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**RESEARCH ARTICLES****Use of Mobile Apps for epidemic surveillance and response – availability and gaps**Biswajit Mohanty, Abrar Chughtai & Fethi Rabhi<sup>1</sup><sup>1</sup> University of New South Wales, Sydney, Australia

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**Abstract**

*Background:* Early detection of disease outbreaks, using appropriate surveillance methods, is a basic principle for effective control of epidemics. Indicator-based surveillance methods, such as comprehensive surveillance, sentinel surveillance and syndromic surveillance, have been routinely utilized for early epidemic detection to minimize mortality and morbidity related to emerging infectious disease threats. In addition, event-based surveillance uses unstructured data sources to detect and monitor outbreaks such as media reports, social media and websites. The use of mobile phone technology is growing in many low and middle-income countries, which has made mHealth an efficient means of health communication in such countries for epidemic surveillance, mitigation and response. Mobile Apps may draw data from validated health sources or unvalidated public sources and convey information to responders. The aim of this study was to review mobile Apps used for epidemic surveillance and response.

*Methods:* A review of Google Play and the App Store was conducted from June 2018 to August 2018 for Apps containing the words “epidemic”, “outbreak”, “pandemic”, “public health”, “infectious diseases”, “infection”, “bioterrorism” or “CBRNE”, “surveillance”. Available Apps were analysed by the intended user, purpose, platform, functions and number of downloads.

*Results:* We found a total of 106 Apps in an initial search, and of those 80 Apps did not meet the selection criteria and were excluded. Finally, 26 relevant surveillance Apps, including 21 free of charge and 5 paid Apps, were included in this review. Of these, 17 Apps are for single disease surveillance, 7 Apps for multiple disease surveillance and 2 Apps provides information on possible bioterrorism agents. The intended user varied from the general public (18 Apps) to health practitioners (4 Apps) and remaining 4 Apps intended for both general public and health practitioners. The Apps included real-time tracking in an interactive map (10 Apps), daily notification alerts (3 Apps), user function to report diseases/ outbreaks (4 Apps) and multiple disease tracking options (7 Apps). The most downloaded Apps were Sickweather with 100,000+ downloads and HealthMap with 10,000+ downloads. Only 4 Apps were available on both Android and iOS platforms.

*Conclusion:* There are at least 26 mobile Apps for surveillance of epidemics, mostly free of charge and mostly for laypeople. Among them, HealthMap is the most comprehensive, but by far the greatest number of downloads was for a consumer App, Sickweather. Some Apps can provide real-time tracking and interactive maps. However, limitations included unavailability of Apps suitable for general public or surveillance of potential bioterrorism incidents, limited geographic or disease relevance, and high cost for some Apps. There is great potential to utilize existing Apps and develop new ones, especially which meet the needs of health professionals and public health authorities for real-time disease surveillance.

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**Introduction**

Early detection of disease outbreaks, using appropriate surveillance methods such as indicator-based surveillance (IBS) and event-based surveillance (EBS), is a basic principle for effective reduction and control of epidemics (1). IBS is comprehensive surveillance, using structured, validated reports of specific diseases from laboratories and the health system to public health officials (2). Sentinel surveillance involves detecting specific diseases or syndromes in sentinel geographic sites to gain early warnings (3). Syndromic surveillance involves detection of clinical syndromes as a signal of severe

infections (2, 4) and is utilized when high-quality data is required for a specific disease (5). EBS is the use of unstructured data such as media reports, rumors, stories, social media and websites to detect and monitor outbreaks. EBS is community-based and utilises reports of health events on news, social media, blogs or messaging systems (6). The development of automated intelligence methods is of growing interest (15), including Open-source intelligence (OSINT) (16).

The availability of information technology (IT) for electronic data collection and execution has given support to Web-based surveillance methods which can notify rapid epidemic intelligence on public health

incidents (7). Web-based sources provide more timely information for identifying infectious disease epidemics, such as detecting cases of disease-relevant keywords in social media like twitter, Instagram or published report of news (8). Several web-based surveillance systems like ProMed-mail, HealthMap and Global Public Health Intelligence Network (GPHIN) have been utilized to monitor disease trends across the globe (2). The use of mHealth technology and mobile Apps are of interest due to high usage of mobile phones and internet in many low and middle-income countries, where other surveillance systems may be weak (9). Mobile health or mHealth is defined as medical and public health services supported by mobile devices such as smartphones, tablets, personal digital assistants (PDAs), patient monitoring devices and wireless devices (10, 11). It provides immediate access to information for effective decision making and supports better communication between healthcare workers and patients (10). Mobile Apps and online portals can link patients to their health providers and their health data to establish high-quality care (10). A mobile phone's key utilities such as voice and short messaging service (SMS) and other essential functionalities including GPRS (general packet radio service), 3G and 4G mobile telecommunications, GPS (global positioning system) and Bluetooth technology can be harnessed through mHealth (11). Common m-health initiatives include health call centers, emergency phone services, managing emergencies and disasters, and mobile telemedicine. However, there are many barriers to mHealth such as technical limitations, lack of knowledge among health staff, high operating cost and infrastructure.

The use of mobile phone technology is growing in many low and middle-income countries, making mHealth an efficient means of health communication in such countries. In countries such as India, for example, mobile phone ownership and usage is almost universal, and much higher than computer ownership, making mHealth a suitable tool for improving healthcare (12, 13). Many governments have shown their interest in mHealth as a tool for strengthening health systems toward attaining the United Nations Sustainable Development Goals in those countries (14-16).

Most of the mobile Apps in health have been designed to be used by patients for individual clinical care, and mostly in chronic disease management (17). Other Apps are used to educate patients about health (18). Apps may receive or convey information from or to a patient or a health professional (19). There is increasing interest in the use of mHealth for epidemic surveillance, mitigation and response (20). In this case Apps may draw data from validated health sources or unvalidated public sources and also convey information to responders (21). The aim of this study was to identify available mobile Apps for epidemic

surveillance, review their utility in public health and identify any gaps in need.

## Methods

A review of Google Play and the App Store was conducted from June 2018 to August 2018 for Apps containing the words “epidemic,” “outbreak,” “pandemic,” “public health,” “infectious diseases,” “infection,” “bioterrorism” or “CBRNE,” “surveillance.” In addition, major sites for public health response to outbreaks such as the US Centers for Diseases Control and Prevention (CDC), World Health Organizations (WHO), United Nations and Australian Department of Health, were searched for relevant Apps. Apps were searched on 20th June 2018 from Google Play and the App Store. In cases where Apps were not available in Google Play, they were searched in google search engine using keyword “App name (XYZ) apk” and downloaded from third party android websites such as Apkpure (22).

Available Apps were analysed by the intended user, purpose, platform, functions and number of downloads. Apps were reviewed for platform (Android or iOS), relevance, purpose, intended users, cost and the number of downloads. We excluded apps related to games, health education for members of the public, or not relevant for public health. All the surveillance apps were compared based on the following criteria: features available in the App, the types of diseases they track, surveillance regions, sources of disease reports, release and last updated date, device compatibility, languages available, number of downloads, ratings, and price (free or paid). In addition, we identified the underlying models or digital technology used to detect the disease epidemics and compared among the reviewed apps. The Apps found from the review of android and iOS stores were categorized by multiple diseases and single disease surveillance App. Furthermore, the apps were categorized based on user-friendliness of their features.

## Results

A total of 106 Apps were found in the initial search. Of those, 80 did not meet the selection criteria and were excluded (Figure 1). Finally, 26 relevant surveillance Apps were included in this review, which are summarised in Table 1. Of 26 relevant surveillance Apps, 21 were free of charge and 5 were paid Apps. Of these, 17 Apps are for single disease surveillance, 7 Apps for multiple disease surveillance and 2 Apps provided information on possible bioterrorism agents. The intended user varied from the general public (18 Apps) to health professionals (4 Apps). A further 4 Apps were intended for both the general public and health professionals. Features included real-time tracking using an interactive map (10 Apps), daily notifications (3 Apps), user ability to report diseases/outbreaks (4 Apps), and multiple disease tracking options (7 Apps). The most downloaded Apps were Sickweather with 100,000+ downloads, followed

by HealthMap with 10,000+ downloads. Other Apps were far less frequently downloaded (17 Apps have downloads less than 10,000, and number of downloads is not available for seven Apps), and 4 Apps were downloaded less than 100 times (Figure 2). The maximum downloads were of Apps available in the Android platform. Only 4 Apps were available on both Android and iOS platforms, while, 16 Apps were available on the Android platform and 6 Apps in iOS platform.

Seven Apps had multiple-disease surveillance (including HealthMap and ProMed-mail); another 17 Apps were for single-disease surveillance, and two Apps provided information on possible bioterrorism agents (Figure 3). Of single disease Apps, 8 were on influenza only, 3 on dengue, 3 on Ebola, 2 on Zika virus and 1 on malaria (Figure 4). Some Apps are country-specific, such as the CDC FluView and Flu-near-you applications, which used for surveillance of influenza-like illness (ILI) activity in the United States. Some were designed to track a geolocation such as Mo-Buzz, which uses hotspot maps to track dengue outbreaks in Colombo city, Sri Lanka. The ECDC Threat Reports App gives reports on communicable disease threats only in the European region. Dengue Map monitors dengue outbreaks in Brazil.

A few Apps can only be accessed from Google play in selected countries, such as MoBuzz and Flutrack (Table 1). Almost all the Apps were in the English language; however, some Apps were available in different languages such as Dengue Map App in Portuguese. Paid Apps had fewer downloads compared to free Apps. Some unique features of these Apps include: the Outbreak App has offline access to incoming updates and pinpoints the exact location of the outbreak; the HealthMap App can give users customised alerts on outbreaks occurring in a specified region; ProMed-mail App allows users to submit reports about disease outbreaks; and the MoBuzz App uses hotspot maps to track dengue affected areas. Of 26 available Apps, 13 Apps had a user rating of 3.5 or higher out of 5, 4 Apps had ratings <3.5 and no rating was available for the rest of the Apps.

### *Mathematical models and digital technologies used*

The following Apps use complex mathematical models or digital technology for surveillance of outbreaks.

1. HealthMap- uses models such as Fisher-Robinson Bayesian filtering, and also relies on Google Maps, Google Map API, Google Translate API for disease tracking (23).
2. Sickweather- uses Advanced machine learning models, Artificial intelligence (AI) and cognitive APIs to forecast the rate of illnesses up to 15 weeks in advance with more than 90% accuracy (24).

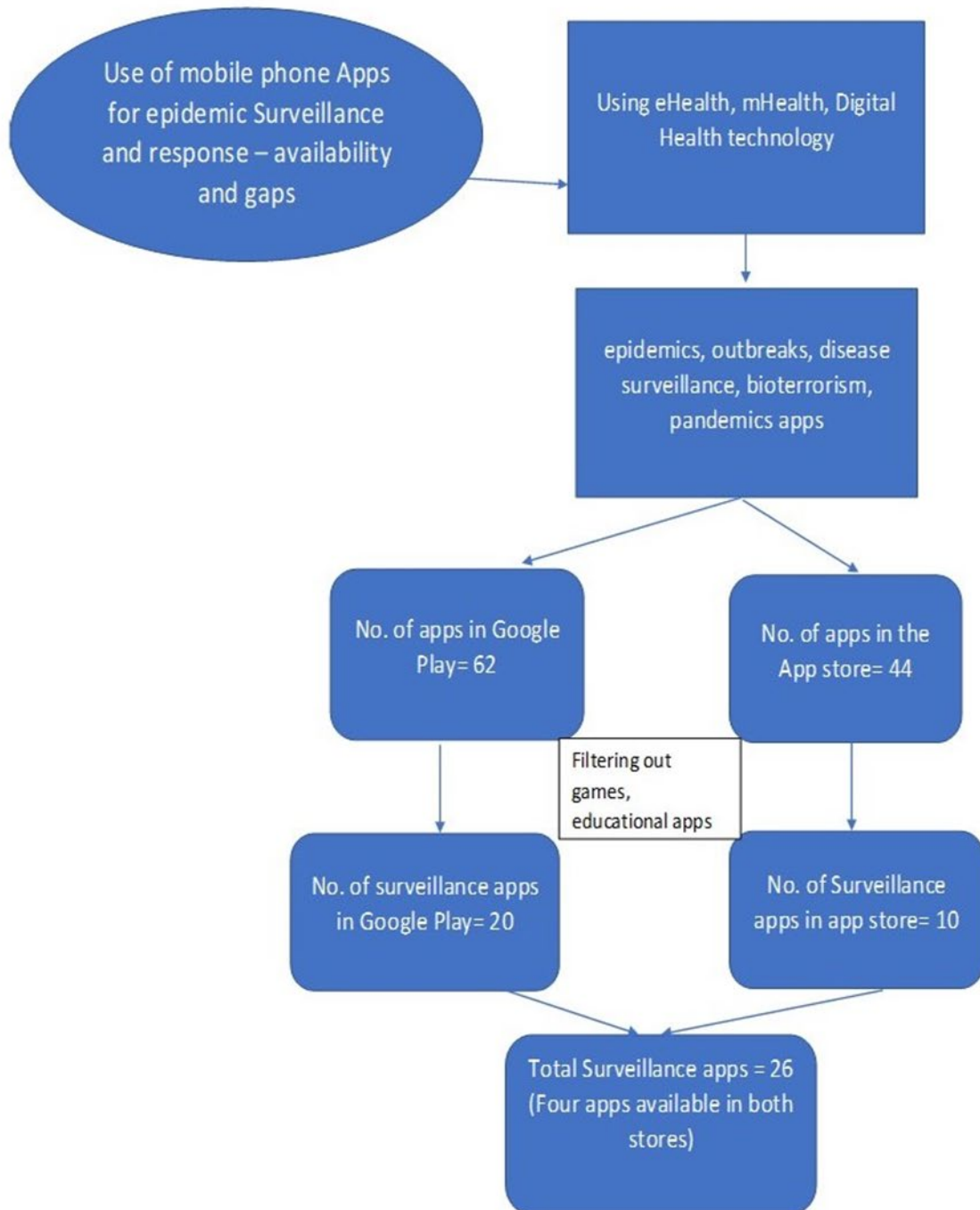
Other apps use simple mathematical models or digital technology for the surveillance using various informal networks such as public, twitter, and social media reports, and formal reports from health organisations, government and humanitarian organizations, clinical data and simple technologies such as Reliefweb API, twitter API, and crowdsourcing technology. Examples include Fluview App, which only uses data collected by CDC in a visualized format of influenza activity. CDC gets data from Influenza-like Illness Surveillance Network (ILInet), U.S. World Health Organization (WHO) Collaborating Laboratories System and National Respiratory, and Enteric Virus Surveillance System (NREVSS) collaborating laboratories. Some other apps which use data from CDC are Flu tracker, Field facts, LRN Rule-Out Refer, Swine Flu 101.

Further examples of simple model surveillance Apps are Flu near you 2, ViralMap, Flutrack, ECDC Threat Reports, Mo-Buzz, Epidemic Tracker, ProMED-mail, LA - Malaria Case Surveillance, Flutac-NTU, Appdemia, DengueWatch, Flu Map Tracker, Zika Tracker.

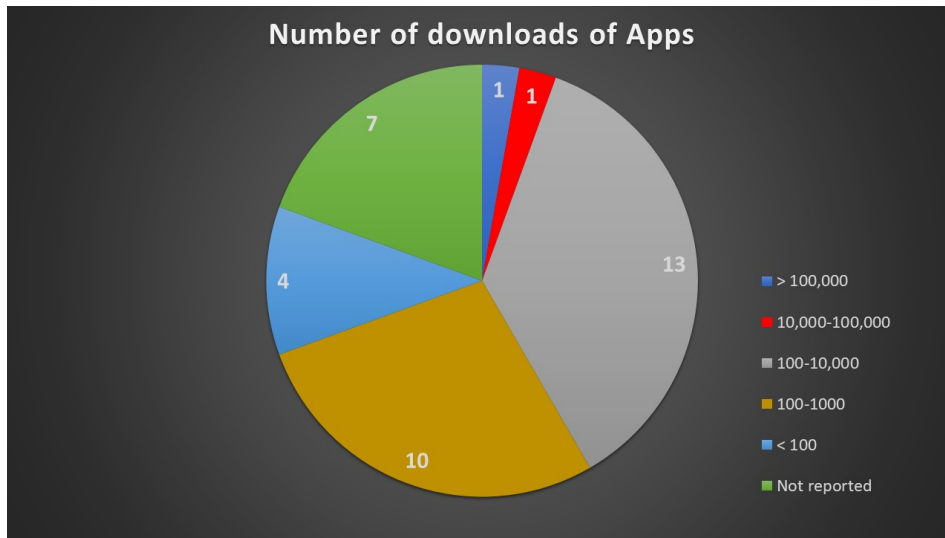
For other Apps such as Ebola tracker, Outbreak app, Dengue Map, Ebola Map Global Ebola Tracker, and Global Zika Tracker, the methods are unknown/undisclosed.

**Figure 1.** Search strategy Diagram containing procedure followed to find out disease surveillance Apps from Google Play and the App store

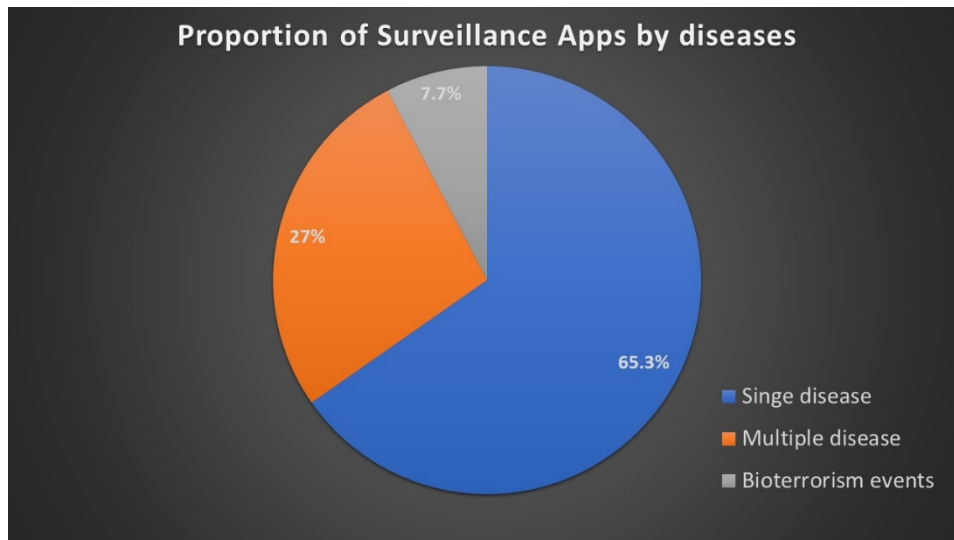
### Search Strategy Diagram for Surveillance Apps



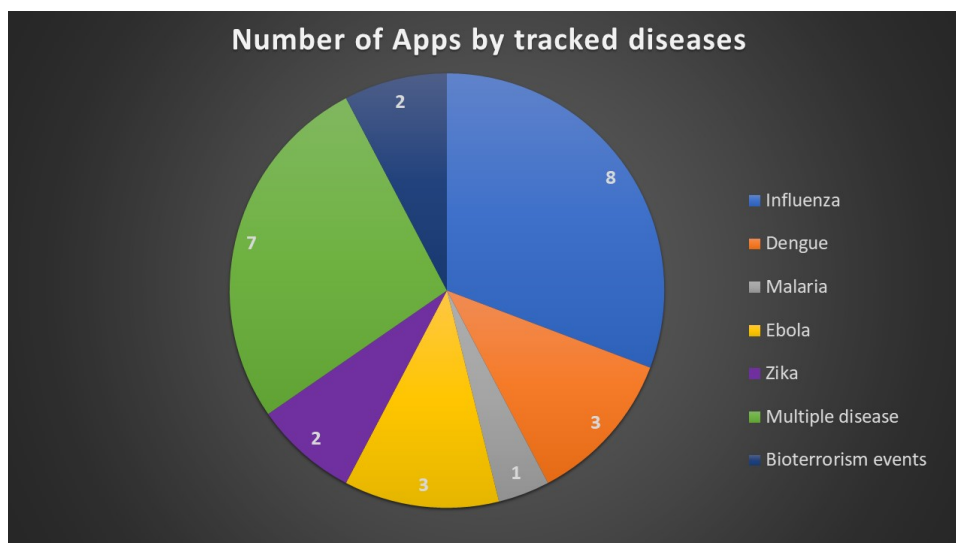
**Figure 2.** Number of Apps according to the number of downloads in Google Play and the App Store



**Figure 3.** Availability of Apps based on surveillance of single disease, multiple diseases and bioterrorism events



**Figure 4.** Disease-specific tracking of Apps





**Table 1.** Diseases or Outbreaks Surveillance, Bioterrorism, Epidemic and Pandemic Apps in Google Play and the App store

Sl No.	App name	Features or Description	Diseases tracked	Category	Intended Users	No. of Downloads	Copyright / Offered by	Source of information	Country Applicable	Price	Compatibility	Rating s	Release date	Last updated	Language s	Cons	Reviews
1	HealthMap: Outbreaks near me	Latest real-time disease outbreak information	All outbreaks	Health & Fitness	General Public	10,000+ (Google Play)	HealthMap	ProMED Mail, WHO, GeoSentinel, OIE - World Organisation for Animal Health, Food and Agriculture Organization of the United Nations (FAO), EuroSurveillance, Google News, Moreover- A news feed aggregation service by VeriSign, Wildlife Data Integration Network, Baidu News, SOSO Info.	Global	Free	Android platform 2.3 or up; Requires iOS 7.1 or later. (iOS Universal)	3.6/5 (Google play); 3.9/5 (Apple store)	April 04, 2012 (Android); Aug 31, 2009(iOS)	March 05, 2015 (Android); Apr 24, 2015(iOS)	English	The App shows error while accessing the geographic location and outbreaks; No. of downloads not available in Apple store	“This App is a great service, but could you consider no longer gathering a list of the Apps on my phone. My security program is complaining that this App is gathering that info.”; “The map doesn't load at all so now the App is useless. I have no immune system because of leukemia and used this App frequently to keep up with outbreaks. Please fix it quickly.”
2	FluView	Explore Influenza-Like Illness (ILI) Activity Levels across the US	Influenza	Medical	Health Practitioners	N/A	CDC	Influenza-like Illness Surveillance Network (ILINet)	U.S.	Free	iOS 4.0 or later. (iOS Universal)	1.8/5	Mar 27, 2012	Mar 27, 2012	English	No. of downloads not available	“It's free and it's from the CDC. Need I say more?” “Accurate fast efficient way to track flu infections wherever you are whether it's traveling for work, or at home with family.”; “Too bad because as a health care provider it would have been handy. Go to the website instead. It has more data, it's current.”
3	Flu tracker	Get flu-related news updates. A map feature shows weekly state by state influenza activity in the US.	Influenza	Medical	General Public	N/A	Anouk Stein, M.D.	CDC	U.S.	Free	Requires iOS 10.1 or later. Compatible with iPhone, iPad and iPod touch.	N/A	May 13, 2011	Dec 04, 2016	English	No. of downloads not available	N/A
4	LRN Rule-Out Refer	Obtains essential information regarding six potential bioterrorism agents	Bacillus anthracis, Brucella species, Yersinia pestis, Francisella tularensis, Burkholderia pseudomallei, and Burkholderia mallei	Medical	Health Practitioners	N/A	CDC	CDC	U.S. laboratories	Free	iOS 7.0 or later(iPad)	N/A	Feb 25, 2015	Sep 13, 2015	English, Korean	Not useful for surveillance of potential bioterrorism incidents.; No. of downloads and user ratings not available	N/A

5	Field Facts	It provides helpful information to first responders for implementation in the initial few hours or moments during a potential bioterrorism incident.	Ricin, Botulism toxin, Bacillus anthracis (anthrax), Yersinia pestis (plague), Francisella tularensis, Brucella (brucellosis), Smallpox virus, Burkholderia (melioidosis and glanders)	Medical	Health Practitioners	500+ (Google Play)	CDC	CDC	U.S.	Free	Android platform 4.0 or up; iOS 8.0 or later. (iOS Universal)	Ratings: 3.7/5 (Google Play)	Dec 18, 2017 (Android); June 07, 2018 (iOS)	Dec 18, 2017 (Android); June 07, 2018 (iOS)	English, Korean	Not useful for surveillance of potential bioterrorism incidents.; No. of downloads not available in Apple store	“I like in this time we need be aware of everything. Also, we should know where the bacteria viruses and plague come from and what to do in case of emergency. Is a proved information. Connected with the CDC even better.”; “It’s a good App very informative.”
6	Flu near you 2	Get real-time updates about the onset of flu in your area. Provides real-time, trending information about influenza-like illness in your immediate vicinity.	Influenza	Unknown	General Public	100+	HealthMap	Individuals reports, Voluntary Participation, Crowdsourced Data, Visualized Data	U.S.	Free	Android 4.1 or above	3.0	N/A	March 02, 2018	English	This App is currently not available in all locations on Google Play	“If Flu Near You worked properly, it’d be a great solution for people who want to avoid getting sick especially during flu season. Unfortunately, numerous bugs with signing in, and a general lack of crowdsourcing data points these days, greatly hamper its effectiveness at most locations.”
7	ViralMap	Monitors tweets related to personal reports involving flu or influenza all around the world.	Influenza	Health & Fitness	General Public	100+	Ricardo Mansilla	tweets related with personal reports	Global	Free	Requires Android 2.2 and up (third party App)	5/5	June 25, 2014	July 1, 2014	English		“Wow Information overload!”
8	Flutrack	Detects flu symptoms using Twitter.	Influenza	Health & Fitness	General public and health practitioners	5+	alex199568	Flu-related tweets using Twitter API	Global	Free	Requires Android 4.1 and up (third party App)	N/A	April 4, 2018	April 10, 2018	English	Rating not available; Not available in all locations on Google Play	N/A

9	Sickweather	It provides real-time alerts from social media whenever you enter a Sick Zone. Provides alerts for Flu, Norovirus, Pink Eye, Whooping Cough, and 19 other illnesses. Allows users to enter symptoms when they are ill.	Influenza, Norovirus, Pink Eye, Whooping cough	Social	General Public	100,000+	Sickweather	Social media monitoring, crowdsourcing, forecasting and output, Population, Sales & Clinical Data	Global	Paid (U.S. \$2.99)	Requires Android 4.4 and up; Requires iOS 9.1 or later. Compatible with iPhone, iPad, and iPod touch	3.7	September 30, 2014	April 24, 2018	English	Uses your location even when it is not open, which can decrease smartphone's battery life.	"So at first this App was really cool, now its constantly saying there's a 98% chance of getting sick, and head lice is being the only thing reported, last week allergies. Way to get it together sickweather."; "Can't figure out how to remove a location."
10	ECDC Thread Reports	Provides direct access to key updates and reports on communicable disease threats of concern to the EU.	Communicable diseases	Medical	General Public and Health practitioners	1,000+	European Union	European Centre for Disease Prevention and Control	Europe	Free	Requires Android 4.1 and up	4.7	December 21, 2016	August 25, 2017	English		N/A
11	Ebola tracker	Up to date mapping Application of the Ebola outbreak currently spreading throughout the world. Shows Number of new cases in the last 24 hours.	Ebola	Medical	General Public	N/A	Ebola Tracker	Unknown	Global	Paid U.S. \$3.99	Requires iOS 10.1 or later. Compatible with iPhone, iPad, and iPod touch.	2.5	Sep 13, 2014	Aug 10, 2017	English	No. of downloads not available	"My guess is the developer was in such a rush to cash in, he never completed the job and released this App before it was ready. The features that could make this App interesting simply do not work."; "The App is good and informative. There is even a section with articles relating to Ebola with 'Breaking News'. The map has locations of people who have Ebola including the patient in Texas, Washington D.C, and Canada. The text info is not regularly updated though."
12	Mo-Buzz	Use hotspot maps to keep track of those parts of your city that are most affected by dengue.	Dengue	Free tools App	General Public	N/A	Cosmic Centre NTU	Crowdsourcing technology and health education	Colombia city, Srilanka	Free	Android 4.0 and up (third party App)	N/A	Dec 15 <sup>th</sup> , 2015	August 17, 2017	English	Not available in all locations on google play	N/A
13	Outbreak	Posts global disease outbreaks such as H1N1, Ebola, Anthrax and Malaria.	H1N1, Ebola, Anthrax, Malaria	News & Magazines	General Public	500+	Junaid Masood	Unknown	Global	Free	Android 5.0 and up	4.4	July 7 <sup>th</sup> , 2015	May 21, 2018	English	Not able to access the App after being downloaded	"Helpful and useful App I recommend to download this App, gives us latest updates of all Hazardous epidemics in our world."; "Nice App Very helpful App"



14	Epidemic Tracker	Helps users follow reports of major current diseases being tracked.	Cholera Dengue Ebola Polio Malaria Measles MERS-CoV Zika	Tools	General Public	100+	Emerging Infections	Reliefweb API, ET, government and humanitarian organizations	Global	Free	Android 4.2 and up	4.0	December 26, 2016	February 18, 2017	English		N/A
15	ProMED-mail	The global electronic reporting system for outbreaks of emerging infectious diseases & toxins, open to all sources.	Outbreaks of emerging infectious diseases	Medical	General Public and Health Practitioners	500+	ProMED-mail, International Society for Infectious Diseases	media reports, official reports, online summaries, local observers	Global	Free	Requires Android 2.3.3 and up; Requires iOS 6.0 or later. Compatible with iPhone, iPad and iPod touch.	4.0	November 30, 2015	August 24, 2016	English		“Handy if you want to review promed when out and about. Standard text quite small but can be enlarged on each article. Would be useful to have a setting to keep text larger. Great idea to increase ease of reporting. Thanks for making it available.”
16	LA - Malaria Case Surveillance	Tracks and reports positive cases of malaria in near real-time using District Health Information Software 2 (DHIS2)	Malaria	Health & Fitness	Health Practitioners	500+	PSI GBS	PSI's District Health Information Software 2 (DHIS2)	Global	Free	Requires Android 4.0.3 and up	5.0	August 30, 2017	September 22, 2017	English	Not available in all locations in Google Play	N/A
17	Flutac-NTU	Provide notification of potential influenza outbreaks in Singapore	Influenza	Tools	General Public	100+	SSHSPH, National University of Singapore	NUS, TTSH, CDC	Singapore	Free	Requires Android 5.1 and up	5.0	April 27, 2018	May 10, 2018	English		N/A
18	Appdemia	Anyone can track the more relevant health occurrences in their region	fever, diarrhea, zika virus, dengue, chikungunya	Health & Fitness	General Public and Health Practitioners	100+	Prosperi Tecnologia	Public reports	Global	Free	Requires Android 4.0.3 and up	4.8	July 20, 2016	October 14, 2016	English		“Very useful” “Good Very good, I especially enjoyed the design.”
19	Dengue Map/ Mapa da Dengue	Monitors dengue outbreaks in your region.	Dengue	Health & Fitness	General Public	1,000+	Web Fantastico	Unknown	Brazil	Free	Requires Android 1.6 and up	3.5	November 20, 2015	December 13, 2015	Portuguese		N/A
20	DengueWatch	Online alerts and notifications of dengue cases reported by users or authorities; near their homes and/or workplace.	Dengue	Health & Fitness	General Public	5+	IMEUS	Users or authorities report	Global	Free	Requires Android 4.1 and up	Not rated	January 30, 2018	January 30, 2018	English		N/A
21	Flu Map Tracker	Tracks Twitted flu all over the world and showing them on the mobile phone's Google Map.	influenza	Health & Fitness	General Public	100+	Devlin Duldulao	Twitted flu reports	Global	Free	Requires Android 6.0 and up	N/A	January 14, 2018	January 14, 2018	English	Rating not available	N/A

22	Ebola Map	Tracks the Ebola outbreak and get up to the minute Ebola locations and status.	Ebola	Health & Fitness	General Public	1,000+	Real IT Experts	Unknown	Global	Free	Requires Android 2.3 and up	3.9	October 18, 2014	November 20, 2014	English		“Nice! Nice map for tracking Ebola.”; “This App is so useful I used to be afraid to go in public. Now, with this amazing App I can just do a quick check to make sure there is no ebola around. It's good to be free again.”
23	Swine Flu 101	Tracks influenza cases around the world. Map of all outbreak cases and corresponding information updated to the minute	influenza	News	General Public	N/A	TapFactory Apps	CDC	Global	Free	Requires iOS 2.2.1 or later. Compatible with iPhone, iPad and iPod touch.	2.5	May 08, 2009	May 16, 2009	English	No. of downloads not available; Currently not available in the App store	N/A
24	Zika Tracker	Daily updated mapping application of the Zika outbreak.	Zika	Medical	General Public	N/A	Zika Tracker	Individuals posts and reports	Global	\$1.99	Requires iOS 9.1 or later. Compatible with iPhone, iPad, and iPod touch.	Not rated	Sep 30, 2016	Aug 09, 2017	English	No. of downloads not available	“App doesn’t work. Upon recent purchase, this App will not connect with satellites to display data. Very disappointing”; “Scam. Doesn’t work as data won’t load. Total scam.”
25	Global Ebola Tracker	Scans the world continent maps for reported Ebola cases from 2014 to the present, Reported and Confirmed Ebola Locations	Ebola	Health & Fitness	General Public	1+	Garden State Software	Unknown	Global	Paid \$1.27	Requires Android 4.0 and up	Not rated	March 20, 2015	March 3, 2016	English		N/A
26	Global Zika Tracker	Scans the world for reported Zika cases from 2015 to the present.	Zika	Health & Fitness	General Public	1+	Garden State Software	Unknown	Global	Paid \$1.39	Requires Android 4.0 and up	Not rated	February 26, 2016	February 26, 2016	English		N/A

## Discussion

For epidemic surveillance, mitigation and response, implementation of mHealth technologies are potential enablers (20), and there are several options available. We found 26 Apps relevant to epidemic surveillance, mostly free of charge, the majority for the Android platform and single diseases, particularly influenza. Some Apps were country- and language-specific and had narrow applicability. Some Apps can provide real-time tracking and interactive maps. HealthMap was the most useful for epidemic surveillance, but a consumer App, Sickweather, was downloaded over 10 times more frequently. However, download statistics suggest that surveillance Apps are not widely used, with only 2 Apps (Sickweather and HealthMap) downloaded more than 10,000 times.

The Apps for the general public and health professionals have different needs and should be tailored accordingly, but there were relatively few Apps for health professionals. Use by general consumers is much more common than by health authorities or health professionals, with only a minority of Apps designed for the health sector. This indicates the potential for more widespread uptake of Apps for epidemic surveillance in public health. This is also an area where more products could be developed to assist disease surveillance. For increased uptake, ideally, apps should be free of cost and available on both the iOS and Android platforms to make them accessible for a larger set of users. The Apps should be accessible in different locations in multi-languages for maximal functionality. By creating awareness among users through several techniques such as Digital marketing, advertisements may also increase the utilization of Apps for disease surveillance.

Existing solutions are inherently prone to many biases (such as the language of reporting) which can affect the validity and reliability of the data due to background noise and lack of representativeness. For example, the HealthMap App had limitations in detecting the outbreaks near some specific geographic locations. Another example is that the Sickweather App uses social media data and validate it against CDC data to forecast the illness instead of directly taking data from CDC, WHO and other official sources. Hence, the results may not always be 100% reliable. The use of rigorous mathematical models and digital technologies such as advanced machine learning models, Artificial intelligence (AI) and cognitive APIs, Google Maps, Google Map API, Google Translate API could improve the user experience and efficiency of Apps by providing more accurate, up to date and meaningful information to users (25). Moreover, the use of crowdsourcing technology, efficient algorithms for social media (e.g. Twitter API) monitoring, techniques to identify affected populations and factors responsible for the health event, and data validation techniques could provide more relevant and validated information for the health professionals. Other

limitations included unavailability of Apps suitable for general public or surveillance of potential bioterrorism incidents and limited geographic or disease relevance.

There is great potential to utilize existing Apps and develop new ones, especially those which meet the needs of health professionals and public health authorities for real-time disease surveillance. In general, mobile Apps can harness vast amounts of open-source data and potentially can provide more timely information to detect signals for infectious disease epidemics, especially if they allow users to submit data. The benefits of these Apps include low logistical burden, easy implementation and improved accessibility to previously inaccessible groups. This type of surveillance cannot replace traditional surveillance but may be a useful adjunct for more timely identification of epidemics. They can also be useful in low-income settings where traditional surveillance systems are weak.

## Acknowledgements

The research was conducted under the direction of Prof. CR MacIntyre and funded by the NHMRC Centre for Research Excellence Integrated Systems for Epidemic Response (ISER) and her NHMRC Principal Research Fellowship. Copyright for the App review is vested in Prof. CR MacIntyre, UNSW.

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**How to cite this article:** Mohanty B, Chughtai AA & Rabhi F. Use of Mobile Apps for epidemic surveillance and response – availability and gaps. *Global Biosecurity*, 2019; 1(2).

**Published:** September 2019

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