

# ScholarWorks@GSU

## Socioeconomic Factors and the 2014-16 Ebola Virus Disease Outbreak in Guinea, Liberia, and Sierra Leone

Authors	Mun, Elena
Citation	Mun, Elena. "Socioeconomic Factors and the 2014-16 Ebola Virus Disease Outbreak in Guinea, Liberia, and Sierra Leone." Thesis, Georgia State University, 2017. <a href="https://doi.org/10.57709/10115029">https://doi.org/10.57709/10115029</a>
DOI	<a href="https://doi.org/10.57709/10115029">https://doi.org/10.57709/10115029</a>
Download date	2026-05-15 17:09:27
Link to Item	<a href="https://hdl.handle.net/20.500.14694/9561">https://hdl.handle.net/20.500.14694/9561</a>

## ABSTRACT

### SOCIOECONOMIC FACTORS AND THE 2014-16 EBOLA VIRUS DISEASE OUTBREAK IN GUINEA, LIBERIA, AND SIERRA LEONE

By

Elena Mun

April 21, 2017

**INTRODUCTION:** Ebola virus disease (EVD) is an infectious disease transmitted by close contact with an estimated case fatality rate fluctuating around 50%. The most affected countries by the 2013-16 West African Ebola outbreak were Guinea, Liberia, and Sierra Leone. These countries reported a total of 28616 probable, suspected and confirmed cases. However, we are still learning about the sociodemographic factors that contributed to the outbreak characteristics at the subnational level.

**METHODS:** Data were collected from the World Health Organization, Demographic Health Surveys, and Global Data Lab for 37 districts (8 for Guinea, 15 for Liberia, and 14 for Sierra Leone). The outcome of interest was epidemic size at the district level for Guinea, Liberia, and Sierra Leone (cumulative number of EVD patient confirmed and probable cases). Socio-demographic predictors included household density, sanitation level, mobility, and wealth status. We also controlled for the timing of the start of the outbreak across districts. Pearson's correlation and multiple linear regression were employed in our analyses. Model building was informed by a review of the relevant literature. Sensitivity analyses were conducted to assess the impact of potential outliers.

**RESULTS:** In the final multivariable regression model, wealth status and household density were positively associated with the epidemic size while sanitation level and the

difference in the outbreak start dates were negatively associated with the outcome. These results did not change in the sensitivity analyses. The regression model explained 57% of the variance in epidemic size (Adj R-Sq=0.57), with the largest contribution from the international wealth index (semi-partial R-square=0.22).

**CONCLUSION:** District sociodemographic characteristics such as household density, wealth and sanitation levels contributed to the EVD outbreak in Guinea, Liberia, and Sierra Leone, which is in agreement with recent studies. However, further research should consider other sociodemographic indicators as well as the role of migration and connectivity among regions.

SOCIOECONOMIC FACTORS AND THE 2014-16 EBOLA VIRUS DISEASE OUTBREAK  
IN GUINEA, LIBERIA, AND SIERRA LEONE

by

ELENA MUN

A Thesis Submitted to the Graduate Faculty  
of Georgia State University in Partial Fulfillment  
of the  
Requirements for the Degree

MASTER OF PUBLIC HEALTH

ATLANTA, GEORGIA  
30303

APPROVAL PAGE

SOCIOECONOMIC FACTORS AND THE 2014-16 EBOLA VIRUS DISEASE OUTBREAK  
IN GUINEA, LIBERIA, AND SIERRA LEONE

by

ELENA MUN

Approved:

Gerardo Chowell, PhD  
Committee Chair

Linh Dinh, MHP  
Committee Member

April 21, 2017

## Author's Statement Page

In presenting this thesis as a partial fulfillment of the requirements for an advanced degree from Georgia State University, I agree that the Library of the University shall make it available for inspection and circulation in accordance with its regulations governing materials of this type. I agree that permission to quote from, to copy from, or to publish this thesis may be granted by the author or, in his/her absence, by the professor under whose direction it was written, or in his/her absence, by the Associate Dean, School of Public Health. Such quoting, copying, or publishing must be solely for scholarly purposes and will not involve potential financial gain. It is understood that any copying from or publication of this dissertation which involves potential financial gain will not be allowed without written permission of the author.

Elena Mun

## TABLE OF CONTENTS

LIST OF TABLES.....	8
LIST OF FIGURES.....	8
INTRODUCTION.....	9
LITERATURE REVIEW.....	10
METHODS AND PROCEDURES.....	14
RESULTS.....	16
DISCUSSION AND CONCLUSION.....	19
TABLES AND FIGURES.....	29

## LIST OF TABLES

**Table 1.** EVD cases in Guinea, Liberia, and Sierra Leone (WHO patient data, 2014-2015)

**Table 2.** Social demographic characteristics and EVD cases in Guinea, Liberia, and Sierra Leone

**Table 3.** Correlation between the epidemic size and sociodemographic and epidemics characteristics (Pearson's Correlation Coefficient,  $N = 37$ )

**Table 4.** Multicollinearity Diagnostics ( $N=37$ )

**Table 5.** Multivariable regression model for the outcome and predictors (Results of sequentially modeling fitting,  $n=36$ )

**Table 6.** Results of the final model ( $n=36$ )

## LIST OF FIGURES

**Figure 1.** Ebola patient data cases in Guinea, Liberia, and Sierra Leone (2014-2015)

**Figure 2.** EVD patient cases in Guinea, Liberia, and Sierra Leone (2014-2015)

**Figure 3.** International Wealth Index Guinea, Liberia, and Sierra Leone

**Figure 4.** Patient cases in Guinea, Liberia, and Sierra Leone

**Figure 5.** Road system Guinea, Liberia, and Sierra Leone

## INTRODUCTION

In August 2005, West Africa Ebola disease virus (EVD) outbreak was classified as a Public Health Emergency (WHO, 2016). Guinea, Liberia, and Sierra Leone of the most affected by EVD areas in this region. These counties altogether reported 28616 EVD suspected, probable, and confirmed cases (WHO, 2016). Durations and intensiveness of the outbreaks were different among the countries (Figure 1). Guinea had the longest Ebola outbreak than Liberia and Sierra Leone but Sierra Leone's outbreak was most intensive (Figure 1 and 4).

Although EVD spreads through person-to-person transmission, socio-demographic factors could contribute to the outbreak as well. There were few studies that implicated socioeconomic status and poor sanitation in EVD epidemic (Krauer, 2016; Valeri, 2016). The studies confirmed social demographic factors such as population density, household, and education played a role in EVD spread in West Africa. However, a relation between the difference in the starts of the outbreaks at the district level and EVD was not accounted for in the articles.

The purpose of this research is to examine the contribution of socioeconomic determinants to the epidemic size of EVD outbreaks in Guinea, Liberia, and Sierra Leone. This ecological study will use the data collected through 37 districts in these West African Countries. The socioeconomic factors will be selected based on the literature review.

## LITERATURE REVIEW

Transmission network during the EVD epidemic in Sierra Leone in 2014 – 2015 was found to be a possible source of the EVD spread (Yang et al., 2015). Results from a spatial-temporal inference model suggested a local household density was associated with EVD transmission (Yang et al., 2015). The more individuals represented larger households in the population, the larger proportion of people with at least one EVD case this population had. A study of transmission chains in N'Zerekore in Guinea from August 2014 to February 2015 indicated that household was the primary condition for EVD for both urban and rural chains (Valencia et al., 2016). Most cases (61%) were linked with a household transmission, 32% with household or burial, and 7% with hospital (Valencia et al., 2016).

Socioeconomic status was another factor associated with the EVD epidemics' spread in Guinea, Liberia, and Sierra Leone (Krauder et al., 2016). A wealth health index indicating socioeconomic level was statistically significant associated with the basic reproductive number ( $\beta= 0.37$ ,  $p=0.017$ ). This index increased when the number of people living in a household were large (Krauder et al., 2016).

Mobility and migration were mentioned as drivers of EVD in West Africa. Different sources showed people moving within and out of the countries could increase the risk of EVD transmission. The United Nations Department of Economic and Social Affairs and the United Nations International Children's Emergency Fund (2013) reported more than 100000 Liberians and 200000 Sierra Leoneans determined Guinea as their destinations. At that time, people from Guinea were also traveling to Liberia and Sierra Leone (UNDESA, 2013). The phylogenetic analysis (Backer & Wallinga, 2016) showed EVD outbreak in Liberia resulted from within-country transmission whereas Guinea's EVD cases were linked to Sierra Leone. Moreover, the analysis revealed Liberia contributed to Guinea's epidemic since there were multiple

introductions from this country to Guinea. The transmission chain defined that the road of Ebola virus started from Sierra Leone and reached Conakry district in Guinea. The spatiotemporal modeling results illustrated the migration to other districts were between 4% - 10% while the migration to other countries could reach 23% (Burghardt et al.,2016). Burghardt et al. (2016) developed this model to examine the EVD spread along and between districts in Guinea, Sierra Leone, and Liberia. The researchers used WHO confirmed and probable cases reported till June 2015 to test the model.

There were articles that mentioned the linkage of global migration and EVD. Rodriguez-Morales et al. (2015) projected there was a possibility to spread EDV beyond West Africa Region, for instance to Latin America. Other findings supported travelers who came to the U.S. from EVD affected countries had a risk to contract Ebola virus (DeVries et al., 2016). In total, 729 travelers were monitored. Among them, 93% people arrived from Liberia, 4% from Sierra Leone, and 3% from Guinea. Liberian nationals made up 61%.

A number of studies aimed to find reasons of migration in the countries with a high burden of EVD. A case study in Fogbo in Sierra Leone (Richards, 2015) emphasized the linkage between long- distance social networking and migration processes. Searching for jobs and education and distance to markets motivated people to leave their places. One EVD outbreak was initiated by a student who visited relatives in Kailahun during the school break (Richards, 2015). The cultural bounds created a Koindu network of people who spoke Kissi language, but were divided into three different states during the colonial epoch, also resulted in a rapid spread of EVD. The WHO (2015) defined West Africa as a region with a high population mobility that was a consequence of poverty and different social-economic situations. Countries with higher economic status were targets for people who intended to improve their living conditions.

A poor economic situation could catalyze Ebola virus dissemination not only through people's movements but also through limited access to food, education, and decent living conditions. In Guinea, people participated in the study (Delamou et al., 2017) identified their social-economic status as poor (90%) and their work settings as less favorable (79%). Only 68.6% of the respondents had education from secondary level to higher level (Delamou et al., 2017). During this cross-sectional study, Delamou et al. (2017) interviewed 121 EVD survivors in Conakry and Coyah districts in Guinea in 2015. The researchers applied the Mc Neman chi-square test to the variable analysis. In 1.5 (95% CI: 1.4–1.6) and 3.5 (95% CI: 3.1–3.9) cases, persons with middle or low socioeconomic status were the source of EVD secondary cases (Mosoka et al. 2015). Consequently, the social- economic factor impacted the Ebola virus spread throughout Monteserrado County in Sierra Leone. Mosoka et al. (2015) analyzed 4437 cases of EDV in Montserrado county of Sierra Leone from February to December 2014 to discover a relationship between social-economic status and the Ebola outbreak. Symptom onset, death, hospitalization, and residency were evaluated across three categories of social-economic status (high, middle, and low).

Ordaz-Németh et al. (2017) discovered that indirect contact with contaminated bushmeat could cause the virus dissemination. The bushmeat consumption depended on economic status in Liberia. The study results illustrated that people with higher economic status reduced bushmeat consumption less compared to people with lower economic status (Ordaz-Németh et al., 2017). Although Liberians decreased their frequency of daily meals, the bushmeat preferences did not change (Ordaz-Németh et al., 2017). To answer the research question, the investigators collected the data from a nationwide chimpanzee and large mammal survey from 2010 to 2012 and a

follow-up nationwide interview survey on socio-economic status and natural resource use of Liberian households during the Ebola crisis in 2015.

Sanitation level may have impacted EVD epidemic as well. Ratnapradipa (2015) suggested water supplies as a potential source of infection since the Ebola virus could be present in human fluids. Edmunds et al. (2016) concluded adequate infection control measures such as protective equipment, hand hygiene, and disinfection could reduce EVD burden. The United Nations Development Program (2014) reported poor sanitation with limited access to health care services especially in remote and rural areas increased the EVD incidence and deaths in Liberia.

Another issue that could aggravate the EVD situation was an inadequate health care system that also was linked with low economic situation. In Democratic Republic of Congo and Uganda, reduced health care access was a key factor for the EVD dissemination. The increased rate of hospitalization led to decreased epidemic size (Legrand et al., 2007). A mathematical modeling was used to understand how the EVD epidemic size changed by transmissions in a community, hospitals, and traditional burial practice in Democratic Republic of Congo and Uganda (Legrand et al., 2007). In Guinea, around 30% of households were under satisfied with health care services (UNDP, 2014). The country experienced a lack of human resources in health care. Only 89 health workers served 100000 people in Guinea. In Liberia, the health sector suffered from insufficient financial resources, old technologies, poor infrastructure, and supply management (UNDP, 2014).

## METHODS AND PROCEDURES

We used the ecological study design where a district was the study unit. The outcome of interest was the epidemic size. According to the literature review, we decided to choose the following predictors: household density, mobility, sanitation and wealth levels. We used SAS 9.4 (SAS Institute, Cary, North Carolina) to run statistical procedures, Excel 2016 and QGIS 2.18.3 to create figures and maps.

We analyzed secondary data for Guinea, Liberia, and Sierra Leone, including 37 units (8 regions for Guinea, 15 counties for Liberia, and 14 districts for Sierra Leone). We collected information on EVD cumulative probable and confirmed cases and the time when the first case occurred from the World Health Organization (WHO) patient database over 2014-2015. Patient database was chosen since they were considered more reliable compared to other sources of information (Camacho et al., 2015). The Demographic Health Surveys (DHS) were a source for social demographic factors: household density and sanitation. These databases were referred to for 2012 for Guinea, 2013 for Liberia and Sierra Leone. The DHS' individual records were used to obtain the information about mobility. The most suitable variable to assess migration was the number of people who made trips the previous year. The mobility data for Liberia were available for 2007. International Wealth Indexes (IWI) was used as the proxy of socioeconomic status since IWI was the more competitive measurement than wealth index available in DHS (Smits & Steendijk, 2015). Data of IWI were derived from the Global Data Lab' s website and the supplemental materials of Valeri et al. (2016) paper.

The epidemic size was log-transformed to approximate to the normal distribution. The log-transformed epidemic size (ESm) was used as the outcome variable in subsequent regression analyses. The household density (HV013) implied a total number of *de facto* household members

gave the number of household members that slept in the household the previous night, including visitors. To measure the mobility, we created the new variable “Trips” from the V167. The “Trips” implied the number of people who replied they had trips last year. Sanitation level was included in our analysis using time to reach the nearest drinking water source (in minutes). “Timelag” reflected the difference in weeks between the starting time of epidemic in the district relative to the onset of first epidemic in three countries (30 December 2013 to 05 January 2014). As “Timelag” was supposed to be associated with the size of outbreak, we included this variable in analysis to control for its confounding effect.

We first examined the bivariate association between variables using Pearson correlation. Following that, linear regression models were sequentially fitted to investigate the contribution of each predictor when included into the model, and to select the best fitted model. Assumptions of linear regression model were checked throughout the model building process. Sensitivity analysis was also conducted for the impact of outliers. We considered 0.05 as the level of significance.

## **RESULTS**

### **Descriptive statistics**

The epidemic characteristics varied across the countries and districts (Table 1 and Figure 2). Sierra Leone had the largest mean of the cumulative Ebola patient cases (847.07) and the highest SD (90.27) that was more than the average values. The means and SDs for Guinea and Liberia were below the average mean (558.3) and SD (773.96). Timelag was accounted for 24.22 weeks (Table 2).

On average, 6 people stayed the previous night in the household. It took about 2 hours to reach the drinking water source (Table 2). Over 200,000 respondents made trips the previous year. The economic status in households was less than 50 (Table 2). The distribution of these socioeconomic factors was different at the country level (Figure 3). IWI made up 35.36 out of 100 in Guinea and did not exceed 25 in Liberia and Sierra Leone. The larger the country population was, the more people made trips the previous year. In Guinea with the population over 10 million people, 431974 respondents confirmed trips while in Sierra Leone where around 7 million people were living 195668 traveled. In Liberia with 3.5 million population, 86971 inhabitants had trips during last year. Access to the drinking water was the indicator of sanitation level. The time given to the water source ranged from 45.69 to 630.52 minutes. The Liberians spent less time on reaching the drinking water spot than people in Guinea and Sierra Leone (the mean in minutes was 98.52 vs. 248.80 and 124.36).

### **Correlation analysis**

The bivariate correlation analysis (Table 3) between ESm and the predictors showed a positive correlation with IWI and Trips. Pearson's coefficients with p value of 0.05 were equaled to 0.40 for IWI and 0.37 for Trips. It was found that Timelag was negatively associated with the

outcome (-0.6,  $p < 0.05$ ). Hereafter, we examined how the covariates were related to each other. Household density increased together with Trips, and Sanitation level (0.51 and 0.37,  $p < 0.05$ ). IWI was strongly correlated with Sanitation level (0.86,  $p < 0.05$ ) and less correlated with Trips (0.53,  $p < 0.05$ ). Timelag was found negatively correlated with IWI and Trips ( $p < 0.05$ ). On the contrary, there was a positive correlation between Sanitation level and IWI (0.86 and 0.37,  $p < 0.05$ ).

### **Multiple linear regression**

We used sequential modelling fitting to define the most appropriate model to assess the relationship between the epidemic size and socioeconomic factors. We started the modeling fitting with IWI, then sequentially added household density, sanitation level, Timelag, and Trips. We compared 5 models (Table 5) and selected the model 4. The model 4 showed the large enough R squared than the previous three models ( $R^2$  for the model 4 =0.61, 0.48 for the model 3, 0.21 for the model 2, and 0.16 for the model 1). Although the model 5 had the largest  $R^2$  (0.65), the adding of Trips was insignificant ( $p > 0.05$ ).

The final multivariable regression model (Table 6) included IWI, household density, Timelag, and Sanitation level. All assumptions of linear regression were satisfied (see Table 4. for multicollinearity assumption checking). The negative association between ESm and Sanitation level was noticed in the multivariable regression analysis ( $\beta = -0.02$ ,  $p < 0.05$ ) whereas there was no relation in the correlation analysis. The relationship of other predictors (Household density, IWI, and Timelag) and the outcome was statistically significant ( $p < 0.05$ ) in both correlation and regression analyses. The model explained 57% the variance in the epidemic size of EDV outbreaks in studied regions (adjusted R- squared=0.57).

### **Sensitivity analysis for outliers**

In our sensitivity analysis, we identified one outlier and removed Kankan district that had an extreme value (1.98). The direction of the association between the epidemic size and the predictors did not change.

## DISCUSSION

In our study, we examined the association between the EVD epidemic size and socioeconomic determinants in Guinea, Liberia, and Sierra Leone. We looked at the descriptive statistics, multicollinearity, outlier presence, and applied the bivariate correlation and multiple linear regression analysis. We aimed to find the factors attributable to the EVD and the sociodemographic model that could affect the EVD situation in West Africa. We determined the relationship between the epidemic size and household density, socioeconomic status, difference in the epidemic starts, and sanitation level was significant when these factors were in the model altogether. In some cases, the association between the dependent and independent variables found in the correlation analysis was not noticed in the multivariable regression.

We found out that the socioeconomic factor was correlated with the epidemic size and was included into the multivariable regression model (Tables 3 and 6). The correlation analysis confirmed the IWI was linked with sanitation level too that might be explained by the composition. The index encompassed components related to sanitation level such as access to water and quality of water sources. The positive correlation between IWI and Trips might be possible because people tended to change poor economic setting and obtain a job and education (Richards, 2015). The road system in this part of West African Region was quite expanded that could facilitate migration (Figure 5). Other researchers also found the relationship between the EVD and people's wealth in their studies (Krauer, 2016; Valeri, 2016). They determined the IWI and the wealth index were linked to EVD in Guinea, Liberia, and Sierra Leone.

Sanitation level was one of the variables that was not correlated with the epidemic size but was included into the model. Krauer et al. (2016) did not discover any association between the EDV basic reproductive number ( $R_0$ ) and the time taken to reach the nearest watercourse.

However, other investigators (Ratnapradipa, 2015; Edmunds, 2016) considered access to clean water as a possible factor for the virus transmission. Besides, historically, water sources attracted people. They settled down near water sources that became places for social interaction (Window seat, 2004).

We had controversial results on household density that was not correlated with the epidemic size in the bivariate analysis but was a significant predictor for the model. Adams & Valencia (2016) identified the household density played a role in the EVD outbreaks in West Africa. Adams (2016) concluded a risk of the Ebola virus' transmission was higher in the larger size household. Valencia et al. (2016) defined the household transmission was the most frequent reported settings where persons were infected with the Ebola virus. Nevertheless, the results of Krauer's study (2016) did not show an association between household density and the EVD  $R_0$  in the univariable linear regression model. In this study the household density implied the number of people per bedroom. In our study the household density presented the number of people stayed overnight in the house. When the household density was together with socioeconomic status and Timalag, the p-value was small enough ( $p < 0.05$ ) to say the household density was the factor for EVD. We could assume that this effect was a result of the contribution of wealth, education level, and cultural specifics to household. Household members' background might have been more important than the number of persons stayed in the household.

During our analysis, we studied the possible relationships between mobility and the epidemic size. There were findings supported migration and people's movements within and outside of the countries could lead to the EVD spread (Backer & Wallinga, 2016). We defined the number of people who made at least one trip during last 12 months as an indicator for mobility. We noted the positive correlation between the epidemic size and the number of

travelers while this indicator did not fit the model. The effect of this variable was not significant ( $p > 0.05$ ).

We detected the statistical difference in the time when the epidemics started (Timelag) and the total number of the EVD cases (Table 3 and 6). The epidemic size and Timelag was negatively correlated ( $r = -0.60$ ,  $p < 0.05$ ). This covariate was also included into the multivariable regression model as the factor that could influence the EVD epidemic in Guinea, Liberia, and Sierra Leone. We conveyed the influence could relate to the EVD control measures that were introduced in the districts at the different time of the EVD outbreaks. Barbarossa et al. (2015) projected that even a delay in few weeks could double the total number of the EVD cases. The WHO (2015) informed the intervention were launched in October 2014 whereas the first case was reported in March 2014.

## **Limitation**

The interpretation of our study results could be limited because of the following reasons. First, we relied on the secondary available data the quality of which may differ and may depend on the countries' contexts. Generally, the health surveillance systems were insufficient to detect and accurately report the EVD cases in Guinea, Liberia, and Sierra Leone. The number of the EVD cases confirmed were an estimation and could encompass double counting. The patient data could change over time due to the data review. The report time unite (a week) represented the estimated report date. We did not exclude underreporting of the EVD cases (Backer & Wallinga, 2016). The DHS data were subject to recall and reporting biases (Boerma & Sommerfelt, 1993). We used the DHS datasets from the different periods (2007, 2012, and 2013) that did not coincide with the time of EVD outbreaks (2014 - 2015) in Guinea, Liberia, and Sierra Leone. The sociodemographic profiles of the countries and migration's dynamic might slightly alter.

We chose the number of people who made at least one trip over last year as a proxy for mobility and migration of people. However, the DHS data could not allow us to destinations and distinguish whether the trips were within or out of the districts and the countries. Due to the limitation of the questions covered by the DHS, we could not assess the association between traditions as funeral practices, food preferences, and family's relationship at the district level.

## **Future research**

The future research will need to understand how a geographic expansion of EVD depends on sociodemographic factors. Once the DHS updated sociodemographic data are available the comparison analysis could be conducted to study whether and why the social demographic characteristics changed before and after the EVD outbreaks in Guinea, Liberia, and Sierra Leone. Research at a person level data may help to shed light on the study of this association. If the data collection enables to trace the EVD case and link it with sociodemographic status, behavior practices, and location, the limitations that ecological studies have, could be minimized. Another comparative analysis could look at the sociodemographic characteristics classifying the districts into lowly- and highly-affected with the EVD zones.

West African Region is culturally diverse (WHO, 2016) the examination of the cultural diversity and its influence on the EVD epidemics should be considered for the future research. The findings will help to develop more effective approaches to the Ebola prevention.

Environmental risk factors as poor hygiene and a low sanitation level are modifiable. Additional studies are needed to identify whether particular practices may cause the EVD contraction. Considering that our study result indicated the possible association between the EVD epidemic size and sanitation level in the multivariate regression but not in the correlation analysis, this uncertainty may be needed to investigate. Other factors related to sanitation level apart of the time taken on walking to drinking water source could be selected as independent variables.

Migration and mobility should be studied more carefully since people's movements may facilitate the Ebola virus transmission (Backer & Wallinga, 2016) and they are difficult to control. This phenomenon can be learned independently or together with other factors, for

instance, urbanicity, infrastructure, and geographic features. Rivas et al. (2010) noted highway network in Nigeria assisted infectious disease such as avian influenza to spread. We hypothesize road network and density might also contribute to the EVD epidemic. Destinations and transportation mean that people prefer to choose can be a part of the research as well.

Research in the Ebola virus disease vaccination has been done with the partnership of national authorities and world-leading research institutions, and there is progress in this field. Henao-Restrepo et al. (2017) reported rVSV-vectored vaccine had been successfully tested in Guinea. When there is sufficient amount of the data, a vaccination may be added as an independent variable to the regression model with sociodemographic and cultural characteristics of countries of the interest.

## **CONCLUSIONS**

Although West Africa has overcome the EVD outbreak, the region will remain the natural areal for the Ebola virus' circulation. Migration within and out of the countries will be an integral part of people living Guinea, Liberia, and Sierra Leone. Moreover, it is difficult to expect that sociodemographic situations will be rapidly improved. For this reason, understanding of the relationship between the EVD cases and social demographic determinants is important for the EVD control programs. Our study purposed to examine this association and found out household density, social-economic status, sanitation level and the difference in the time when outbreaks started in the district contributed to the EVD spread. The EVD problem is complex and requires much research to reexamine the association of the EVD and sociodemographic factors. The research findings could depict a full picture of the EVD transmission and help to consolidate efforts in the most effective Ebola control measures in West African Region.

## REFERENCES

- Adams, B., (2016). Household demographic determinants of Ebola epidemic risk, *Journal of Theoretical Biology*, Volume 392, 7 March 2016, Pages 99-106, ISSN 0022-5193, <http://dx.doi.org/10.1016/j.jtbi.2015.11.025>.  
(<http://www.sciencedirect.com/science/article/pii/S0022519315005809>)
- Backer, J. A., & Wallinga, J. (2016). Spatiotemporal Analysis of the 2014 Ebola Epidemic in West Africa. *Plos Computational Biology*, 12(12), 1-17.  
doi:10.1371/journal.pcbi.1005210
- Barbarossa, M. V., Dénes, A., Kiss, G., Nakata, Y., Röst, G., & Vizi, Z. (2015). Transmission Dynamics and Final Epidemic Size of Ebola Virus Disease Outbreaks with Varying Interventions. *Plos ONE*, 10(7), 1-21. doi:10.1371/journal.pone.0131398
- Boerma, JT., Sommerfelt AE. (1993), Demographic and health surveys (DHS): contributions and limitations, 1993;46(4):222-6.  
[http://apps.who.int/iris/bitstream/10665/51969/1/WHISQ\\_1993\\_46\\_4\\_p222-226\\_eng.pdf](http://apps.who.int/iris/bitstream/10665/51969/1/WHISQ_1993_46_4_p222-226_eng.pdf)
- Burghardt, K., Verzijl, C., Huang, J., Ingram, M., Song, B., & Hasne, M. (2016). Testing Modeling Assumptions in the West Africa Ebola Outbreak. *Scientific Reports*, 34598.  
doi:10.1038/srep34598
- C. Valencia, H. Bah, B. Fatoumata, G. Rodier, B. Diallo, M. Koné, C. Giese, L. Conde, E. Malano, T. Mollet, J. Jansa, D. Coulombier, B. Sudre, Network visualization for outbreak response: Mapping the Ebola Virus Disease (EVD) chains of transmission in N'Zérékoré, Guinea, *Journal of Infection*, Volume 74, Issue 3, March 2017, Pages 294-301, ISSN 0163-4453, <http://dx.doi.org/10.1016/j.jinf.2016.09.012>.  
(<http://www.sciencedirect.com/science/article/pii/S0163445316302833>)
- Camacho, A., Kucharski, A., Aki-Sawyer, Y., White, M. A., Flasche, S., Baguelin, M., ... Funk, S. (2015). Temporal Changes in Ebola Transmission in Sierra Leone and Implications for Control Requirements: a Real-time Modelling Study. *PLoS Currents*, 7, ecurrents.outbreaks.406ae55e83ec0b5193e30856b9235ed2.  
<http://doi.org/10.1371/currents.outbreaks.406ae55e83ec0b5193e30856b9235ed2>
- Delamou, A., Camara, B. S., Kolie, J. P., Guemou, A. D., Haba, N. Y., Marquez, S., & ... van Griensven, J. (2017). Profile and reintegration experience of Ebola survivors in Guinea: a cross-sectional study. *Tropical Medicine & International Health*, 22(3), 254-260.  
doi:10.1111/tmi.12825
- DeVries, A., Talley, P., Sweet, K., Kline, S., Stinchfield, P., Tosh, P., & Danila, R. (2016). Development and Implementation of the Ebola Traveler Monitoring Program and Clinical Outcomes of Monitored Travelers during October – May 2015, Minnesota. *Plos ONE*, 11(12), 1-11. doi:10.1371/journal.pone.0166797

- Edmunds, K. L., Abd Elrahman, S., Bell, D. J., Brainard, J., Dervisevic, S., Fedha, T. P., & ... Pond, K. (2016). Recommendations for dealing with waste contaminated with Ebola virus: a Hazard Analysis of Critical Control Points approach. *Bulletin Of The World Health Organization*, 94(6), 424-432. doi:10.2471/BLT.15.163931
- Henao-Restrepo, A. M., Camacho, A., Longini, I. M., Watson, C. H., Edmunds, W. J., Egger, M., & ... Kieny, M. (2017). Articles: Efficacy and effectiveness of an rVSV-vectored vaccine in preventing Ebola virus disease: final results from the Guinea ring vaccination, open-label, cluster-randomised trial (Ebola Ça Suffit!). *The Lancet*, 389505-518. doi:10.1016/S0140-6736(16)32621-6
- Krauer F, Gsteiger S, Low N, Hansen CH, Althaus CL (2016) Heterogeneity in District-Level Transmission of Ebola Virus Disease during the 2013-2015 Epidemic in West Africa. *PLoS Negl Trop Dis* 10(7): e0004867. doi:10.1371/journal.pntd.0004867
- Legrand, J., Grais, R. F., Boelle, P. Y., Valleron, A. J., & Flahault, A. (2007). Understanding the dynamics of Ebola epidemics. *Epidemiology And Infection*, 135(4), 610-621.
- Mosoka P, F., Laura A, S., Shai, G., Dan, Y., & Alison P, G. (2015). Quantifying Poverty as a Driver of Ebola Transmission. *Plos Neglected Tropical Diseases*, Vol 9, Iss 12, P E0004260 (2015), (12), e0004260. doi:10.1371/journal.pntd.000426
- Ordaz-Németh, I., Arandjelovic, M., Boesch, L., Gatiso, T., Grimes, T., Kuehl, H. S., & ... Junker, J. (2017). The socio-economic drivers of bushmeat consumption during the West African Ebola crisis. *Plos Neglected Tropical Diseases*, 11(3), 1-22. doi:10.1371/journal.pntd.0005450
- Ratnapradipa, K. (2015). 2014 Ebola Outbreak: Implications for Environmental Health Practice. *Journal Of Environmental Health*, 78(4), 18-21.
- Richards, P., Amara, J., Ferme, M. C., Kamara, P., Mokuwa, E., Sheriff, A. I., & ... Voors, M. (2015). Social Pathways for Ebola Virus Disease in Rural Sierra Leone, and Some Implications for Containment. *Plos Neglected Tropical Diseases*, 9(4), 1-15. doi:10.1371/journal.pntd.0003567
- Rivas, A. L., Chowell, G., Schwager, S. J., Fasina, F. O., Hoogesteijn, A. L., Smith, S. D., & ... Hyman, J. M. (2010). Lessons from Nigeria: the role of roads in the geo-temporal progression of avian influenza (H5N1) virus. *Epidemiology And Infection*, 138(2), 192-198. doi:10.1017/S0950268809990495
- Rodríguez-Morales, A. J., Marín-Rincón, H. A., Sepúlveda-Arias, J. C., & Paniz-Mondolfi, A. E. (2015). Correspondence: Assessing the potential migration of people from Ebola affected West African countries to Latin America. *Travel Medicine And Infectious Disease*, 13264-266. doi:10.1016/j.tmaid.2014.12.015

- Smits, J., & Steendijk, R. (2015). The International Wealth Index (IWI). *Social Indicators Research*, 122(1), 65-85. doi:10.1007/s11205-014-0683-x
- United Nations Development Program (UNDP)., (2014). Title Assessing the socio-economic impacts of Ebola Virus Disease in Guinea, Liberia and Sierra Leone The Road to Recovery  
Retrieved from <http://www.africa.undp.org/content/dam/rba/docs/Reports/EVD%20Synthesis%20Report%2023Dec2014.pdf>
- United Nations Department of Economic and Social Affairs (UNDESA)., (2013). Guinea Migration Profile.  
Retrieved from <https://esa.un.org/migmgprofiles/indicators/files/Guinea.pdf>
- United Nations Department of Economic and Social Affairs (UNDESA)., (2013). Liberia Migration Profile.  
Retrieved from <https://esa.un.org/MigGMGProfiles/indicators/files/Liberia.pdf>
- United Nations Department of Economic and Social Affairs (UNDESA)., (2013). Sierra Leone Migration Profile. Retrieved from <https://esa.un.org/migmgprofiles/indicators/files/SierraLeone.pdf>
- Valeri L, Patterson-Lomba O, Gurm Y, Ablorh A, Bobb J, Townes FW, et al. (2016) Predicting Subnational Ebola Virus Disease Epidemic Dynamics from Sociodemographic Indicators. *PLoS ONE* 11(10): e0163544. doi:10.1371/journal.pone.0163544
- World Health Organization (WHO)., (2016). Situational Report, June 2016  
[http://apps.who.int/iris/bitstream/10665/208883/1/ebolasitrep\\_10Jun2016\\_eng.pdf?ua=1](http://apps.who.int/iris/bitstream/10665/208883/1/ebolasitrep_10Jun2016_eng.pdf?ua=1)
- World Health Organization (WHO)., (2015). One year into the Ebola epidemic–Report (accessed 28 Jan 2015) <http://www.who.int/csr/disease/ebola/one-year-report/ebola-report-1-year.pdf?ua=1>
- WINDOW SEAT: Reading the Landscape from the Air (Book). (2004). *Publishers Weekly*, 251(14), 58.
- Yang, W., Zhang, W., Kargbo, D., Yang, R., Chen, Y., Chen, Z., & ... Shaman, J. (2015). Transmission network of the 2014-2015 Ebola epidemic in Sierra Leone. *Journal Of The Royal Society, Interface*, 12(112), doi:10.1098/rsif.2015.0536

## TABLES AND FIGURES

**Table 1.** EVD cases in Guinea, Liberia, and Sierra Leone (WHO patient data, 2014-2015)

Variable	Country	N	M	SD	Min	Max	Population size
Epidemic size (cumulative number of EVD cases)	All countries	37	558.2972973	773.9590811	2.0000000	3165.00	
	Guinea	8	475.5000000	557.8517468	7.0000000	1547.00	10523261
	Liberia	15	332.9333333	688.1798422	4.0000000	2685.00	3476608
	Sierra Leone	14	847.0714286	910.2679626	2.0000000	3165.00	7071632

**Table 2.** Social demographic characteristics and EVD cases in Guinea, Liberia, and Sierra Leone

Variable	Country	N	M	SD	Min	Max
Household density (Number of de facto members)	All countries	37	5.57	0.73	4.06	6.98
	Guinea	8	6.18	0.61	5.31	6.98
	Liberia	15	4.95	0.47	4.06	5.80
	Sierra Leone	14	5.88	0.52	5.07	6.97
International Wealth Index (0 - 100)	All countries	37	26.58	11.06	15.30	72.60
	Guinea	8	35.36	15.47	26.20	72.60
	Liberia	15	23.51	7.53	15.30	45.90
	Sierra Leone	14	24.86	9.35	16.20	52.40
Timelag (Difference in the epidemic starts at the district level, week)	All countries	37	24.22	9.9	0	55.00
	Guinea	8	18.75	17.17	0	55.00
	Liberia	15	25.53	7.99	11.00	37.00
	Sierra Leone	14	25.92	4.48	20.00	36.00
Trips Number of people who made at least one trip the previous year	All countries	37	202695.40	169515.92	13638.51	643441.57
	Guinea	8	431974.81	151071.97	198517.54	643441.57
	Liberia	15	86971.92	116152.70	13638.51	471562.23
	Sierra Leone	14	195668.03	70011.62	76317.55	334415.84
Sanitation level (time in minutes to drinking water source)	All countries	37	140.79	103.58	45.69	630.52
	Guinea	8	248.80	162.39	143.82	630.52
	Liberia	15	98.52	45.76	45.69	226.38
	Sierra Leone	14	124.36	60.99	63.35	312.59

**Table 3.** Correlation between the epidemic size and sociodemographic and epidemics characteristics (Pearson's Correlation Coefficient, N = 37).

	ESm	Household density	IWI	Timelag	Trips	Sanitation level
ESm	1.00	0.28968	0.39947*	-0.59963*	0.37541*	0.12486
Household density	0.28968	1.00	0.19705	-0.27104	0.51007*	0.37148*
IWI	0.39947*	0.19705	1.00	-0.37944	0.53127*	0.85966*
Timelag	-0.59963*	-0.27104	-0.37944*	1.00	-0.43449*	-0.22927
Trips	0.37541*	0.51007*	0.53127*	-0.43449*	1.00	0.59856
Sanitation level	0.12486	0.37148	0.85966*	-0.22927	0.59856*	1.00

\*p<0.05

**Table 4. Multicollinearity Diagnostics (N=37)**

	Parameter Estimate	Standard Error	Pr >  t	Tolerance	Variance Inflation
IWI	0.18632	0.04447	0.0002	0.19560	5.11238
Household density	0.83653	0.37061	0.0278	0.64023	1.56193
Sanitation level	-0.02008	0.00492	0.0003	0.18213	5.49049
Timelag	-0.05610	0.02698	0.0464	0.66359	1.50696
Trips	0.00000193	0.00000184	0.3069	0.48466	2.06331

**p < 0.0001****Table 5. Multivariable regression model for the outcome and predictors (Results of sequentially modeling fitting, n=36)**

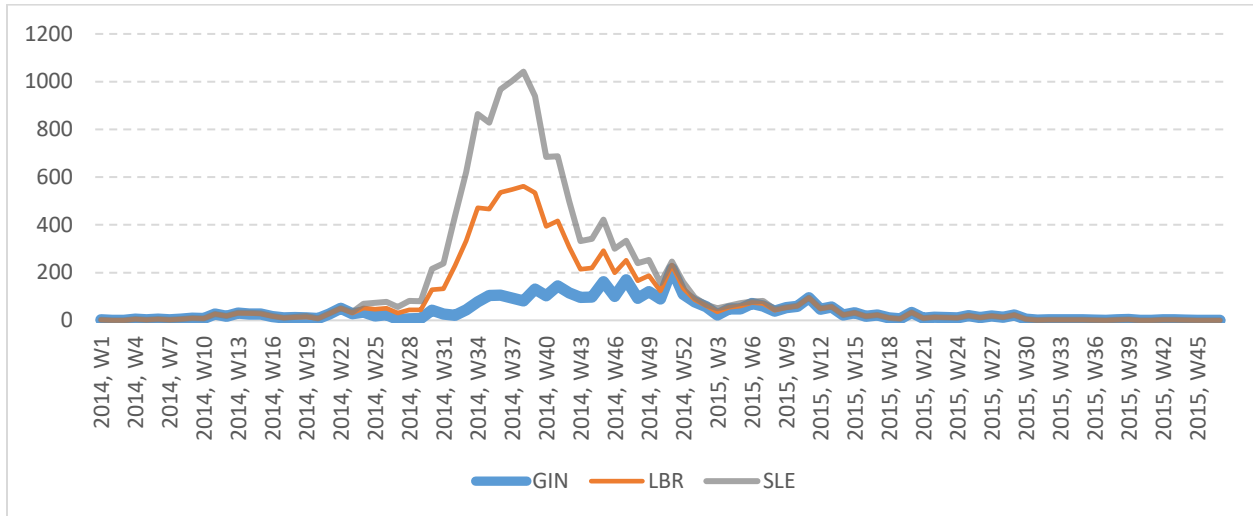
	Parameter Estimate ( <i>se</i> )				
	Model 1	Model 2	Model 3	Model 4	Model 5
IWI	0.07031 (0.02777)	0.06294 (0.02786)	0.23778 (0.04344)	0.18507 (0.04430)	0.18304 (0.04297)
Household density		0.61511 (0.43325)	1.31254 (0.37123)	1.03555 (0.35487)	0.86379 (0.35813)
Sanitation level			-0.02281 (0.00490)	-0.01869 (0.00474)	-0.02096 (0.00478)
Timelag				-0.07022 (0.02610)	-0.05913 (0.02611)
Trips					0.00000337 (0.00000195)
Root MSE	1.83925	1.80773	1.42094	1.29988	1.26022
R <sup>2</sup>	0.1586	0.2070	0.4830	0.6168	0.6515
Model F-test	6.41	4.31	11.90	12.48	11.21
p	0.0161	0.0218	<0.0001	<0.0001	<0.0001

**Table 6. Results of the final model (n=36)**

	Est.	se	p-value	95%C.I.	Semi-partial R square
intercept	-1.19463	2.51817	0.6385	-6.33047, 3.94122	
IWI	0.18507	0.04430	0.0002	0.09471, 0.27542	0.21569
Household density	1.03555	0.35487	0.0065	0.31180, 1.75930	0.10526
Sanitation level	-0.01869	0.00474	0.0004	-0.02834, -0.00903	0.19243
Timelag	-0.07022	0.02610	0.0114	-0.12345, -0.01699	0.08947

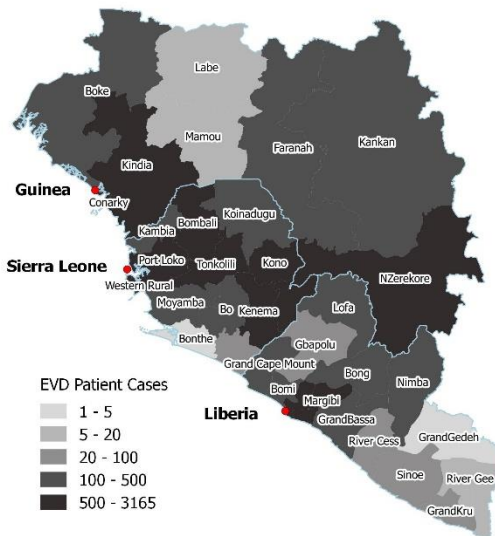
\*Adj R<sup>2</sup>=0.57; F= 12.48; p <0.0001

**Figure 1.** Ebola patient data cases in Guinea, Liberia, and Sierra Leone (2014-2015)



**Figure 2.**

**EVD patient cases in Guinea, Liberia, and Sierra Leone in 2014-2015**



**Figure 3.**

**International Wealth Index in Guinea, Liberia, and Sierra Leone**

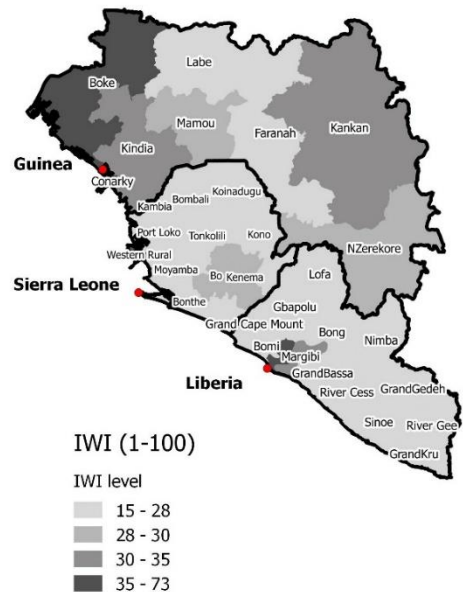


Figure 4.

Patient cases in Guinea, Liberia, and Sierra Leone

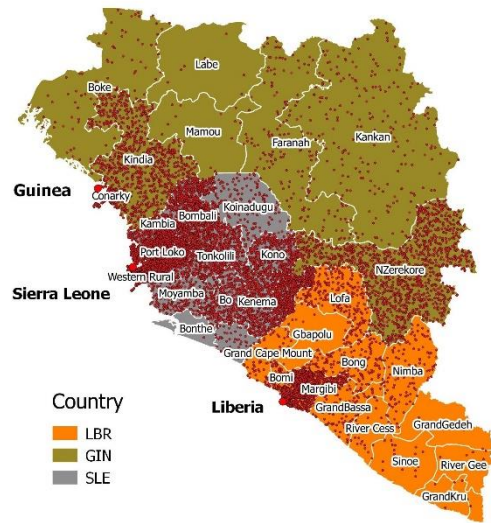


Figure 5.

Road System in Guinea, Liberia, and Sierra Leone

