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THE IMPACT OF EMERGENCY RESPONSE TRAINEES DURING THE EBOLA OUTBREAK IN SIERRA LEONE, 2014-2016

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Honors Thesis

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ABSTRACT

THE IMPACT OF EMERGENCY RESPONSE TRAINEES DURING THE EBOLA OUTBREAK IN SIERRA LEONE, 2014-2016

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This research aims to address the impact of non-health and health trainees as a part of the emergency health response during the Ebola outbreak within Sierra Leone. The non-health trainees, including sanitation workers within health settings, ambulance drivers, burial teams, prison officers, community engagement staff, border officers, traditional birth assistants, etc. were contrasted with individuals receiving clinical or patient-care training. The data were taken from weekly situation reports published by the Internal Organization for Migration in 2015. Using a negative binomial model, we determined the incidence rate ratio of weekly cases and deaths as a result of new trainees. Trainees were measured in counts as either clinical health workers or non-health workers. The non-health category included individuals trained in sanitation, transportation or 'safe and dignified burials' as instructed by the World Health Organization. There was no significant association found between the number of weekly trainees and new cases of Ebola. There was no significant association for the number of weekly trainees and deaths due to Ebola.

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Introduction

Ebola Virus Disease, EVD is an acute viral syndrome. It is a zoonotic virus as it requires an animal host to survive. The common carrier of EVD is believed to be bats, although it has been detected within other species such as gorillas and chimpanzees (Baseler et al, 2017). EVD was believed to be introduced into the human population as a result of spill over: humans become infected with the virus by exposure to infected fluids from the animal. This was mostly likely a result of hunting and consuming bush meat (WHO, 2014). EVD has an incubation period of up to 21 days (WHO, 2014), meaning an infected person can pass on the virus to anyone within that time frame. An infected individual is most contagious at death (WHO, 2020). This increases the risk of transmission for individuals exposed to infected bodies after death. Contact with infected bodily fluids such as blood, semen, vaginal fluids leads to viral transmission (WHO, 2014).

In a newsletter from January, 2015, the WHO published 14 papers which contained in-depth reviews about West Africa's Ebola outbreak in 2014. One in particular addressed several high risk behaviors and contextual factors that had contributed to the spread of EVD and impeded interventions. Movement across borders in West Africa is extremely common, which increased the risk of transmission between countries and led to difficulties in contact tracing. (WHO, 2015). Poverty and poor infrastructure were matched with an ill-prepared health system. In Sierra Leone prior to the outbreak, there were about 1-2 doctors for every 100,000 people (WHO, 2015). Across West Africa in 2014 there were several instances of healthcare workers going on strike for not receiving pay, or having to work in unsafe conditions. Cases of EVD among clinical staff was common (WHO, 2015). Reliance on traditional healers and burial practices had been connected with the disease in countries such as Sierra Leone and Guinea by means of contact tracing. In November of 2014, the WHO estimated that nearly 80% of cases in Sierra Leone were linked to unsafe burials.

According to the CDC, the first case of Ebola Virus Disease (EVD) in West Africa was recorded in December of 2013 in Guinea. It was issued as an unidentified disease within the Ministry of Health. Due to several factors such as a lack of border surveillance, poor public health infrastructure and a lack of knowledge about the disease, the initial case was soon followed by cases in Sierra Leone and Liberia (CDC, 2019). It was not until August 8th, 2014 that a Public Health

Emergency of International Concern was declared. There were confirmed EVD cases in ten different countries as a result of the outbreak in West Africa (CDC, 2019). Sierra Leone experienced its first spike in cases after a funeral of a traditional healer on May 10th, 2014 (WHO, 2015). She became sick after treating ebola patients travelling from Guinea. This funeral sparked several other transmission chains of new cases, deaths and more funerals. This event was estimated to have caused 365 ebola-related deaths (WHO, 2015). On June 12, 2014, a state of public emergency was declared which closed all schools, border checkpoints, and social meeting places. Areas with confirmed cases soon faced a huge strain on hospital capacity, resources and staffing. Small outbreak clusters in rural areas spread rapidly to urban areas. The capital Freetown became the new epicenter of EVD in September, 2014. By the first week of December, Sierra Leone surpassed Liberia and Guinea in the number of cumulative cases (WHO, 2015).

Due to the disjointed and delayed public health response at both the national and international level, data and statistical records contain many differences among sources. The President of Sierra Leone removed operational control from the Ministry of Health and Sanitation, MOHS, and created the National Ebola Response Centre, NERC in October of 2014 (Ross, 2017). This force was backed by the United Nations Mission for Ebola Emergency Response. Many international corporations such as the WHO and the MOHS published case reports which significantly downplayed the outbreak, so as to avoid extreme reactions from the President or other significant actors (Ross, 2017). For these reasons, data on weekly trainee counts was collected from NERC starting in January of 2015. These numbers were reported by the International Organization of Migration within Sierra Leone in situation reports.

This research was conducted with the aim of measuring the association between the number of individuals trained to combat the Ebola outbreak within Sierra Leone, and the number of weekly deaths and new cases of Ebola. It was hypothesized that there would be significant associations between the trainees, both cases and deaths. An inverse relationship was predicted; with an increase in trainees and a decrease in cases and deaths. The categories of “health” and “non-health” trainees were created as exposure variables to determine the difference in impact on the outbreak in terms of new cases and deaths.

A special interest was taken with the trainees who were trained in non-clinical roles. The most common non-health training course delivered by the National Ebola Training Academy focused on infection prevention and control, IPC. This training was conducted with the aim of reducing transmission for those not directly responsible for patient care. Individuals who had received the training included public sanitation workers, ambulance drivers, burial teams, prison officers, community engagement staff, border officers, and traditional birth assistants. More individuals received basic IPC training nearly every week from January to September of 2015 compared to health care workers that received simulated patient care training and clinician IPC training. Due to the larger volume of trainees and wider range of specialization, I hypothesized that this category of trainees may have a greater impact on the actions of communities across Sierra Leone compared to health care trainees restricted to clinical settings.

Methods

Study Design and Sample

The study was structured as a retrospective ecological study. The study population included individuals living within Sierra Leone from 2014 - 2016. The population of 14 districts and the population density of each district were recorded in the 2015 census. The total population in 2015 was 7,092,113 (Weekes & Bah, 2017).

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Exposure Assessment

The trainees were divided into two different groups: non-health professionals and health professionals trained from January through October, 2015. A non-health worker was defined as a volunteer that received training for a non-clinical role. Examples of the non-health trainees include those who participated in the course named "3 day basic IPC/PPE," which involved sanitation protocol for emergency vehicle drivers or burial teams. Health workers were defined as volunteers that received clinical training, including medical screeners, nurses, and doctors. Courses that fell under this category were "1 day clinical augmentations" or "3 day Ebola clinician IPC 2 day simulated Patient care."

Outcome Assessment

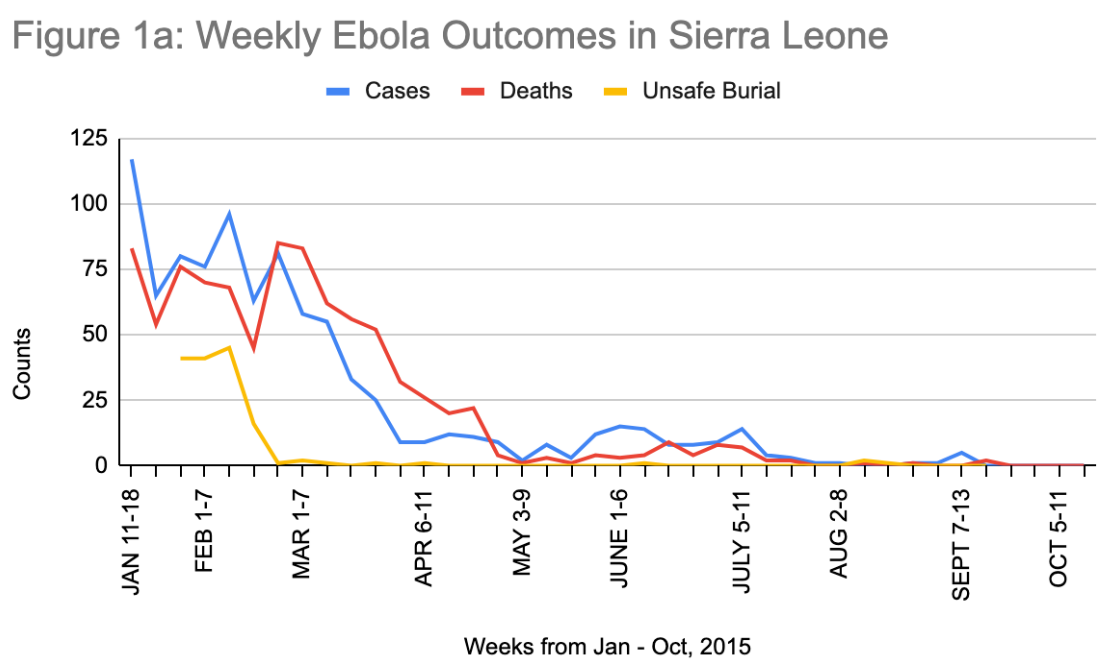
Outcome variables were measured as the number of new, confirmed cases of Ebola within the country each week as well as the number of deaths within Sierra Leone from each week. The weekly case and deaths counts were taken from WHO situation reports. These are consistent with the IOM reports but do not have any missing weeks. Unsafe burials were also recorded within IOM and WHO reports, but were not included in any statistical analysis. Death counts published by the WHO were reported as taken from hospital records and local health clinics. The number of new weekly cases were determined by lab samples which had tested positive for EVD.

Statistical Analyses

The data collected was not linear and the exposure variables were overdispersed, so a negative binomial regression model was used to determine association. With a negative binomial model, count data can be used as the response variable (number of Ebola cases and deaths), while still maintaining multiple explanatory variables (health trainees and non-health trainees). Lag variables were also created for the health and non-health trainees so as to determine the effect of trainees from 0-3 weeks previous on Ebola cases and deaths. For example, a one week lag would mean looking at current cases and deaths in relation to trainees one week previous. This would account for any delay in cases or deaths due to the incubation period of the Ebola virus. A lag may also account for delays in impact as an increase in trainees one week may not impact the number of cases or deaths until several weeks later. The Akaike Information Criterion (AIC) was used to select the best model which included the most appropriate lag for health trainees and non-health trainees.

A secondary analysis was conducted using the same outcome variables and categories of trainees as the exposure. However, the cumulative count of trainees from week to week was used as the exposure rather than only the new trainees during a reported week. An additional analysis for association was conducted using the VARMAX procedure within SAS. This type of autoregression, or 'moving average' model would allow the data to be analyzed as a time series. Missing weeks were replaced with an average of the surrounding 6 weeks. Stability of the data was achieved by taking the log of weekly deaths and cases, then subtracting log-value of the previous from the current week. The log transformation of the data created stationarity in the variance. Differencing the data points created stationarity in the mean. Parameter estimates were produced between contemporary data and past data, similar to the lag variables created in the primary statistical analysis.

Results - *Primary Statistical Analyses*



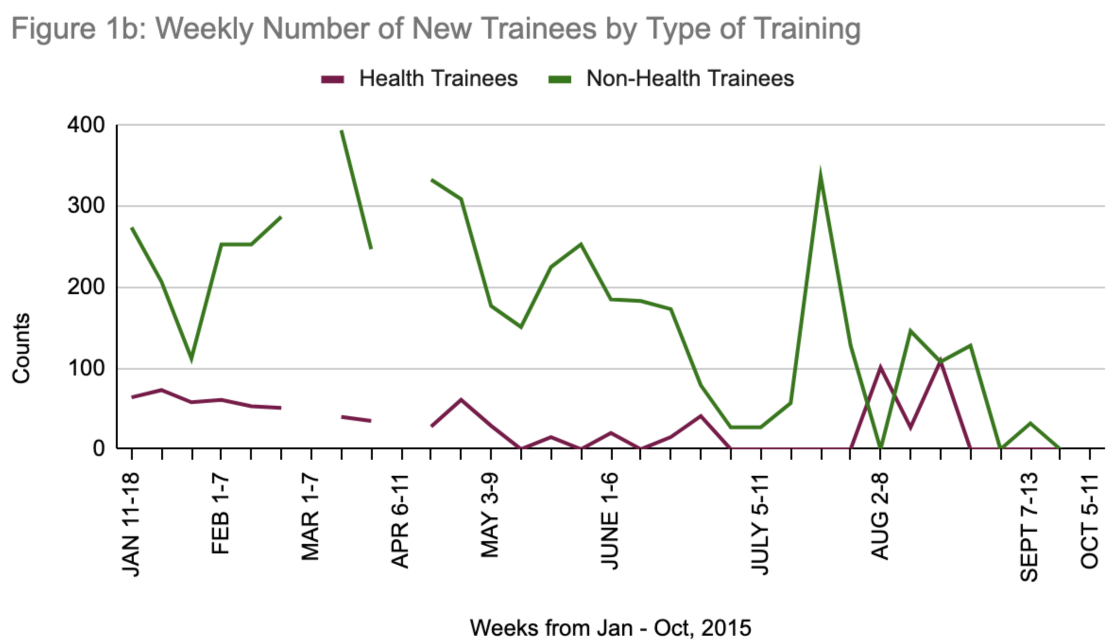


Figure 1a shows the distribution of outcome variables for EVD across the 40 weeks of data collection. The number of cases and deaths peaked (117 cases and 83 deaths) during the week of January 11, 2015. **Figure 1b** shows the distribution of health and non-health trainees across the period of observation. These explanatory variables follow a different, more unpredictable trend compared to Ebola cases and deaths

Table 1a: Deaths Model AIC Selection

DEATHS Model	AIC (lowest is best)
Hlth NonHlth	213.0
Hlth NonHlthLag1	182.2
Hlth NonHlthLag2	152.8
Hlth NonHlthLag3	135.1
HlthLag1 NonHlth	178.5
HlthLag1 NonHlthLag1	203.0
HlthLag1 NonHlthLag2	176.5
HlthLag1 NonHlthLag3	146.6
HlthLag2 NonHlth	149.8
HlthLag2 NonHlthLag1	174.2
HlthLag2 NonHlthLag2	172.7
HlthLag2 NonHlthLag3	170.6
HlthLag3 NonHlth	**133.5**
HlthLag3 NonHlthLag1	150.2
HlthLag3 NonHlthLag2	171.4
HlthLag3 NonHlthLag3	190.1

Table 1b: Cases Model AIC Selection

CASES Model	AIC (lowest is best)
Hlth NonHlth	233.3
Hlth NonHlthLag1	205.3
Hlth NonHlthLag2	176.2
Hlth NonHlthLag3	158.2
HlthLag1 NonHlth	201.7
HlthLag1 NonHlthLag1	225.5
HlthLag1 NonHlthLag2	199.2
HlthLag1 NonHlthLag3	172.6
HlthLag2 NonHlth	173.2
HlthLag2 NonHlthLag1	195.1
HlthLag2 NonHlthLag2	217.2
HlthLag2 NonHlthLag3	193.7
HlthLag3 NonHlth	**152.6**
HlthLag3 NonHlthLag1	169.4
HlthLag3 NonHlthLag2	188.5
HlthLag3 NonHlthLag3	210.8

Tables 1a and **1b** display the AIC values for all the possible combinations of lagged variables. Table 1a shows that the health workers lagged by 3 weeks and the current non-health workers were the best fit for the outcome variable of death. For the cases model, the same variables produced the lowest AIC. A low AIC indicates the best fitting model for the data provided. The variables selected for the negative binomial models and in bold.

Figure 2a: Fit Plot for Cases by Non-Health Trainees

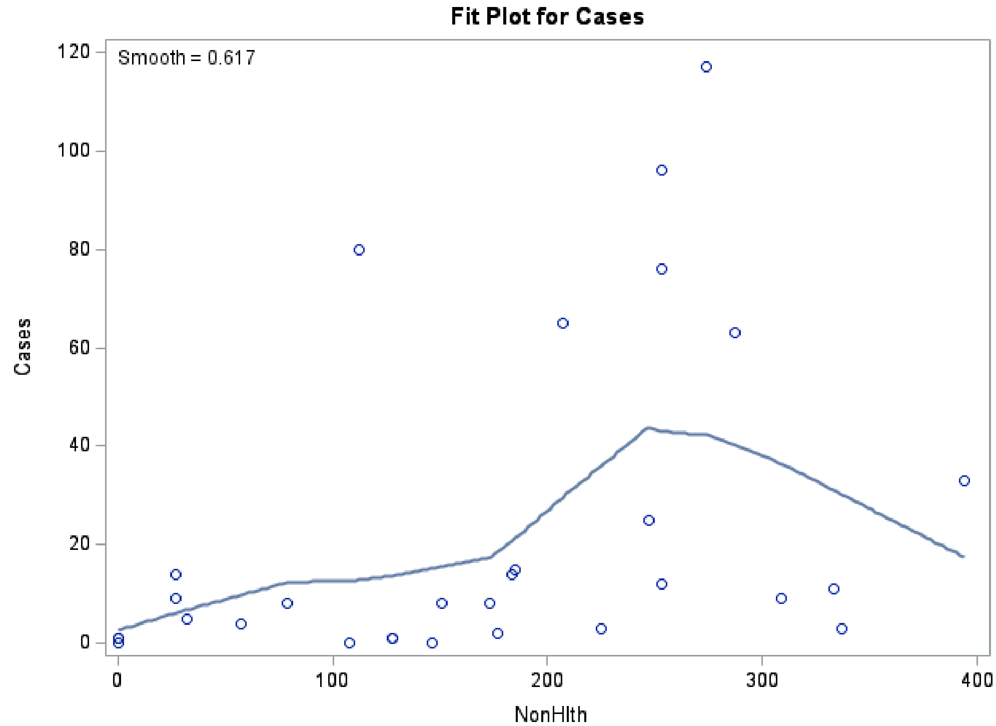


Figure 2b: Fit Plot for Deaths by Non-Health Trainees

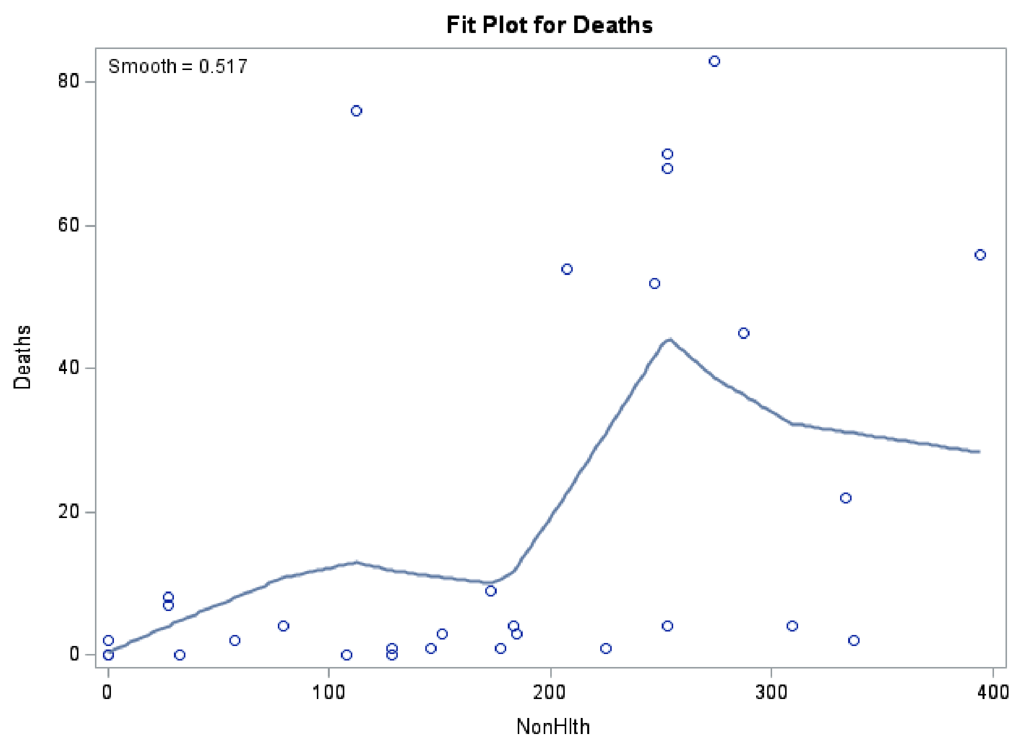


Figure 2c: Fit Plot for Cases by Health Trainees, 3 Week Lag

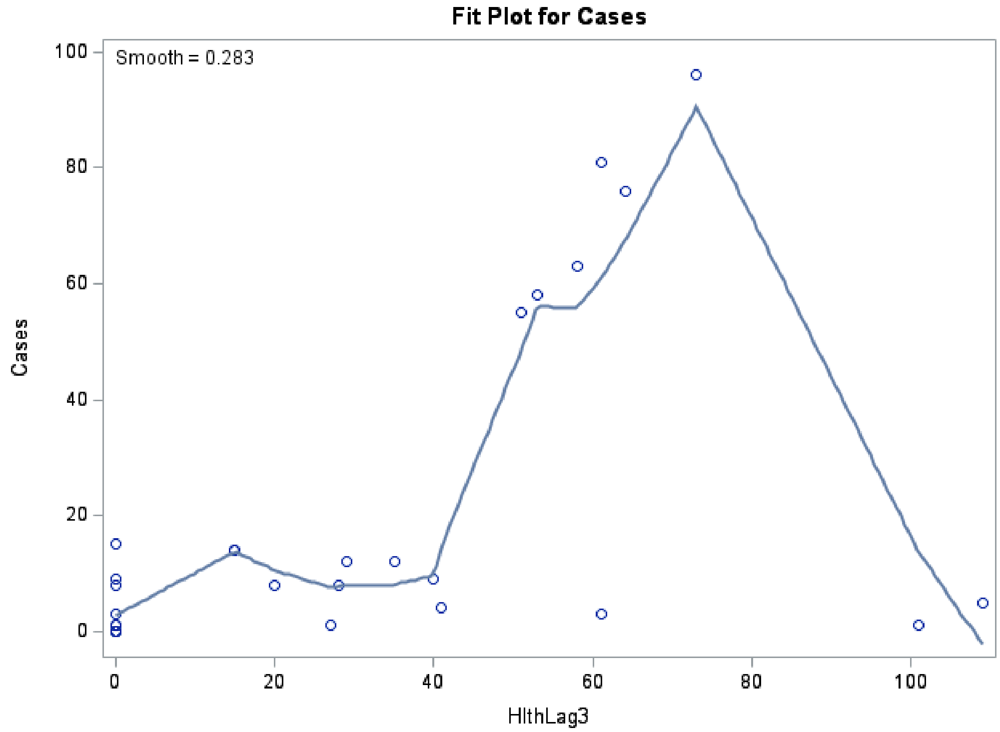
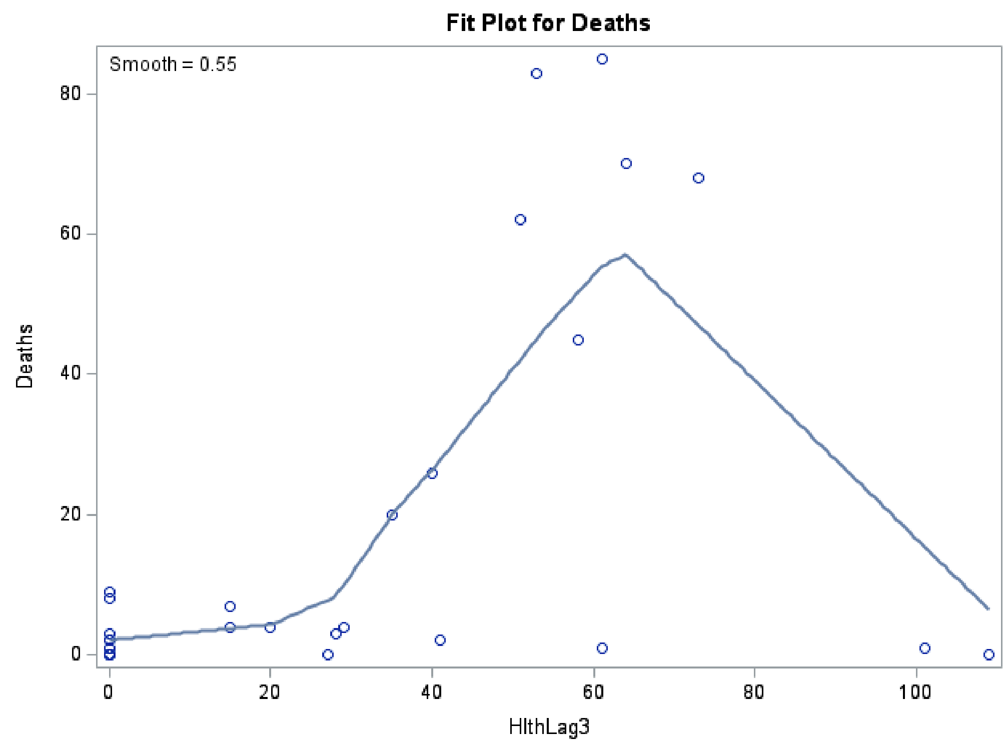


Figure 2d: Fit Plot for Deaths by Health Trainees, 3 Week Lag



Figures 2a-2d display the relationship between the two categories of trainee and the outcome of new Ebola cases or deaths due to Ebola. The line on each scatterplot is a LOWESS line (locally weighted scatterplot smoother). The degree of smoothness between data points was determined by the LOESS procedure within SAS 94. These graphs display the count of trainees, “NonHlth” or “HlthLag3,” and the death or new case count from the corresponding week. The “HlthLag3” variable was selected due to the lowest AIC model as seen in Tables 1a and 1b. These plots show a trend contrary to the hypothesis. Rather than seeing a trend line with a negative slope indicating an inverse relationship between the number of trainees and number of deaths or cases, the plots show a curve with a clearly defined peak. These plots infer that a smaller number of weekly trainees would be predictive of fewer Ebola cases or deaths.

Table 2a. Incidence Rate Ratios of Deaths due to Ebola Virus Disease

	IRR	95% CI		P-value
HlthLag3	1.0126	0.9846	1.0415	0.3811
NonHlth	1.0077	1.0036	1.0140	0.0009***

*** Indicates a statistically significant p-value.

Table 2b. Incidence Rate Ratio of New Cases of Ebola Virus Disease

	IRR	95% CI		P-value
HlthLag3	1.0183	1.0027	1.0342	0.0215***
NonHlth	1.0062	1.0014	1.0110	0.0114***

*** Indicates a statistically significant p-value.

Tables 2a and **2b** include the results from the negative binomial regression model. For both deaths and cases, variable selection for the best model was determined in Tables 1a and 1b. While several of the estimates were statistically significant, the overall effect of trainees, either health or non-health, on Ebola cases and deaths is very close to 1, meaning no change in outcome per unit change of exposure. For example, the incidence rate ratio (IRR) of Ebola cases for non-health trainees is 1.0062 (CI: 1.0014, 1.0110; p-value: 0.0144). This means that there is a .62% increase in new cases of Ebola per week for each new non-health trainee trained.

Results from Secondary Statistical Analyses

The same negative binomial model analysis was performed with the cumulative counts of trainees signified by the variables “C_HlthLag3” and “C_NonHlth”. The negative binomial model included variables with the lowest AIC scores. Results from the model can be seen in tables 3a and 3b.

Table 3a. Incidence Rate Ratio of New Cases of Ebola Virus Disease, Cumulative Trainee Analysis

	IRR	95% CI		P-value
C_HlthLag3	1.0031	0.9960	1.0104	0.3903
C_NonHlth	0.9986	0.9974	0.9997	0.0166***

*** Indicates a statistically significant p-value.

Table 3b. Incidence Rate Ratio of Deaths due to Ebola Virus Disease, Cumulative Trainee Analysis

	IRR	95% CI		P-value
C_HlthLag3	0.9965	0.9882	1.0049	0.4142
C_NonHlth	0.9995	0.9982	1.0009	0.4951

*** Indicates a statistically significant p-value.

The cumulative non-health trainees did have a significant IRR in relation to the number of new cases. Most notably, this IRR was less than 1, meaning that there was a decrease in the number of new cases per unit increase of non-health trainees. However, this value is so close to 1 that this would only account for a .14% decrease in new cases at most.

A time series analysis was conducted using the VARMAX procedure within SAS 94. There were no statistically significant estimates between health trainees and new Ebola cases or deaths due to Ebola. There were also no statistically significant estimates between non-health trainees and new Ebola cases or deaths due to Ebola. Despite p-values greater than 0.05, the estimates themselves were very small in value, indicating little to no impact of trainees on the number of deaths or cases.

Discussion

All statistical analyses showed that health and non-health trainees during the Ebola outbreak in Sierra Leone had little to no impact on the number of Ebola cases and deaths. There could be several reasons for this, one being insufficient variables or data. For example, the impact of new trainees could have been miniscule compared to established health and non-health workers within Sierra Leone previous to the Ebola outbreak. The cumulative trainee analysis was carried out with this in mind. There was one significant relationship between cumulative non-health trainees and new cases, yet the incidence rate ratio value was very close to one, indicating a very small decline in cases associated with an increase in non-health trainees. The cumulative counts of trainees only accounted for personnel trained from January to October of 2015. It can be assumed that there were other professionals functioning in public health, sanitary or clinical roles before this time with the goal of mitigating the spread of this Ebola outbreak. These numbers were not recorded within the IOM reports, but could better inform the research question if available.

In addition to counts of professionals previously working as a part of Ebola relief, this research would be improved by having a greater timespan of data. January 2015 marked a point in which cases of Ebola and deaths due to Ebola were coming down from the recorded peak, which could be implied from Figures 1a and 1b. If more data or in-country situation reports were available at an earlier point in the outbreak, the data become a more accurate representation of the disease progression within Sierra Leone.

Another limitation of this study came from the data used to represent the population of Sierra Leone. There may be inaccurate modeling for the counts of new weekly trainees. There were several consecutive weeks where situation reports were not published. However, the amount of new cases, deaths, and unsafe burials were all reported in WHO weekly reports within the timespan of interest. The IOM situation reports do not begin until January of 2015, a full year into the outbreak within Sierra Leone. This was because of slow internal and international responses. Ideally, complete data would have been available

throughout the duration of the epidemic so as to have a better representation of the fluctuations in deaths, cases and unsafe burials, or how these variables may interact with response trainees.
A strength of this study includes its novelty. Many studies and reports have been written about the Ebola outbreak in Western Africa during this time, but none of this design and specific variables. Measuring impact is a goal of many international aid organizations or non-profit organizations but is often done without proper study design or statistical associations. This study aims to measure the effect, or impact, of an intervention created by the government of Sierra Leone on Ebola-related outcomes such as death and new cases. Despite a lack of significant results, this study provides multiple analyses and methods of finding results which could be applied to future research with a similar goal. The use of country-wide data is also a strength of the study, as all 14 districts of the country are represented.

Possible confounders could include the influence of international organizations. Donations and international funds may have impacted the amount of people able to receive training. Funding within the country or internationally also would have impacted the infrastructure of the country during the time. This area supports security personnel enforcing quarantine, or those responsible for border control with neighboring countries also affected by Ebola. A variable which may have acted as a confounder in the number of new cases or number of deaths could be the number of unsafe burials performed within the country. This variable was intended to be included within statistical analyses, but as seen in Figure 1a, the counts fall to zero by early March. In November of 2014, the WHO released new protocol on how to conduct 'safe and dignified burials,' as local burial practices often include touching and washing the deceased. Contact tracing stated with the IOM situation reports confirmed positive cases of EVD as a result of attending traditional burials. If there was sufficient data from 2014 when traditional burials were more frequent, there may be an opportunity to better understand the impact of unsafe burials on new Ebola cases or deaths.

This research would be enhanced by including a qualitative analysis of the situation reports from Sierra Leone. A qualitative approach may also include other posts, publications or interviews from those who had worked in various fields during the outbreak in Sierra Leone. For example, the HEART resource center and Elrha charity group created online platforms for medical anthropologists to describe strategies for community engagement and share valuable resources. Within these online platforms there are field notes describing community responses and feelings toward EVD and associated policies. A qualitative analysis may be the best method to understand the change in number of unsafe burials across the span of the outbreak in Sierra Leone. Other socio-cultural factors or well-received interventions may be identified by examining these resources. As early as 2003, qualitative studies have been published regarding socio-cultural factors connected to EVD within other countries (Hewlett & Amola, 2003). Identifying common themes in response to different events or policies using qualitative analyses within the provided time frame may create better understanding of this non-linear relationship between number of trainees and cases or deaths. I would hypothesize that non-health trainees or volunteers may be associated with a greater amount of positive community feedback compared to health care workers.

Conclusion

As part of the emergency health response during the Ebola outbreak within Sierra Leone, The research conducted in this report aimed to address the impact of non-clinical and clinical health trainees. The data published by the Internal Organization for Migration of weekly situation reports allowed us to analyze the data through the use of a negative binomial regression model. The incidence rate ratios of weekly cases and deaths as a result of new trainees were measured, but ultimately did not confirm the hypothesis that a greater number of trainees would decrease the amount of cases and deaths due to Ebola. Although there were some instances of statistically significant incidence rate ratios, there was no major effect of the number of weekly non-health or health trainees on new Ebola cases or deaths.

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