education is positively associated with Ebola exposure but that this effect appears to be mainly concentrated in Sierra Leone. When we control for community-level education we also reduce the associations with individual-level measures of education, but only slightly and it remains significant in Sierra Leone. Controlling for community-level SES does not systematically affect our associations between individual and household-level SES and exposure. Adding sub-national regional fixed-effects also does not affect our observed effects, although we do observe some regions have higher or lower propensity to reporting knowing someone with Ebola (not shown, but available upon request). We also replicate all of the same regression results using knowing someone who died of Ebola, and the results are presented in Appendix Table 2. Given the similarity in this measure with our other dependent variable, unsurprisingly, we find nearly the exact same pattern of associations as with knowing someone with Ebola.

We also explore the determinants of Ebola exposure in a model that has been stratified by rural and urban populations in Appendix Table 4. Despite the much smaller sample sizes, which makes it more difficult to find strong associations, we also see some differences in the sub-samples. For example, while there is no association between gender and exposure in the full sample, we see that males were more likely to be exposed in the rural sample but not in the urban sample.

5. Discussion

Socio-economic status, in particular poverty, has been implicated as an important driver of the transmission of EVD during the West African outbreak, however, previous studies have not always found consistent results and also were not based on nationally representative data of EVD exposure nor were they able to adequately control for individual, household, and community-level factors, all of which might independently help to explain exposure patterns to EVD. In this paper, we developed a conceptual model which provided pathways through which both high and low levels of SES might be associated with increased EVD exposure at the population and community-levels as well as the individual and household-levels. Data from a nationally representative household-level survey data from Sierra Leone and Liberia, the two most heavily affected countries during the West African outbreak, we explored how various measures of exposure to EVD were associated with measures of SES at different levels. We make a number of important contributions to the literature.

First, while we find no overall association between household-level wealth and EVD exposure, we find that within countries there are very

Table 2
Determinants of Ebola exposure.

	Pooled			Sierra Leone			Liberia		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Male	1.07	1.12	1.12	1.15	1.18	1.18	1.02	1.05	1.07
	(0.91–1.27)	(0.95–1.32)	(0.95–1.33)	(0.90–1.46)	(0.92–1.51)	(0.92–1.52)	(0.81–1.28)	(0.83–1.33)	(0.84–1.36)
Age Groups (18–24 omitted)									
25–34	1.08	1.02	1.00	0.87	0.89	0.89	1.35	1.28	1.22
	(0.77–1.52)	(0.72–1.44)	(0.71–1.41)	(0.52–1.46)	(0.54–1.46)	(0.55–1.46)	(0.87–2.10)	(0.80–2.07)	(0.75–1.99)
35–44	1.14	1.12	1.12	0.95	1.01	1.02	1.43	1.40	1.35
	(0.81–1.59)	(0.78–1.60)	(0.78–1.60)	(0.57–1.59)	(0.61–1.69)	(0.62–1.68)	(0.91–2.24)	(0.85–2.29)	(0.83–2.21)
45+	1.22	1.30	1.25	0.88	0.96	0.94	2.38***	2.37***	2.24***
	(0.89–1.67)	(0.93–1.81)	(0.89–1.77)	(0.55–1.39)	(0.60–1.53)	(0.59–1.50)	(1.44–3.91)	(1.40–4.01)	(1.28–3.93)
Education (no formal education omitted)									
Some primary	0.97	0.82	0.82	0.82	0.71*	0.72	0.79	0.75	0.76
	(0.71–1.32)	(0.60–1.12)	(0.61–1.11)	(0.54–1.22)	(0.47–1.06)	(0.48–1.07)	(0.50–1.25)	(0.47–1.18)	(0.48–1.20)
Some secondary	1.47**	1.15	1.10	1.56**	1.31	1.31	0.99	0.74	0.70
	(1.07–2.02)	(0.85–1.55)	(0.81–1.49)	(1.05–2.31)	(0.87–1.96)	(0.88–1.96)	(0.62–1.59)	(0.48–1.15)	(0.43–1.15)
Some post-secondary	1.48*	1.06	1.07	1.33	1.17	1.16	1.44	0.92	0.89
	(0.98–2.23)	(0.70–1.60)	(0.72–1.60)	(0.75–2.35)	(0.68–2.02)	(0.67–2.00)	(0.84–2.44)	(0.52–1.63)	(0.49–1.61)
Number of Adults in HH	1.00	1.00	1.01	1.02	1.02	1.03	0.97	0.96	0.96
	(0.97–1.04)	(0.96–1.04)	(0.97–1.05)	(0.97–1.07)	(0.97–1.08)	(0.98–1.08)	(0.92–1.04)	(0.90–1.03)	(0.90–1.03)
Household SES Quintiles (lowest quintile omitted)									
2	1.07	1.12	1.13	1.38	1.41	1.34	0.88	0.92	0.93
	(0.75–1.53)	(0.78–1.62)	(0.79–1.62)	(0.80–2.37)	(0.80–2.49)	(0.77–2.32)	(0.59–1.33)	(0.60–1.41)	(0.59–1.47)
3	0.86	0.88	0.88	1.39	1.46	1.29	0.50***	0.46***	0.51**
	(0.61–1.21)	(0.63–1.25)	(0.60–1.27)	(0.83–2.33)	(0.88–2.41)	(0.76–2.18)	(0.32–0.77)	(0.29–0.75)	(0.30–0.89)
4	0.93	0.87	0.82	1.73*	1.62	1.43	0.47***	0.40***	0.40***
	(0.65–1.35)	(0.60–1.28)	(0.57–1.18)	(0.97–3.09)	(0.90–2.92)	(0.81–2.54)	(0.30–0.74)	(0.25–0.64)	(0.25–0.66)
5 (High SES)	0.84	0.80	0.77	2.00**	1.86*	1.66	0.32***	0.31***	0.33***
	(0.58–1.20)	(0.55–1.16)	(0.51–1.14)	(1.12–3.58)	(0.96–3.58)	(0.87–3.16)	(0.20–0.52)	(0.19–0.52)	(0.19–0.56)
Urban	1.80***	1.35*	1.07	1.49	1.03	0.83	1.62***	1.25	1.03
	(1.32–2.45)	(0.96–1.88)	(0.75–1.53)	(0.85–2.61)	(0.53–2.03)	(0.41–1.68)	(1.19–2.23)	(0.91–1.73)	(0.70–1.51)
Community Education (avg. of some primary omitted)									
Avg. some secondary		1.99***	1.86***		2.12***	2.04***		1.21	1.17
		(1.40–2.84)	(1.28–2.70)		(1.26–3.58)	(1.21–3.43)		(0.79–1.87)	(0.71–1.94)
Avg. some post-secondary		2.41***	1.95***		1.24	1.19		2.34***	2.07**
		(1.51–3.84)	(1.18–3.20)		(0.49–3.17)	(0.46–3.12)		(1.33–4.14)	(1.03–4.19)
Community SES Quintiles (lowest quintile omitted)									
2		1.17	1.10		1.39	1.44		1.13	0.77
		(0.78–1.74)	(0.69–1.74)		(0.78–2.48)	(0.81–2.57)		(0.70–1.80)	(0.38–1.57)
3		1.62**	1.34		2.88**	2.81**		0.78	0.65
		(1.02–2.58)	(0.76–2.37)		(1.26–6.56)	(1.20–6.56)		(0.47–1.28)	(0.32–1.33)
4		1.21	1.12		1.21	1.29		0.88	0.69
		(0.73–1.99)	(0.62–2.02)		(0.54–2.68)	(0.58–2.86)		(0.54–1.45)	(0.33–1.43)
5 (High SES)		1.04	1.19		1.85	1.89		0.60**	0.81
		(0.66–1.65)	(0.62–2.32)		(0.64–5.37)	(0.62–5.75)		(0.36–0.99)	(0.36–1.83)
Region fixed effects	NO	NO	YES	NO	NO	YES	NO	NO	YES
Observations	2279	2172	2172	1135	1135	1135	1145	1039	1039

Coefficients presented are odds ratios with confidence intervals in parentheses. Logistic regression was run using survey weights provided by Afrobarometer, post-stratified using region-level population figures, and Taylor-linearized variance estimation. Regional fixed effects are included in some models, but not shown. The lower number of observations in some columns were due to missing data in variables that make up the community SES index. The number of observations in columns 2, 3, 8, and 9 vary due to missing data for the variables which make up the community SES index.
***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

different patterns of exposures, with higher SES households reporting more exposure to the virus in Sierra Leone and the opposite effect in Liberia. This finding suggests that there appears to have been different factors driving exposure patterns in these neighboring countries during the outbreak. It also suggests that it is too simplistic to simply assume that poverty was an important driver of the outbreak, as it may have been in some areas, but not others. It may also be that absolute poverty might help explain why West Africa was particular hard hit by the outbreak, perhaps due to its proximity to the zoonotic reservoirs of EVD, but that relative wealth appears to be more important within countries in explaining patterns of exposure. Given this finding, we believe there is an urgent need to better explore these patterns, perhaps spatially or using qualitative approaches to better understand why wealth might have had such a differential effect in these two different countries.

Second, across our various specifications, we also find that education of the survey respondent was consistently positively associated with Ebola exposure overall, although the estimates were not always significant. More educated people were more likely to report knowing someone with Ebola, even after controlling for household, community, and regional-level factors although our associations are reduced. While our data do not allow us to pinpoint the reasons for this association, we speculate that it could be that more educated people in general know more people in their communities or may have more knowledge of the people in their networks. Also, given that some professions, for example health workers, were identified in other studies as having had higher levels of exposure to EVD than the general population, it may also be that specific jobs or occupations, which would be associated with education levels, may have made these people more likely to come into contact with more cases of EVD (Evans et al., 2015). Unfortunately, we were unable to control for occupation in our analysis to further explore this potential channel.

Third, urban households were more likely than rural households to report higher levels of exposure of the outbreak, however, the reasons for this association are not clear but it does not seem to be explained simply by higher incomes in urban areas and important associations between other SES variables persist even within the urban sample. People in urban areas may also know more people or again know more about the people in their network. Unfortunately, we were unable to control for network size in our analysis but it points to the need to control for such factors in future analyses and to collect such data in future surveys.

While our study has helped to shed some light on the exposure patterns of EVD along SES lines, it has many important limitations that must be taken into consideration when interpreting out results. First, our measure of EVD exposure, namely whether or not people reported knowing a close friend or family member with Ebola or knowing someone who died of Ebola is different from actual cases of EVD or other ways to define exposure. Plus, this simple measure of exposure lacks information on how many cases a person knew, or of cases that they would not define as close friends or family members. However, if we assume that there were approximately 25,000 cases of Ebola in the 2 countries with a combined population of approximately 13,000,000 people, then it would mean that 1 in 520 people in those countries were actually infected with EVD. Given that in our sample, roughly 40% of people knew a close friend or family member with Ebola, assuming random mixing, it means that on average people must have at least 200 people in their close circle of friends or family members, which is a plausible figure given estimates of network sizes that have been observed in different human populations (Dunbar, 1993). Given that cases of EVD likely clustered, we might be worried that this estimate would underestimate the number of close friends and colleagues each individual would have to have, since people who knew one case likely knew more than one, however, on the other hand given that many of the people who actually knew cases also died, this might bias the estimates in the other direction since people who died did not answer the survey. Second, we only have data from two of the most heavily affected countries and lack data from Guinea, and therefore we cannot speculate if our results would be consistent in that country. Third, we are comparing data from two countries with sub-national units of different sizes (counties vs. provinces and potentially also at the sampling unit). These differences could also potentially affect our estimates, especially with regards to the calculation of the community-level variables which have been aggregated at the sampling unit-level.

6. Conclusions

The recent West African outbreak of EVD was a wake-up call to the global health community that we need to do a better job at preventing and mitigating the spread of infectious diseases with epidemic potential. Knowing how the virus may spread along SES lines is one way to help prepare for future outbreaks. Our study suggests that there is a lot that we still do not fully understand about the way in which EVD spread along individual, household, and community-levels but it is too simplistic to simply assume that poorer people living in poorer communities were more exposed. There is an urgent need to better understand these patterns to help prepare for future infectious disease outbreaks.

Research ethics statement

This paper relies entirely on secondary data, therefore, research ethics approval was not required.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2019.100472.

Appendix

Appendix Table 1
Summary of variables to calculate household and community wealth indices

	Pooled		Sierra Leone		Liberia	
	mean	**n**	**mean**	**n**	**mean**	**n**
Roofing materials						
Thatched	0.16	2390	0.19	1191	0.13	1199
Metal	0.79	2390	0.79	1191	0.78	1199
Other	0.05	2390	0.02	1191	0.09	1199
Water Source						
In household	0.04	2390	0.01	1191	0.08	1199
On compound	0.14	2390	0.14	1191	0.14	1199
Outside compound	0.81	2390	0.85	1191	0.77	1199
Toilet Location						
In household	0.11	2390	0.04	1191	0.22	1199

(continued on next page)

Appendix Table 1 (*continued*)

	Pooled		Sierra Leone		Liberia	
	mean	**n**	**mean**	**n**	**mean**	**n**
On compound	0.31	2390	0.44	1191	0.13	1199
Outside compound	0.55	2390	0.50	1191	0.61	1199
No toilet	0.03	2390	0.02	1191	0.03	1199
Shelter Type						
Flat in a block of flats	0.15	2390	0.19	1191	0.10	1199
Non-traditional/formal house	0.53	2390	0.51	1191	0.55	1199
Single room in a larger dwelling structure or backyard	0.04	2390	0.01	1191	0.07	1199
Temporary structure/shack	0.04	2390	0.02	1191	0.07	1199
Traditional house/hut	0.24	2390	0.26	1191	0.21	1199
Receives Remittances	0.27	2390	0.18	1191	0.41	1199
Household always has ...						
Food	0.36	2390	0.42	1191	0.27	1199
Water	0.42	2390	0.52	1191	0.27	1199
Medication	0.38	2390	0.49	1191	0.22	1199
Fuel	0.58	2390	0.71	1191	0.38	1199
Cash	0.17	2390	0.21	1191	0.13	1199
Household always has						
Radio	0.76	2386	0.71	1191	0.84	1195
TV	0.25	2378	0.19	1191	0.33	1187
Vehicle	0.14	2380	0.09	1191	0.22	1189
Mobile phone	0.71	2383	0.66	1190	0.78	1193
Community has ...						
Electricity grid	0.30	2390	0.29	1191	0.31	1199
Piped water	0.23	2366	0.27	1191	0.18	1175
Cell phone service	0.85	2366	0.88	1191	0.81	1175
Post office	0.06	2358	0.01	1191	0.14	1167
School	0.87	2390	0.80	1191	0.97	1199
Police station	0.33	2382	0.24	1191	0.46	1191
Health clinic	0.59	2390	0.49	1191	0.75	1199
Market stalls	0.47	2366	0.35	1191	0.64	1175
Bank	0.16	2382	0.10	1191	0.23	1191
Public transportation	0.97	2390	0.99	1191	0.94	1199

Appendix Table 2
Regression results (know someone that died of Ebola)

	Pooled			Sierra Leone			Liberia		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Male	1.07	1.12	1.12	1.15	1.18	1.19	1.02	1.05	1.07
	0.39	0.19	0.18	0.25	0.19	0.19	0.88	0.67	0.60
Age Groups (18–24 omitted)									
25–34	1.08	1.02	1.00	0.87	0.89	0.89	1.35	1.28	1.22
	0.65	0.91	0.99	0.61	0.64	0.65	0.18	0.30	0.42
35–44	1.14	1.12	1.12	0.95	1.02	1.02	1.43	1.40	1.35
	0.46	0.53	0.54	0.85	0.95	0.94	0.12	0.18	0.23
45+	1.22	1.30	1.26	0.88	0.96	0.94	2.38**	2.37**	2.24**
	0.22	0.13	0.20	0.57	0.86	0.81	0.00	0.00	0.01
Education (no formal education omitted)									
Some primary	0.97	0.82	0.82	0.82	0.71*	0.72	0.79	0.75	0.76
	0.83	0.21	0.19	0.32	0.09	0.11	0.31	0.21	0.24
Some secondary	1.47**	1.15	1.10	1.56**	1.31	1.31	0.99	0.74	0.70
	0.02	0.37	0.54	0.03	0.19	0.18	0.97	0.18	0.16
Some post-secondary	1.48*	1.06	1.07	1.33	1.17	1.16	1.44	0.92	0.89
	0.06	0.78	0.74	0.32	0.58	0.59	0.18	0.77	0.70
Number of Adults in HH	1.00	1.00	1.01	1.02	1.02	1.03	0.97	0.96	0.96
	0.82	0.88	0.58	0.49	0.36	0.23	0.40	0.24	0.23
HH SES Quintiles (lowest quintile omitted)									
2	1.07	1.12	1.13	1.38	1.41	1.34	0.89	0.92	0.93
	0.69	0.53	0.51	0.24	0.23	0.30	0.56	0.70	0.76
3	0.86	0.88	0.88	1.39	1.46	1.29	0.50**	0.47**	0.51**
	0.37	0.48	0.48	0.21	0.14	0.34	0.00	0.00	0.02

(*continued on next page*)

Appendix Table 2 (*continued*)

	Pooled			Sierra Leone			Liberia		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
4	0.93	0.87	0.82	1.73*	1.62	1.43	0.47**	0.40**	0.40**
	0.72	0.49	0.28	0.06	0.11	0.21	0.00	0.00	0.00
5 (High SES)	0.84	0.80	0.77	2.00**	1.86*	1.66	0.32**	0.31**	0.33**
	0.34	0.23	0.19	0.02	0.06	0.13	0.00	0.00	0.00
Urban	1.80**	1.35*	1.07	1.49	2.12**	2.04**	1.63**	1.21	1.17
	0.00	0.08	0.72	0.16	0.00	0.01	0.00	0.38	0.54
Community Education (avg. of some primary omitted)									
Avg. some secondary		1.99**	1.86**		1.24	1.19		2.34**	2.07**
		0.00	0.00		0.65	0.72		0.00	0.04
Avg. some post-secondary		2.41**	1.95**		1.39	1.44		1.13	0.78
		0.00	0.01		0.26	0.21		0.62	0.48
Community SES Quintiles (lowest quintile omitted)									
2		1.17	1.10		2.88**	2.81**		0.78	0.65
		0.45	0.70		0.01	0.02		0.32	0.24
3		1.62**	1.34		1.21	1.29		0.88	0.69
		0.04	0.31		0.64	0.53		0.62	0.31
4		1.21	1.12		1.85	1.89		0.60**	0.81
		0.46	0.71		0.26	0.26		0.05	0.61
5 (High SES)		1.04	1.20		1.03	0.83		1.26	1.03
		0.85	0.60		0.93	0.61		0.16	0.90
Sierra Leone (Eastern omitted in country-specific regresson)									
Eastern			0.59						
			0.18						
Northern			0.58			1.03			
			0.14			0.93			
Southern			0.48**			0.83			
			0.03			0.60			
Western			1.23			1.68			
			0.60			0.16			
Liberia (Bomi omitted)									
Bong			0.69						0.93
			0.29						0.82
Gbarpolu			0.49						0.37*
			0.31						0.08
Grand Bassa			0.18**						0.30**
			0.00						0.01
Grand Cape Mount			0.87						1.00
			0.80						1.00
Grand Gedeh			0.76						1.16
			0.50						0.75
Grand Kru			1.80						2.58**
			0.18						0.03
Lofa			0.81						0.98
			0.62						0.95
Margibi			0.70						0.78
			0.39						0.57
Maryland			1.09						1.89
			0.84						0.11
Montserrado			0.94						1.39
			0.87						0.37
Nimba			0.51						0.59
			0.16						0.26
River Gee			2.02*						2.49**
			0.05						0.02
Rivercess			0.53						0.68
			0.11						0.37
Sinoe			1.04						1.33
			0.92						0.55
Observations	2184	2184	2184	1140	1140	1140	1151	1151	1151

P-values are presented in parenthesis. Logistic regression was run using survey weights provided by Afrobarometer, post-stratified using province- and county-specific population figures, and Taylor-linearized variance estimation.

Notes: p-value in parenthesis, $p < 0.05$* $p < 0.01$**.

Appendix Table 3
Summary statistics according to exposure to Ebola

	Know someone who was infected with Ebola		Know someone who died of Ebola	
	mean	N	mean	N
Male	0.42	1162	0.39	1152
Female	0.40	1160	0.37	1159
Age Groups				
18–24	0.41	360	0.36	360
25–34	0.43	737	0.39	732
35–44	0.42	638	0.38	634
45+	0.39	587	0.37	585
Education				
No formal education	0.34	604	0.31	600
Some primary	0.36	585	0.34	588
Some secondary	0.47	724	0.42	717
Some post-secondary	0.51	396	0.47	393
Adults in household (n)				
1-4 adults	0.38	521	0.37	518
5-7 adults	0.42	1083	0.37	1078
8 + adults	0.43	718	0.39	715
HH SES quintile				
1	0.39	459	0.36	458
2	0.42	461	0.40	461
3	0.38	463	0.33	459
4	0.41	458	0.38	456
5	0.46	462	0.41	458
Community Education				
Avg. some primary	0.29	681	0.26	679
Avg. some secondary	0.44	1133	0.40	1131
Avg. some post-secondary	0.52	508	0.49	501
Community SES quintile				
1	0.34	443	0.30	441
2	0.40	442	0.36	443
3	0.48	438	0.44	436
4	0.44	442	0.41	440
5	0.42	447	0.40	440
Urban	0.49	995	0.46	988
Rural	0.36	1327	0.32	1323
Regions				
East	0.41	284	0.36	283
North	0.28	376	0.27	375
South	0.31	253	0.29	250
Western	0.50	229	0.49	229
Bomi	0.41	32	0.41	32
Bong	0.49	109	0.38	110
Gbarpolu	0.40	30	0.26	31
Grand Bassa	0.15	79	0.15	79
Grand Cape Mount	0.59	39	0.55	38
Grand Gedeh	0.48	48	0.46	48
Grand Kru	0.73	15	0.69	16
Lofa	0.35	94	0.31	93
Margibi	0.41	71	0.40	70
Maryland	0.54	39	0.53	38
Montserrado	0.56	396	0.52	391
Nimba	0.28	149	0.23	149
River Gee	0.74	23	0.61	23
Rivercess	0.33	24	0.29	24
Sinoe	0.69	32	0.63	32

Figures are simple means and numbers (n) of survey respondents in each variable group.

Appendix Table 4
Stratefied by rural and urban samples

	Pooled Rural			**Sierra Leone** Rural	**Liberia** Rural			Pooled Urban			**Sierra Leone** Urban			**Liberia** Urban		
	(1)	(2)	(3)	(4)	(7)	(8)	(9)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Male	1.23*	1.34**	1.37**	1.24	1.28	1.47*	1.51*	0.97	0.98	0.98	1.08	1.11	1.12	0.81	0.77*	0.78*
	(0.97–1.57)	(1.05–1.71)	(1.07–1.77)	(0.88–1.74)	(0.88–1.86)	(0.98–2.20)	(1.00–2.30)	(0.78–1.21)	(0.79–1.22)	(0.78–1.22)	(0.77–1.53)	(0.77–1.60)	(0.77–1.63)	(0.62–1.06)	(0.59–1.01)	(0.60–1.03)
Age Groups (18–24 omitted)																
25–34	1.46	1.29	1.29	1.05	2.28**	1.92*	1.89	0.76	0.76	0.76	0.62	0.68	0.70	0.85	0.87	0.92
	(0.91–2.37)	(0.79–2.11)	(0.76–2.21)	(0.55–2.01)	(1.13–4.60)	(0.88–4.19)	(0.80–4.49)	(0.46–1.24)	(0.45–1.28)	(0.46–1.26)	(0.27–1.44)	(0.30–1.57)	(0.31–1.59)	(0.49–1.46)	(0.49–1.55)	(0.49–1.74)
35–44	1.20	1.08	1.09	1.06	1.68	1.33	1.36	1.05	1.10	1.13	0.82	0.95	1.01	1.22	1.32	1.36
	(0.71–2.01)	(0.62–1.89)	(0.61–1.94)	(0.53–2.13)	(0.76–3.68)	(0.55–3.21)	(0.54–3.39)	(0.68–1.63)	(0.69–1.74)	(0.70–1.81)	(0.41–1.63)	(0.49–1.86)	(0.52–1.98)	(0.69–2.17)	(0.71–2.44)	(0.70–2.65)
45+	1.23	1.26	1.21	0.90	2.84**	2.48*	2.45*	1.17	1.29	1.30	0.83	1.01	1.09	1.96**	2.04**	2.03**
	(0.74–2.06)	(0.73–2.17)	(0.68–2.17)	(0.49–1.65)	(1.18–6.88)	(0.99–6.23)	(0.91–6.64)	(0.76–1.82)	(0.82–2.03)	(0.79–2.14)	(0.39–1.75)	(0.46–2.19)	(0.50–2.40)	(1.11–3.48)	(1.11–3.75)	(1.02–4.03)
	1.12	0.93	0.91	1.00	0.81	0.72	0.75	0.64	0.57*	0.59*	0.43*	0.36**	0.35**	0.91	0.89	0.89
Education (no formal education omitted)																
Some primary	(0.79–1.59)	(0.66–1.33)	(0.64–1.28)	(0.64–1.56)	(0.46–1.41)	(0.40–1.31)	(0.41–1.39)	(0.34–1.22)	(0.31–1.05)	(0.32–1.08)	(0.18–1.02)	(0.16–0.80)	(0.15–0.81)	(0.42–1.94)	(0.42–1.91)	(0.42–1.88)
	1.46*	1.07	1.02	1.71**	0.80	0.54**	0.53*	1.12	0.96	0.94	0.96	0.91	0.92	1.37	1.06	0.92
Some secondary	(0.94–2.27)	(0.71–1.59)	(0.66–1.59)	(1.04–2.82)	(0.43–1.49)	(0.29–0.99)	(0.26–1.09)	(0.67–1.88)	(0.61–1.53)	(0.58–1.53)	(0.49–1.87)	(0.49–1.72)	(0.47–1.79)	(0.70–2.68)	(0.57–1.99)	(0.48–1.78)
	1.47	1.09	1.15	1.86	0.80	0.58	0.63	1.14	0.88	0.89	0.80	0.81	0.80	2.57**	1.50	1.28
Some post-secondary	(0.85–2.53)	(0.58–2.05)	(0.62–2.14)	(0.85–4.10)	(0.37–1.70)	(0.19–1.73)	(0.19–2.08)	(0.61–2.11)	(0.52–1.48)	(0.52–1.51)	(0.38–1.69)	(0.40–1.67)	(0.39–1.64)	(1.15–5.71)	(0.72–3.12)	(0.59–2.75)
Number of Adults in HH	1.03	1.03	1.03	1.05	0.98	0.96	0.96	0.94**	0.94**	0.95*	0.95	0.94	0.95	0.95	0.95	0.95
	(0.98–1.09)	(0.98–1.08)	(0.98–1.09)	(0.99–1.12)	(0.89–1.07)	(0.87–1.06)	(0.86–1.06)	(0.88–0.99)	(0.88–0.99)	(0.90–1.00)	(0.88–1.02)	(0.87–1.02)	(0.88–1.02)	(0.88–1.03)	(0.87–1.05)	(0.86–1.06)
Household SES Quintiles (lowest quintile omitted)																
2	1.30	1.37	1.36	1.58	1.11	1.14	1.15	0.62	0.55*	0.55	0.81	0.73	0.57	0.80	0.71	0.77
	(0.86–1.97)	(0.89–2.12)	(0.87–2.13)	(0.89–2.78)	(0.60–2.06)	(0.56–2.32)	(0.55–2.39)	(0.32–1.21)	(0.28–1.07)	(0.26–1.16)	(0.17–3.95)	(0.16–3.40)	(0.12–2.72)	(0.47–1.37)	(0.40–1.26)	(0.38–1.57)
3	0.74	0.79	0.77	1.16	0.40***	0.42***	0.48*	1.17	0.89	0.81	3.68*	2.83	2.08	0.64	0.44*	0.45
	(0.49–1.13)	(0.53–1.20)	(0.48–1.22)	(0.64–2.12)	(0.22–0.73)	(0.23–0.80)	(0.22–1.04)	(0.58–2.36)	(0.42–1.92)	(0.34–1.95)	(0.80–16.85)	(0.59–13.51)	(0.39–11.15)	(0.31–1.32)	(0.19–1.06)	(0.16–1.23)
4	0.93	0.85	0.79	1.39	0.42**	0.36***	0.34**	0.78	0.64	0.53*	2.51	1.93	1.33	0.53**	0.38***	0.39**
	(0.59–1.49)	(0.53–1.38)	(0.48–1.28)	(0.71–2.71)	(0.20–0.89)	(0.17–0.77)	(0.14–0.82)	(0.40–1.52)	(0.33–1.24)	(0.26–1.09)	(0.52–12.10)	(0.43–8.64)	(0.27–6.50)	(0.31–0.93)	(0.20–0.71)	(0.19–0.82)
5 (High SES)	1.16	1.20	1.22	2.61*	0.52*	0.72	0.73	0.67	0.51**	0.36***	2.47	1.77	1.01	0.23***	0.17***	0.18***
	(0.65–2.07)	(0.63–2.28)	(0.60–2.48)	(0.91–7.44)	(0.25–1.08)	(0.32–1.62)	(0.29–1.83)	(0.36–1.24)	(0.27–0.97)	(0.17–0.77)	(0.57–10.63)	(0.40–7.87)	(0.21–4.79)	(0.13–0.44)	(0.08–0.36)	(0.08–0.43)
Community Education (avg. of some primary omitted)																
Avg. some secondary	1.69***	1.61**			0.86	0.90		4.84***	5.15***		9.78***	11.07***		2.44	3.17*	
	(1.14–2.50)	(1.05–2.48)			(0.55–1.36)	(0.58–1.41)		(1.89–12.36)	(2.23–11.94)		(1.86–51.39)	(3.10–39.58)		(0.83–7.18)	(0.95–10.55)	
Avg. some post-secondary	2.52***	1.59			1.63	1.16		4.88***	4.43***		6.35**	7.47***		4.67**	5.65***	
	(1.32–4.83)	(0.78–3.21)			(0.73–3.64)	(0.43–3.09)		(1.85–12.92)	(1.86–10.52)		(1.09–37.13)	(1.85–30.25)		(1.44–15.11)	(1.57–20.29)	
Community SES Quintiles (lowest quintile omitted)																
2	1.30	1.22			1.85**	1.01		0.63	0.42*					0.62	0.39**	
	(0.82–2.07)	(0.70–2.14)			(1.11–3.09)	(0.45–2.31)		(0.27–1.45)	(0.17–1.06)					(0.30–1.28)	(0.16–0.96)	
3	1.94***	1.89*			0.77	0.81		0.66	0.32**		1.23	0.83		0.51*	0.37**	
	(1.22–3.09)	(0.98–3.64)			(0.47–1.28)	(0.34–1.97)		(0.24–1.77)	(0.12–0.82)		(0.31–4.94)	(0.23–2.92)		(0.23–1.10)	(0.15–0.89)	
4	1.73	1.65			1.35	0.12*		0.49*	0.26***		0.47*	0.35**		0.51*	0.37**	
	(0.90–3.34)	(0.74–3.67)			(0.79–2.30)	(0.01–1.16)		(0.22–1.08)	(0.11–0.62)		(0.21–1.07)	(0.14–0.86)		(0.26–1.01)	(0.16–0.85)	
5 (High SES)	0.97	0.75			0.42***	0.13*		0.54	0.31**		0.65	0.38*		0.51*	0.48	
	(0.54–1.74)	(0.18–3.09)			(0.24–0.73)	(0.01–1.41)		(0.25–1.16)	(0.13–0.76)		(0.28–1.52)	(0.13–1.11)		(0.25–1.05)	(0.19–1.23)	

(*continued on next page*)

Appendix Table 4 (*continued*)

	Pooled Rural			**Sierra Leone** Rural	**Liberia** Rural			Pooled Urban			**Sierra Leone** Urban			**Liberia** Urban		
	(1)	(2)	(3)	(4)	(7)	(8)	(9)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Regions																
Sierra Leone (Eastern omitted in country-specific regresson)																
Eastern		0.55							1.02							
		(0.24–1.25)							(0.47–2.21)							
Northern		0.59*							1.25			1.38				
		(0.33–1.07)							(0.28–5.57)			(0.39–4.88)				
Southern		0.34***							2.83***			2.84**				
		(0.17–0.65)							(1.56–5.11)			(1.09–7.44)				
Western		1.43							3.11***			2.46*				
		(0.43–4.73)							(1.67–5.80)			(0.95–6.37)				
Liberia (Bomi omitted)																
Bong		0.57				0.95			2.10						1.53	
		(0.28–1.13)				(0.44–2.04)			(0.57–7.66)						(0.52–4.53)	
Gbarpolu		0.52				0.49			0.18***						0.09***	
		(0.14–1.96)				(0.19–1.25)			(0.09–0.35)						(0.04–0.22)	
Grand Bassa		0.26*				2.06			0.49						0.29	
		(0.06–1.16)				(0.22–18.92)			(0.13–1.84)						(0.05–1.61)	
Grand Cape Mount		0.78				1.25										
		(0.25–2.42)				(0.48–3.26)										
Grand Gedeh		1.33				11.66*			1.62						0.95	
		(0.34–5.26)				(0.98–138.80)			(0.64–4.09)						(0.17–5.25)	
Grand Kru		1.45				2.89**										
		(0.55–3.85)				(1.12–7.41)										
Lofa		0.70				0.98			1.14						0.61	
		(0.30–1.62)				(0.41–2.32)			(0.70–1.86)						(0.29–1.25)	
Margibi		1.00				3.95			1.81						1.01	
		(0.21–4.80)				(0.38–41.47)			(0.82–3.99)						(0.35–2.91)	
Maryland		0.54*				1.35			3.41**						2.82**	
		(0.28–1.07)				(0.63–2.91)			(1.21–9.60)						(1.18–6.73)	
Montserrado		2.62				15.62**			2.05**						1.24	
		(0.63–10.78)				(1.72–142.29)			(1.11–3.77)						(0.66–2.34)	
Nimba		0.40				0.60			0.50						0.70	
		(0.12–1.35)				(0.17–2.09)			(0.19–1.28)						(0.28–1.71)	
River Gee		1.79				2.37***			5.36***						4.94***	
		(0.79–4.05)				(1.26–4.48)			(3.11–9.24)						(2.18–11.19)	
Rivercess		0.37**				0.58										
		(0.17–0.79)				(0.23–1.45)										
Sinoe		0.90				1.97			1.53						1.24	
		(0.32–2.51)				(0.60–6.44)			(0.63–3.69)						(0.54–2.82)	
Observations	1300 1233	1233	713	587	520	520	979	939	939	422	422	422	558	519	519	

Coefficients presented are odds ratios with confidence intervals in parentheses. Logistic regression was run using survey weights provided by Afrobarometer, post-stratified using province- and county-specific population figures, and Taylor-linearized variance estimation. Two columns for SL rural are missing because the logistic regression model would not converge with the addition of community SES, community education and regional dummy variables.

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

References

Abramowitz, S. A., McLean, K. E., McKune, S. L., Bardosh, K. L., Fallah, M., Monger, J., et al. (2015). Community-centered responses to Ebola in urban Liberia: The view from below. *PLoS Neglected Tropical Diseases, 9*, e0003706. https://doi.org/10.1371/journal.pntd.0003706.

Afrobarometer. (2016). *Afrobarometer*.

de Alencar Ximenes, R. A., de Fatima Pessoa Militao de Albuquerque, M., Souza, W. V., Montarroyos, U. R., Diniz, G. T. N., Luna, C. F., et al. (2009). Is it better to be rich in a poor area or poor in a rich area? A multilevel analysis of a case-control study of social determinants of tuberculosis. *International Journal of Epidemiology, 38*, 1285–1296. https://doi.org/10.1093/ije/dyp224.

Alexander, K. A., Sanderson, C. E., Marathe, M., Lewis, B. L., Rivers, C. M., Shaman, J., et al. (2015). What factors might have led to the emergence of Ebola in West Africa? *PLoS Neglected Tropical Diseases, 9*, e0003652. https://doi.org/10.1371/journal.pntd.0003652.

Amouzou, A., & Hill, K. (2004). Child mortality and socioeconomic status in sub-Saharan Africa. *African Population Studies*.

Anderson, M. L. (2012). Multiple inference and gender differences in the effects of early intervention: A reevaluation of the Abecedarian, Perry Preschool, and early training projects. *Journal of the American Statistical Association, 103*, 1481–1495. https://doi.org/10.1198/016214508000000841.

Blair, R. A., Morse, B. S., & Tsai, L. L. (2017). Public health and public trust: Survey evidence from the Ebola virus disease epidemic in Liberia. *Social Science & Medicine*. https://doi.org/10.1016/j.socscimed.2016.11.016.

Bogoch, I. I., Creatore, M. I., Cetron, M. S., Brownstein, J. S., Pesik, N., Miniota, J., et al. (2014). Assessment of the potential for international dissemination of Ebola virus via commercial air travel during the 2014 West African outbreak. *Lancet*. https://doi.org/10.1016/S0140-6736(14)61828-6.

Bowles, J., Hjort, J., Melvin, T., & Werker, E. (2015). Ebola, jobs and economic activity in Liberia. *Journal of Epidemiology & Community Health*. https://doi.org/10.1136/jech-2015-205959, 2015–205959.

Bucchianeri, G. W. (2010). Is SARS a poor man's disease? Socioeconomic status and risk factors for SARS transmission. *Forum for Health Economics & Policy, 13*. https://doi.org/10.2202/1558-9544.1209.

Chowell, G., & Nishiura, H. (2014). Transmission dynamics and control of Ebola virus disease (EVD): A review. *BMC Medicine, 12*, 196. https://doi.org/10.1186/s12916-014-0196-0.

Dunbar, R. I. M. (1993). Coevolution of neocortical size, group size and language in humans. *Behavioral and Brain Sciences, 16*, 681–694. https://doi.org/10.1017/S0140525X00032325.

Evans, D. K., Goldstein, M., & Popova, A. (2015). Health-care worker mortality and the legacy of the Ebola epidemic. *The Lancet Global Health, 3*, e439–e440. https://doi.org/10.1016/S2214-109X(15)00065-0.

Fallah, M. P., Skrip, L. A., Gertler, S., Yamin, D., & Galvani, A. P. (2015). Quantifying poverty as a driver of Ebola transmission. *PLoS Neglected Tropical Diseases, 9*, e0004260. https://doi.org/10.1371/journal.pntd.0004260.

Feinstein, J. S. (1993). The relationship between socioeconomic status and health: A review of the literature. *The Milbank Quarterly, 71*, 279–322.

Filmer, D., & Pritchett, L. H. (2001). Estimating wealth effects without expenditure data—or tears: An application to educational enrollments in States of India*. *Demography, 38*, 115–132. https://doi.org/10.1353/dem.2001.0003.

Fox, A. M. (2012). The HIV-poverty thesis re-examined: Poverty, wealth or inequality as a social determinant of HIV infection in sub-saharan Africa? *Journal of Biosocial Science, 44*, 459–480. https://doi.org/10.1017/s0021932011000745.

Fuller, T. L., Calvet, G., Estevam, C. G., Angelo, J. R., Abiodun, G. J., Halai, U.-A., et al. (2017). Behavioral, climatic, and environmental risk factors for Zika and Chikungunya virus infections in Rio de Janeiro, Brazil, 2015-16. *PLoS One, 12*, e0188002. https://doi.org/10.1371/journal.pone.0188002.

Grépin, K. A. (2015). International donations to the Ebola virus outbreak: Too little, too late? *BMJ, 350*, h376. https://doi.org/10.1136/bmj.h376.

Grépin, K. A., & Bharadwaj, P. (2015). Secondary education and HIV infection in Botswana. *The Lancet Global Health, 3*, e428–e429. https://doi.org/10.1016/S2214-109X(15)00050-9.

Hargreaves, J. R., Bonell, C. P., Boler, T., Boccia, D., Birdthistle, I., Fletcher, A., et al. (2008). Systematic review exploring time trends in the association between educational attainment and risk of HIV infection in sub-Saharan Africa. *AIDS, 22*, 403–414. https://doi.org/10.1097/QAD.0b013e3282f2aac3.

Hargreaves, J. R., Morison, L. A., Chege, J., Rutenburg, N., Kahindo, M., Weiss, H. A., et al. (2002). Socioeconomic status and risk of HIV infection in an urban population in Kenya. *Tropical Medicine and International Health, 7*, 793–802. https://doi.org/10.1046/j.1365-3156.2002.00943.x.

Harman, S. (2016). Ebola, gender and conspicuously invisible women in global health governance. *Third World Quarterly, 37*, 524–541. https://doi.org/10.1080/01436597.2015.1108827.

Helleringer, S., Grépin, K. A., & Noymer, A. (2015). Ebola virus disease in West Africa — the first 9 months. *New England Journal of Medicine, 372*, 188–189. https://doi.org/10.1056/NEJMc1413884.

Heymann, D. L. (2005). *Social, behavioural and environmental factors and their impact on infectious disease outbreaks* (Vol. 26, pp. 133–139). https://doi.org/10.1057/palgrave.jphp.3200004.

International Ebola Response Team, Agua-Agum, J., Ariyarajah, A., Aylward, R. B., Bawo, L., Bilivogui, P., et al. (2016). Exposure patterns driving Ebola transmission in West Africa: A retrospective observational study. *PLoS Medicine, 13*, e1002170. https://doi.org/10.1371/journal.pmed.1002170.

Krauer, F., Gsteiger, S., Low, N., Hansen, C. H., & Althaus, C. L. (2016). Heterogeneity in district-level transmission of Ebola virus disease during the 2013-2015 epidemic in West Africa. *PLoS Neglected Tropical Diseases, 10*, e0004867. https://doi.org/10.1371/journal.pntd.0004867.

Link, B., & Phelan, J. (1995). Social Conditions As Fundamental Causes of Disease. *Journal of Health and Social Behavior, 35*, 80. https://dx.doi.org/10.2307/2626958.

Mamelund, S. E. (2018). 1918 pandemic morbidity: The first wave hits the poor, the second wave hits the rich. *Influenza and Other Respiratory Viruses, 12*, 307–313. https://doi.org/10.1111/irv.12541.

Marmot, M. (2005). Social determinants of health inequalities. *Lancet, 365*, 1099–1104. https://doi.org/10.1016/S0140-6736(05)71146-6.

Marmot, M. (2007). *The status syndrome*. Macmillan.

Marmot, M. (2007). Achieving health equity: From root causes to fair outcomes. *The Lancet, 370*, 1153–1163.

Mohd, H. A., Al-Tawfiq, J. A., & Memish, Z. A. (2016). Middle East Respiratory Syndrome Coronavirus (MERS-CoV) origin and animal reservoir. *Virology Journal, 13*, 87. https://doi.org/10.1186/s12985-016-0544-0.

Morse, B., Grépin, K. A., Blair, R. A., & Tsai, L. (2016). Patterns of demand for non-Ebola health services during and after the Ebola outbreak: Panel survey evidence from Monrovia, Liberia. *BMJ Global Health, 1*, e000007. https://doi.org/10.1136/bmjgh-2015-000007.

Nkangu, M. N., Olatunde, O. A., & Yaya, S. (2017). The perspective of gender on the Ebola virus using a risk management and population health framework: A scoping review. *Infectious Disease Poverty, 6*, 135. https://doi.org/10.1186/s40249-017-0346-7.

Parkhurst, J. O. (2010). Understanding the correlations between wealth, poverty and human immunodeficiency virus infection in African countries. *Bulletin of the World Health Organization, 88*, 519–526. https://doi.org/10.2471/BLT.09.070185.

Phua, K.-L., & Lee, L. K. (2005). Meeting the challenge of epidemic infectious disease outbreaks: An agenda for research. *PubMed - NCBI, 26*, 122–132. https://doi.org/10.1057/palgrave.jphp.3200001.

Pigott, D. M., Golding, N., Mylne, A., Huang, Z., Henry, A. J., Weiss, D. J., et al. (2014). Mapping the zoonotic niche of Ebola virus disease in Africa. *eLife, 3*, e04395. https://doi.org/10.7554/eLife.04395.

Poirier, M. J. P., Grignon, M., Grépin, K. A., & Dion, M. L. (2018). Transnational wealth-related health inequality measurement. *SSM - Population Health*. https://doi.org/10.1016/j.ssmph.2018.10.009.

Richards, P., Amara, J., Ferme, M. C., Kamara, P., Mokuwa, E., Sheriff, A. I., et al. (2015). Social pathways for Ebola virus disease in rural Sierra Leone, and some implications for containment. *PLoS Neglected Tropical Diseases, 9*, e0003567. https://doi.org/10.1371/journal.pntd.0003567.

Rutstein, S. O., & Johnson, K. (2004). The DHS wealth index [WWW document]. *ORC Macro*. URL http://www.measuredhs.com/pubs/pdf/CR6/CR6.pdf accessed 7.19.13.

Shi, Z., & Hu, Z. (2008). A review of studies on animal reservoirs of the SARS coronavirus. *Virus Research, 133*, 74–87. https://doi.org/10.1016/j.virusres.2007.03.012.

Stanturf, J. A., Goodrick, S. L., Warren, M. L., Jr., Charnley, S., & Stegall, C. M. (2015). Social vulnerability and Ebola virus disease in rural Liberia. *PLoS One, 10*, e0137208. https://doi.org/10.1371/journal.pone.0137208.

Valeri, L., Patterson-Lomba, O., Gurmu, Y., Ablorh, A., Bobb, J., Townes, F. W., et al. (2016). Predicting subnational Ebola virus disease epidemic dynamics from sociodemographic indicators. *PLoS One, 11*, e0163544. https://doi.org/10.1371/journal.pone.0163544.

Wilkinson, A., & Fairhead, J. (2016). Comparison of social resistance to Ebola response in Sierra Leone and Guinea suggests explanations lie in political configurations not culture. *Critical Public Health, 27*, 14–27. https://doi.org/10.1080/09581596.2016.1252034.

World Health Organization. (2016). *Ebola virus disease: Situation report*. WHO.