American Journal of Infection Control 43 (2015) 563-71

Contents lists available at ScienceDirect

American Journal of Infection Control

journal homepage: www.ajicjournal.org

Major article

What can we learn about the Ebola outbreak from tweets?

Michelle Odlum EdD, MPH, Sunmoo Yoon RN, PhD *

School of Nursing, Columbia University Medical Center, New York, NY

Key Words:
Ebola outbreak
Social media
Data mining

Background: Twitter can address the challenges of the current Ebola outbreak surveillance. The aims of this study are to demonstrate the use of Twitter as a real-time method of Ebola outbreak surveillance to monitor information spread, capture early epidemic detection, and examine content of public knowledge and attitudes.

Methods: We collected tweets mentioning Ebola in English during the early stage of the current Ebola outbreak from July 24-August 1, 2014. Our analysis for this observational study includes time series analysis with geologic visualization to observe information dissemination and content analysis using natural language processing to examine public knowledge and attitudes.

Results: A total of 42,236 tweets (16,499 unique and 25,737 retweets) mentioning Ebola were posted and disseminated to 9,362,267,048 people, 63 times higher than the initial number. Tweets started to rise in Nigeria 3-7 days prior to the official announcement of the first probable Ebola case. The topics discussed in tweets include risk factors, prevention education, disease trends, and compassion.

Conclusion: Because of the analysis of a unique Twitter dataset captured in the early stage of the current Ebola outbreak, our results provide insight into the intersection of social media and public health outbreak surveillance. Findings demonstrate the usefulness of Twitter mining to inform public health education.

The current Ebola virus disease (EVD) outbreak is of major global concern and is classified by the World Health Organization (WHO) as an international health emergency. Beginning in December 2013 in the eastern section of the Republic of Guinea,[1-3] new cases were reported regularly by the Ministries of Health in Guinea, Liberia, Sierra Leone, and recently Senegal (daily direct flights to John F. Kennedy International Airport [New York, NY], Washington Dulles International Airport [Dulles, VA], and Charles de Gaulle Airport [Roissy-en-France, France]).[4-6] With a cumulative case total of >13,567 (case) and 4,951 deaths,[7,8] the first major West African outbreak of the most virulent Zaire strain of EVD is now the largest EVD outbreak to date.[9] Local, regional, and international agencies are challenged to contain the epidemic, reduce fatalities, and allay the climate of fear.[9,10] However, ongoing disease containment and surveillance is difficult because of the current outbreak. Furthermore, in resource-limited settings, barriers to optimal public health outbreak surveillance exist.[4] With Ebola in the United States and the recent New York City diagnosed case,[11] there is valid cause for concern of spread in developed countries. In populated cities such as New York City, contamination is a sobering reality, and with its rodent population out numbering the humans, endemic Ebola is not outside the realm of possibility. Rodents are a main reservoir of viral hemorrhagic fevers. Similar to Lassa fever, another hemorrhagic disease, the mode of transmission is direct exposure to excreta of infected rats.[12] The certainty of EVD containment in the immediate future is not known. To improve compliance with measures of prevention and control, several priority actions are recommended for strengthened surveillance systems. These include the use of emerging technologies to support early warning systems for communication between agencies and the general public.[1]

* Address correspondence to Sunmoo Yoon, RN, PhD, School of Nursing, 630 W 168th St, Mail Code 6, New York, NY 10032.

E-mail address: sy2102@columbia.edu (S. Yoon).

Author contributions: Yoon and Odlum designed the study. All of the authors drafted the manuscript, critically revised the manuscript for important intellectual content, had full access to all of the data in the study, and take responsibility for the integrity of the data and the accuracy of the data analysis.

Disclaimer: This study used publically available data, and analyses meet the criterion for exemption §46.101(b)4 research, involving the collection or study of existing data, documents, records, pathologic specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects.

Conflicts of interest: None to report.

0196-6553/$36.00 - Copyright © 2015 by the Association for Professionals in Infection Control and Epidemiology, Inc. Published by Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.ajic.2015.02.023

The Department of Communicable Diseases Surveillance and Response at the WHO endorsed the conceptual framework of public health surveillance and action.[13] This framework demonstrates how public health surveillance and action relate through data information messages.[14] Public health action includes acute (epidemic-type) responses, defining a framework for both surveillance and action during emergent outbreak situations.[15] In the event of re-emerging rare infections, such as EVD, active systems for surveillance and acute response are used to halt transmission.[14] Although emergent diseases are to be viewed in relation to control strategies and national surveillance, resources are often limited. If surveillance systems are not timely, complete, efficient, or adaptable, gaps in knowledge may occur.[16] Optimal outbreak surveillance for public health action should comprehensively uses multiple modalities for data collection, analysis, and dissemination.[17] Knowledge transfer tools to support strategies for outbreak control are necessary.[15]

Social network sites (SNSs) allow users to play active roles in the reporting and dissemination of news events. Users share insights, opinions, and apprehensions, while disseminating interpretations of health events outside a public health context.[17,18] There is an increasing need to both develop and share health information which is essential in outbreak surveillance efforts. Surveillance through electronic mediums, such as the Internet, provides tremendous opportunities for public health practice.[17] Twitter, one of the most popular SNSs, is a microblogging application allowing for communication through 140 characters called tweets. Streams of tweets can contain useful information, with news events documented, shared, and discussed.[19] Twitter users interact through direct messages or solicited replies that can be largely disseminated through forwarding (retweeting), allowing for rapid and broad propagation.[18] Over 645 million registered Twitter users exist globally with a distribution of >58 million tweets daily.[20] The community of Twitter users reflects a diverse and rapidly growing global population.[21,22] Twitter is viewed as an emerging broadcast medium for information and news regarding public health events, evidenced by its usefulness during the influenza A virus subtype H1N1 pandemic planning activities.[18] Twitter's capacity for broad reach, timeliness, and low overhead has the potential to capture epidemic trends, gather information, and disseminate knowledge.[17,23] The utility of Twitter supports its potential to impact public health outbreak surveillance efforts in new and innovative ways.

Taking advantage of this unique opportunity to examine the use of a powerful SNS tool during a public health crisis, the aim of our study was to provide a snapshot of EVD-related tweets in the midst of the current outbreak to monitor trends of information spread, examine early epidemic detection, and determine public knowledge and attitudes.

METHODS

Tweet corpus

Tweets mentioning EVD were collected daily from Twitter (https://twitter.com/) via a Google Chrome–based version of NCapture (QSR International; Melbourne, Australia) from July 24-August 1, 2014. Key words used for the identification of EVD-related data included #Ebola, #EbolaOutbreak, #EbolaVirus, and #EbolaFacts. Key word selection for our data corpus was informed by Twitter search trends and suggested search functions. Data elements collected for each tweet included content, time stamp, geographic location with latitude and longitude codes from the sender's Internet Protocol (IP) address and self-identified address, user name, message type (unique or retweet), and the number of followers (number of disseminated). For example, if a celebrity sent out a tweet message, which was cited by 100 people, it would be calculated as follows: the number of posted tweets marked as 101 (unique = 1, retweet = 100), and the number of disseminated tweets is counted as 54 million in this study (dissemination = 54 million).

Trends of information spread

We investigated the trends of geographic spread of EVD information within Twitter. To evaluate EVD temporal patterns of information dissemination, the number of posted (unique and retweet) and disseminated tweets was characterized by date in an early stage of Ebola outbreak. Descriptive statistics, including the volume of posted (unique and retweet) and disseminated tweets, were traced according to geographic location. The poster's locations were indicated using an interactive, data visualization, and business intelligent software (Tableau 8.1; Tableau, Seattle, WA). Time series analysis using an exponential smoothing algorithm[24] was used to identify trends of how fast the tweets mentioning Ebola were disseminated. The trend model of the dissemination speed of tweets mentioning EVD was visualized.

Content analysis

A content analysis was conducted to capture public perceptions of EVD and to reduce noise. We used an natural language processing approach in the analysis of EVD tweet content. To identify topics of collected tweets, we cleaned symbols and Web addresses and transformed text to a vector form and N-gram and reduced the dimensionality of the volume using Notepad++ (Notepadd++: Don Ho, Paris, France Weka: University of Waikato, Hamilton, Waikato, New Zealand) and Weka software. The detailed steps of tweet cleaning, preparation, and refinement are described in the author's (S.Y.) other article.[25] The N-gram forms (unigram, bigram, and trigram) of tweet messages were clustered based on content similarities for topic detection. K-means algorithm was then applied using Weka. Clusters were visualized to summarize the detected topics.

RESULTS

Trends of information spread

A total of 42,236 tweets mentioning the recent EVD outbreak were posted (16,499 unique and 25,737 retweets) and disseminated to 9,362,267,048 people from July 24-August 1, 2014 (Fig 1). On July 24, the baseline of 382 posted tweets (128 unique and 254 retweets) was disseminated to 1,502,743 Twitter users. On July 26, with the announcement of the EVD infection of an American physician, the baseline number increased 8-fold to 3,222 posted tweets (1,574 unique and 1,648 retweets), with a 644-fold increase in disseminated tweets (967,404,925). The number of tweets decreased for 3 days and started drastically increasing on July 30 with the announcement of the Sierra Leone emergency declaration, the U.K. foreign secretary's official message, and the Peace Corp pulling volunteers.[26] After the first press announcement from the Centers for Disease Control and Prevention (CDC) on July 28,[27] the number of tweets increased 2-fold. Within 3 days of this announcement, the number of tweets continued to spread quickly with increasing news events, including the WHO's $100 million plan; the CDC's level 3 notice for Liberia, Sierra Leone, and Guinea; and the infected American physician's return with EVD. On July 31, 2014 (3 days after the first CDC announcement), EVD news items were disseminated to 4,864,972,879 Twitter users, 63 times higher than the initial number.

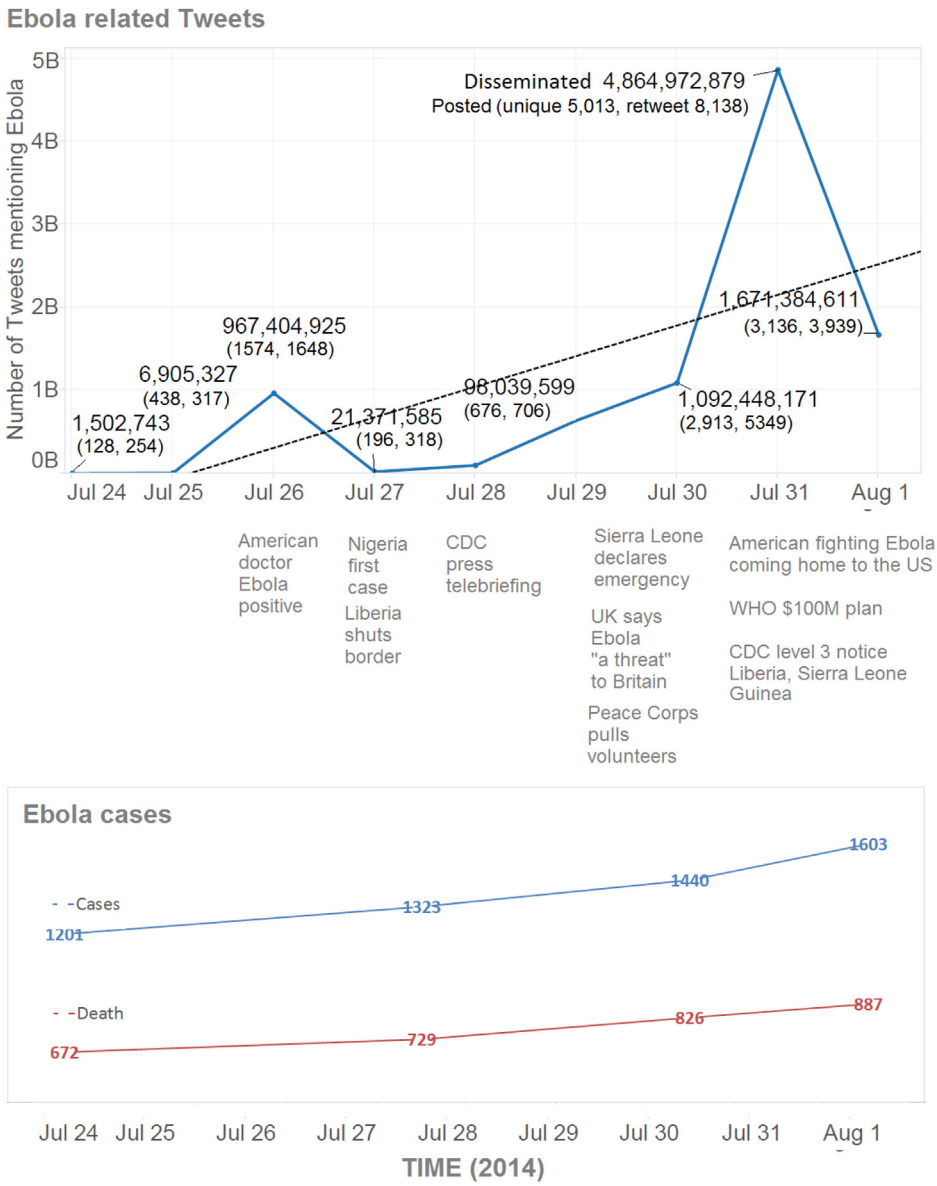

Fig 1. Time trends in tweets mentioning Ebola in an early stage of world emergency response. *CDC*, Centers for Disease Control and Prevention; *WHO*, World Health Organization.

Time series analysis

Time series analysis showed the rate of information dissemination within Twitter gradually increasing (number of disseminated tweets = 520,441 × minute of time + −2.17785e+010; $P < .0001$; SE 7.80976e+006). This model explained a 520,441 increment of disseminated tweets every minute. Figure 1 illustrates the frequency of tweets mentioning EVD and news alerts in an early stage of the world emergency response. The daily geographic spread of tweets mentioning EVD is displayed in Figure 2. Before the CDC's health advisory announcement on July 28, 2014, EVD conversations on Twitter were limited to African and European countries, with a small portion of North Americans tweeting. After the July 29 announcement by the CDC, the rate of posted tweets increased to span additional global locations, such as Europe, North America, Africa, Asia, and Australia. Approximately 2,000 tweets were posted from Africa and North America. The Chikungunya outbreak was continuously mentioned in the Caribbean region (marked in blue). EVD-related tweets (marked in orange) spanned the globe. Despite global awareness of EVD, only a few people in the Caribbean region mentioned EVD (Fig 2).

Early epidemic detection: Nigeria cases

Increases in tweet frequency from cities in Nigeria were identified. Tweets steadily increased (6-fold in posted tweets and 20-fold in disseminated tweets) from July 24-31, the day of the CDC official Nigeria case report, as shown in Figure 3. Tweets started to rise in Nigeria prior to the official announcement of the first probable EVD case. On July 24, Twitter users discussed the first case of EVD in related tweets (eg, "#EbolaVirus 1st case discovered Lagos, pls spread the word" and "Guys,#EbolaVirus is in Lagos. Be informed. Be careful."). The first probable EVD case was announced by the Nigerian Ministry of Health on July 27 and by the CDC on July 31. The first case of EVD news in Nigeria was tweeted on July 24 and reached 1,196,793 people, and 120,574,549 people were reached on July 30, a hundred times higher than the initial number.

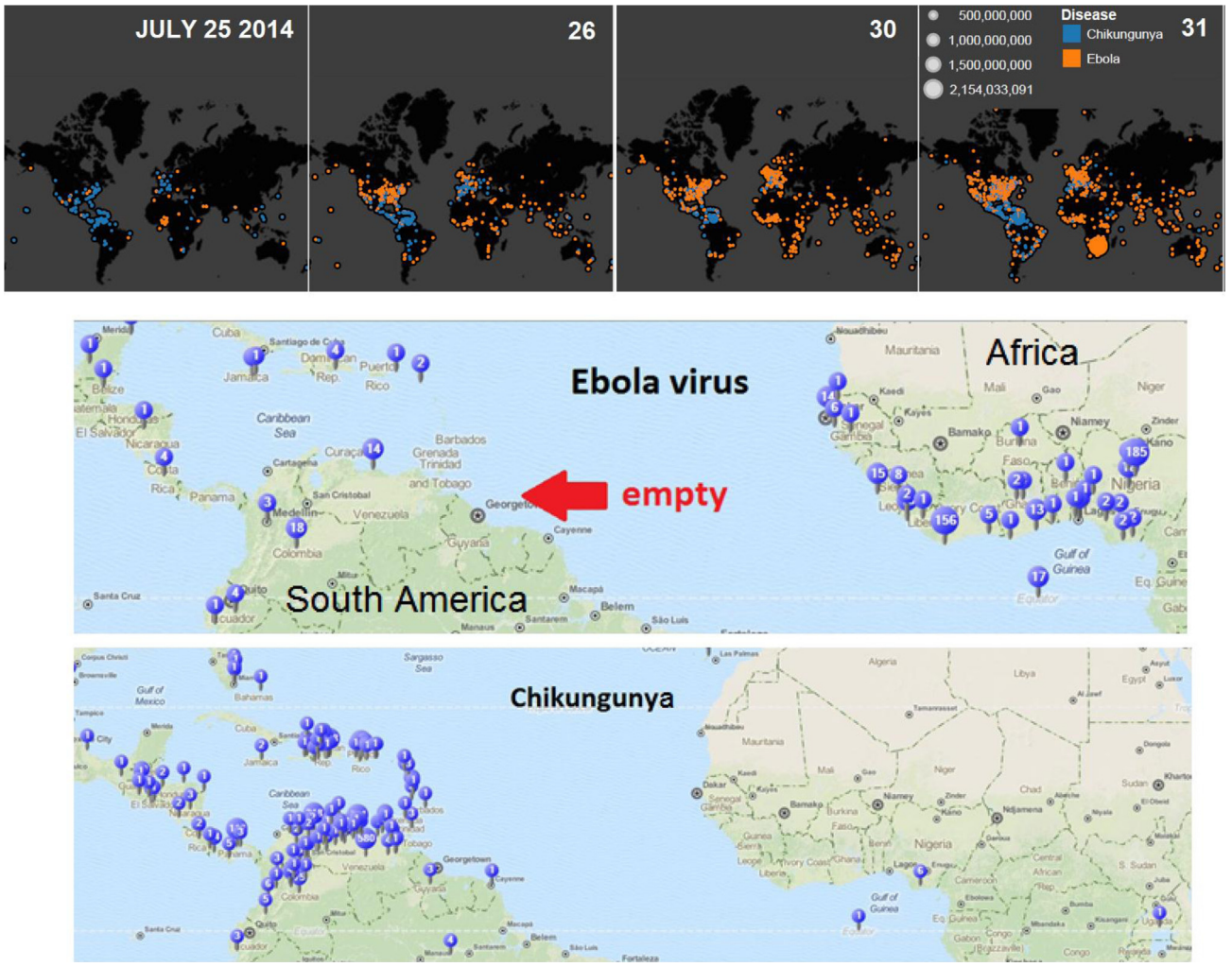

Fig 2. Geographic location of disseminated tweets mentioning Ebola and Chikungunya (top), and number of tweets generated on July 30, 2014 in the Caribbean area and Africa (bottom).

Content analysis

Four main public topics of concern were discussed in tweet content (Fig 4). They are as follows: (1) risk factors: cause of EVD (ie, transmission, infection); (2) prevention education: health information (ie, prevention methods, signs, symptoms); (3) disease trends: spread and location (ie, name of locations, information about spread); and (4) compassion: prayer for countries in Africa. An N-gram was computed from the natural language processing and cluster analysis results (Fig 4). The bubble chart in Figure 4 illustrates the 4 topics of EVD tweets. The sizes of chart bubbles are normalized by clusters and represent the relative frequency of the N-gram. Topic 1, cause of EVD, includes "transmitted" (0.21) and "animal" (0.20), which were the most frequent words. Topic 2, prevention education, includes "signs and symptoms" (3.76) and "symptoms and prevention" (3.76), the most frequent words. "Virus" (0.49) and "Africa" (0.25) frequently appeared in topic 3. "Pray for Sierra," "Sierra Leone Guinea," and "pray for Africa" were the frequent words in topic 4.

DISCUSSION

The conceptual framework of public health surveillance and action identifies the essential need for active surveillance during re-emerging rare infections such as EVD. The framework also demonstrates how health systems can link outbreak surveillance to action through data information messages.[14] The current study reveals how tweets can be collected and analyzed to support early warning systems for epidemic trends and to inform data information messages for health education interventions.[28] The delivery of useful and effective information is the foundation of outbreak surveillance.[16] Moreover, outbreak public health education efforts, suggested by the CDC, include surveying public knowledge and attitudes and disseminating mass media messages. Electronic information sources that provide additional opportunities to improve health knowledge with respect to person, place, or time,[16] such as Twitter, have the ability to support achievement of these goals.

Early warning signs and timely detection

We demonstrated how Twitter can support and contribute to early warning systems in outbreak surveillance. Our unique dataset reflects the early stage of health alerts around the recent EVD spread during the current outbreak. Our geocode was provided by 2 sources, IP addresses of users and self-report through tweet content analysis. Our novel findings are 2-fold. The analysis captured progressive increases in the number of tweets discussing EVD case identification in Nigeria beginning on July 24, 2014, occurring 3 days prior to the news alert and 7 days before the official CDC

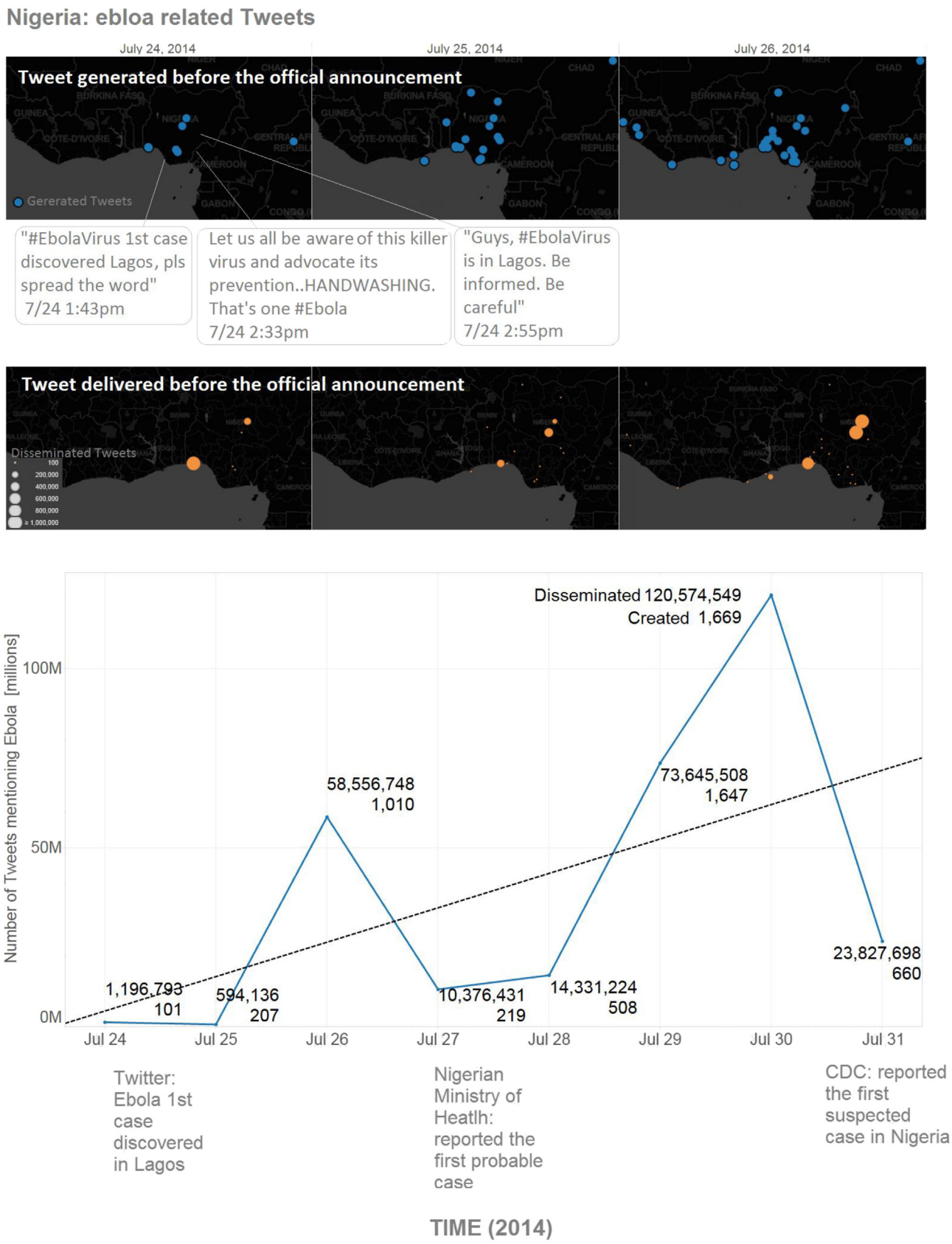

Fig 3. Time of first Nigerian Ebola case on Twitter, Ministry of Health, and CDC. *CDC*, Centers for Disease Control and Prevention.

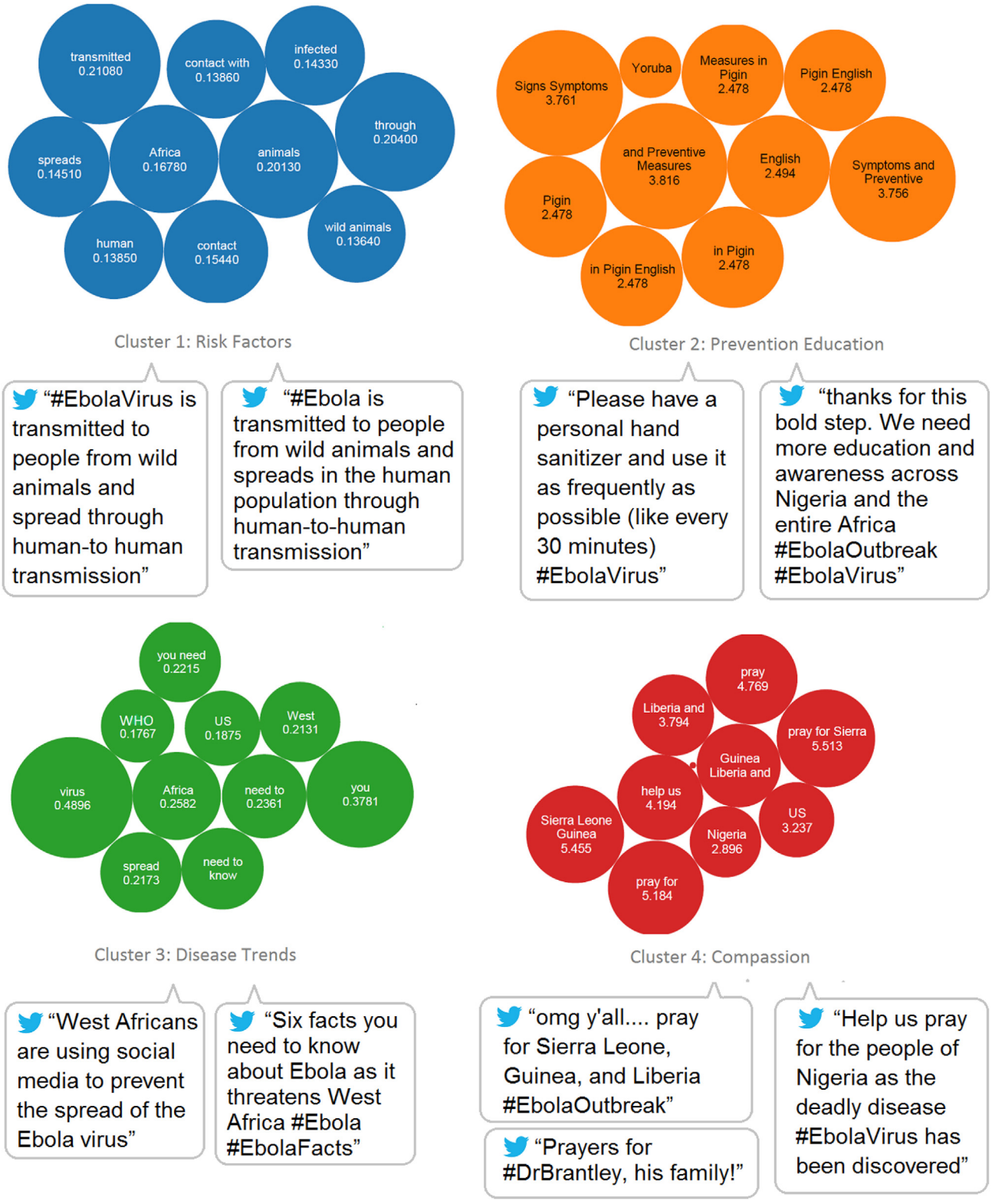

Fig 4. Four topics of tweets mentioning Ebola. N-gram and frequency broken down by cluster. Color shows details about cluster. Size is normalized by clusters and shows frequency of the N-gram. *WHO*, World Health Organization.

update. On July 31, 2014, the CDC indicated a probable case in Nigeria reported by the WHO and Nigerian Ministry of Health.[29] We have also shown that although Twitter adoption and use in resource-limited settings such as Nigeria are lagging, there was an increase in the frequency of EVD-related tweets in the days leading up to the official news alert. These results indicate how Twitter can be used to support early warning systems in outbreak surveillance efforts in settings where surveillance systems are not optimal.

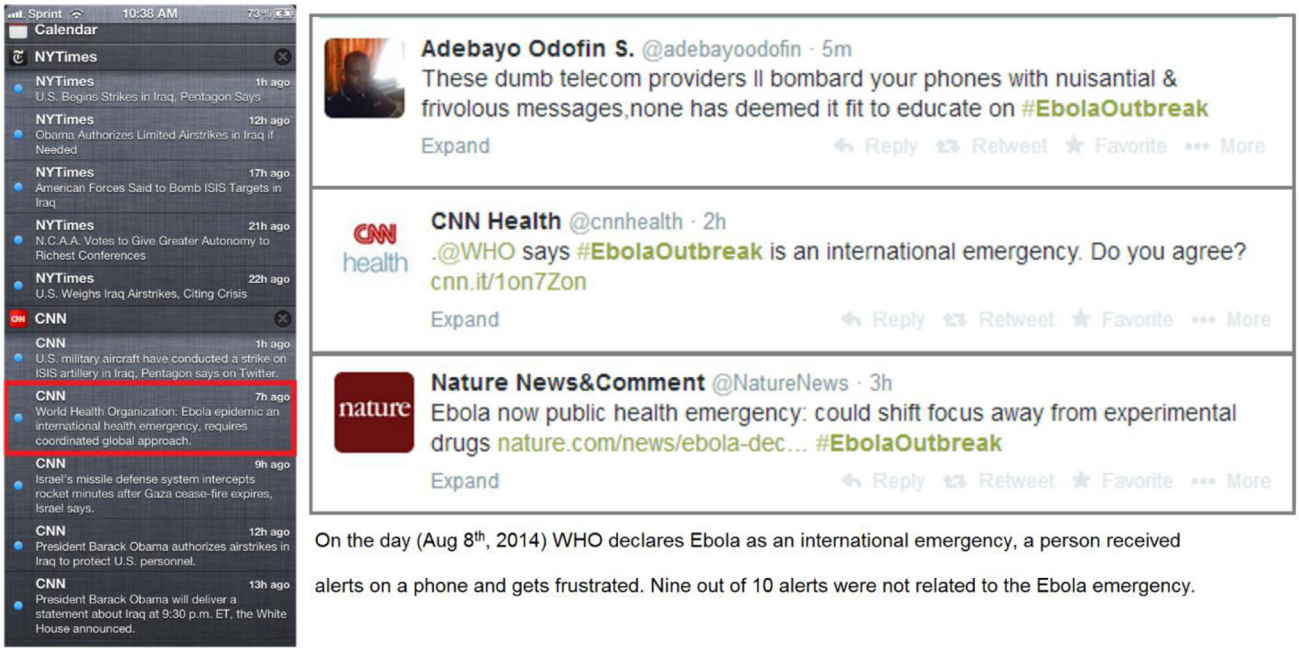

Fig 5. An example of a person's perception on the day of the Ebola emergency declaration by the World Health Organization. (A person received 10 alerts and expressed his opinion on Twitter.)

Timely systematic collection, interpretation, and dissemination of health-related data during outbreak and surveillance efforts are important for containment and control.[23] Failure to recognize a public health threat or missing opportunities to intervene can result when information is not timely.[16] Africans are participating in global conversations more and more. According to the United Nations, a social media boom has been reported in Africa. Studies have indicated that Africans go online through their mobile phones and spend most of their time on SNSs such as Facebook and Twitter. Understanding these increasing trends, the Central Intelligence Agency uses technology for SNS surveillance in attempts to thwart terrorist activities.[30] The value of SNS content and reach cannot be ignored. SNS data have and will continue to prove valuable in support of global health efforts and outcomes.[31]

Public perception, needs, and education

Public attitudes were captured through trend analysis, revealing communication stimulated by public concern and mirroring news alerts. Tweets occurred around health advisories, case identification, and return of infected health workers to the United States. We observed EVD-related tweets increasing in frequency and fear intensity from Africa, Europe, and North America with the growing number of cases. Although tweeting increased across North America, the Caribbean remained almost silent regarding the epidemic. The recent Chikungunya outbreak was of major importance in the Caribbean, evidenced in regional tweets. Nevertheless, isolation from the EVD outbreak is concerning given the close proximity to West Africa. Furthermore, factors driving the EVD epidemic make it difficult to contain, increasing the likelihood of a global spread.[32]

Health information dissemination is critical during acute epidemic-type response, to support public health action and inform data information messages. However, health information needs must be adequately assessed for effective communication. Our results captured public knowledge, showing how tweet analysis can be useful in identifying and measuring the need for health education intervention. Messages are propagated and broadly disseminated through retweeting. Our results also show effective dissemination of health alerts. The number of EVD public concern retweets almost doubled in the day after the CDC's health advisory on July 28, 2014. Tweets were generally about health information seeking, confirming the need for appropriate health education messages to accompany alerts. It can be argued that prevention education messages will be minimal immediately after health alerts. However, our results indicate that a week after the July 26, 2014 news of the U.S. physician return, EVD education messages were still minimal. Columbia, Harvard, and Mayo Clinic tweeted about EVD prevention during these early days of news and health alerts. However, dissemination was inadequate as a result of limited following and reach, with no major news networks retweeting these prevention messages. Followers of these institutions are not representative of the general population and are characterized by higher functional and health literacy. In fact, a recent Harvard poll on U.S. EVD concerns revealed adults with less than high school education expressed greater concern than college graduates about a potential EVD outbreak and indicated major knowledge gaps regarding treatment.[33] This poll reinforces the need to provide appropriate health information messages for all literacy levels. Our results can be used in outbreak surveillance to support and evaluate the effectiveness of prevention education efforts and activities.

Four major topics were tweeted about EVD. Three topics comprised of deficiencies in health education, which identified knowledge gaps. EVD information was both provided and sought. Twitter users sought information regarding transmission, infection, prevention, location, and frequency (Fig 4). Such content provides insight into targeted areas for health education mass dissemination. A recent tweet by the WHO supports our recommendations. In an effort to dispel social media rumors and claims of products to prevent and cure Ebola, the WHO used Twitter to provide warnings.[34] Compassion in the form of prayer was also identified in our analysis. Twitter users prayed for affected countries, victims, and families. Our findings also indicate care and consolation for others. Results further support the need to improve educational efforts to diminish fear as evidenced in the U.S. sentiment to prevent the return of infected health workers.[7,35] As the EVD outbreak spirals out of

control in Liberia with the number of reported deaths as high as 200 per day,[7] increasing fear is inevitable. Misplaced fear, resulting in irrational thought or behavior, is a major barrier to outbreak prevention, containment, and care, as demonstrated in Figure 5.

Limitations of this study

The generalizability of this study is limited because of a single language (English) and social medium (Twitter) analysis. Our search strategies used possible variations with hashtags in an attempt to include the maximum number of EVD-related tweets. Our study also used the IP-based and self-report–based geographic location, potentially decreasing the accuracy of findings. Future studies analyzing data sources, including different social media, blogs, or community Web sites, may complement the understanding and dissemination of EVD-related information.

CONCLUSIONS

It is important to emphasize the ongoing and critical need for effective health education messages to accompany news alerts regarding EVD and other global outbreaks. With the recent cases of EVD in the United States, several confusing and flawed messages were issues by the CDC, prompting lawmakers to question the agency's ability to handle the EVD health crisis.[36] Although information is widely disseminated, the American people remain confused and fearful. Alternatively, there is something to be learned from the power of health education and communication from Nigeria. Their quick and forceful public health response through rapid tracking, monitoring, and isolation has been lauded by the WHO as world-class epidemiologic implementation.[37] In addition to a team of 150 contact tracers, teams of social mobilizers were deployed by Nigeria's Emergency Operations Center. Social mobilizers were responsible for providing health information to areas around the homes of EVD contacts.[38] Their efforts were tremendous, reaching 26,000 households.[38] Nigeria's effective response reinforces the importance of health communication. Twitter can support similar efforts for mass dissemination.

Using Twitter in outbreak surveillance is immense, allowing for real-time data capture. Global use of SNSs is on the rise. An expanded definition of public health outbreak surveillance is needed because social media content can be used to support and enhance existing early warning systems. Twitter users provide multiple dimensions of concern, regardless of character limitations. In spite of evident public unease, our analysis reveals no health education resolve. Twitter allows for government and health agencies to engage and guide the public during outbreak surveillance efforts. For effective data information messaging, Twitter can inform content for desired outcomes. Access to such data allows for greater accuracy and sensitivity in the assessment of behavioral response. Because fear and knowledge deficits drive epidemics, outbreak alerts must accompany population-specific and literacy-appropriate health education messages for intervention and outbreak control.

Acknowledgments

We thank Elaine L. Larson, RN, PhD, and Jacqueline A. Merrill, RN, MPH, PhD, for their insights in initiation of the project. We were able to capture the rare but critical data before the Ebola outbreak to contribute to the early detection of the outbreak using Twitter. We thank Suzanne R. Bakken, RN, PhD, for her support in several years of training for the authors to learn the analytic skills of Twitter.

References

1. Ansumana R, Bonwitt J, Stenger DA, Jacobsen KH. Ebola in Sierra Leone: a call for action. Lancet 2014;384:303.
2. Gatherer D. The 2014 Ebola virus disease outbreak in West Africa. J Gen Virol 2014;95:1619-24.
3. Green A. Ebola emergency meeting establishes new control centre. Lancet 2014;384:118.
4. Dolan N. Infectious disease surveillance update. Lancet 2014;14:1055-64.
5. Torjesen I. Two doctors die from Ebola and lives of others under threat in West Africa. BMJ 2014;349:g4895.
6. World Health Organization. IHR Emergency Committee on Ebola outbreak in West Africa. Ebola virus disease update – Senegal. Global alert and response: disease outbreak news. Geneva Switzerland: WHO; 2014.
7. Izadi E. Ebola death toll rises to 2,296 as Liberia struggles to keep up. Washington Post; 2014. Available from: http://www.washingtonpost.com/news/to-your-health/wp/2014/09/09/ebola-death-roll-rises-to-2296-as-liberia-struggles-to-keep-up/. Accessed March 23, 2015.
8. Sifferlin A. WHO: more than 1,000 killed in Ebola outbreak. TIME; 2014. Available from: http://time.com/3108357/ebola-outbreak-who/. March 23, 2015.
9. Dixon MG, Schafer IJ. Ebola viral disease outbreak West Africa 2014. MMWR Morb Mortal Wkly Rep 2014;63:548-51.
10. Feldmann H. Ebola - a growing threat? N Engl J Med 2014;371:1375-8.
11. Drazen JM, Kanapathipillai R, Campion EW, Rubin EJ, Hammer SM, Morrissey S, et al. Ebola and quarantine. N Engl J Med 2014;371:2029-30.
12. Centers for Disease Control and Prevention. Viral hemorrhagic fevers. Fact sheet. Georgia; 2013.
13. Calain P. Exploring the international arena of global public health surveillance. Health Policy Plan 2007;22:2-12.
14. McNabb SJ, Surdo AM, Redmond A, Cobb J, Wiley J, Chakrabarti S, et al. Applying a new conceptual framework to evaluate tuberculosis surveillance and action performance and measure the costs, Hillsborough County, Florida, 2002. Ann Epidemiol 2004;14:640-5.
15. Ridley RG. Research on infectious diseases requires better coordination. Nat Med 2004;10(12 Suppl):S137-40.
16. Hall HI, Correa A, Yoon PW, Braden CR. Lexicon, definitions, and conceptual framework for public health surveillance. MMWR Surveill Summ 2012;61-(Suppl):10-4.
17. Khan AS, Fleischauer A, Casani J, Groseclose SL. The next public health revolution: public health information fusion and social networks. Am J Public Health 2010;100:1237-42.
18. Sullivan SJ, Schneiders AG, Cheang CW, Kitto E, Lee H, Redhead J, et al. 'What's happening?' A content analysis of concussion-related traffic on Twitter. Br J Sports Med 2012;46:258-63.
19. Signorini A, Segre AM, Polgreen PM. The use of Twitter to track levels of disease activity and public concern in the U.S. during the influenza A H1N1 pandemic. PLoS One 2011;6:e19467.
20. Statistic Brain. Twitter statistics. 2014. Available from: http://www.statisticbrain.com/twitter-statistics/2014. Accessed March 23, 2015.
21. Bosley JC, Zhao NW, Hill S, Shofer FS, Asch DA, Becker LB, et al. Decoding twitter: surveillance and trends for cardiac arrest and resuscitation communication. Resuscitation 2013;84:206-12.
22. Heaivilin N, Gerbert B, Page JE, Gibbs JL. Public health surveillance of dental pain via Twitter. J Dent Res 2011;90:1047-51.
23. Henning KJ. What is syndromic surveillance? MMWR Morb Mortal Wkly Rep 2004;53(Suppl):5-11.
24. Gardner ES. Exponential smoothing - the state of the art. J Forecasting 1985;4:1-28.
25. Yoon S, Elhadad N, Bakken S. A practical approach for content mining of tweets. Am J Prev Med 2013;45:122-9.
26. Lewis D, Farge E. Wrapup 1-Liberia shuts schools as Ebola spreads, Peace Corps leaves 3 countries. Reuters; 2014. Available from: http://www.reuters.com/article/2014/07/31/health-ebola-idUSL2N0Q53DV20140731. Accessed March 23, 2015.
27. Centers for Disease Control and Prevention. CDC telebriefing on Ebola outbreak in West Africa. Georgia; 2014.
28. Tappero JW, Tauxe RV. Lessons learned during public health response to cholera epidemic in Haiti and the Dominican Republic. Emerg Infect Dis 2011;17:2087-93.
29. Centers for Disease Control and Prevention. Ebola hemorrhagic fever. Previous updates: 2014 West Africa Outbreak July 31. Georgia; 2014. Available from: http://www.cdc.gov/vhf/ebola/outbreaks/2014-west-africa/previous-updates.html. Accessed March 23, 2015.
30. Giles J. 'Unlike' the FBI on Facebook. New Sci 2012;214:24.
31. Essoungou A. The social media boom begins in Africa. The United Nations Africa Renewal; 2010. Online Available from: http://www.un.org/africarenewal/magazine/december-2010/social-media-boom-begins-africa. Accessed March 23, 2015.
32. Changula K, Kajihara M, Mweene AS, Takada A. Ebola and Marburg virus diseases in Africa: increased risk of outbreaks in previously unaffected areas? Microbiol Immunol 2014;58:483-91.
33. Harvard School of Public Health. Poll finds many in U.S. lack knowledge about Ebola and its transmission. News Press Release; 2014. Available from: http://www.hsph.harvard.edu/news/press-releases/poll-finds-many-in-us-lack-knowledge-about-ebola/. Accessed March 23, 2015.

34. Jones B, Elbagir N. Are myths making the Ebola outbreak worse? CNN World; 2014. Available from: http://www.cnn.com/2014/08/20/world/africa/ebola-myths/. Accessed March 23, 2015.
35. Stanglin D. 2 American Ebola patients head to USA. USA Today; 2014. Available from: http://www.usatoday.com/story/news/nation/2014/08/01/ebola-liberia-american-patient-emory/13453997/. Accessed March 23, 2015.
36. Begley S. U.S. health agency chief faulted over confusing Ebola messages. Reuters; 2014. Available from: http://www.reuters.com/article/2014/10/17/us-health-ebola-usa-message-analysis-idUSKCN0I62DU20141017. Accessed March 23, 2015.
37. Fasina F, Shittu A, Lazarus D, Tomori O, Simonsen L, Viboud C, et al. Transmission dynamics and control of Ebola virus disease outbreak in Nigeria, July to September 2014. Euro Surveill 2014;19:20920.
38. Courage K. How did Nigeria quash its Ebola outbreak so quickly?. Scientific American October 18, 2014. Available from: http://www.scientificamerican.com/article/how-did-nigeria-quash-its-ebola-outbreak-so-quickly/. Accessed March 23, 2015.