Use of Bibliometric Indicators to Assess the Scientific Productivity and Impact of an Infectious Disease Surveillance Program

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ABSTRACT

Bibliometric analyses have been used to evaluate scientific impact of scientific research programs, yet are not used routinely in the field of health surveillance. We propose that bibliometric indicators can be a useful tool to measure scientific value in surveillance systems and demonstrate utility of these indicators by applying them to a federally supported infectious disease surveillance program. We were able to visualize the strengths of the surveillance program, and identify areas that could be strengthened scientifically. Additionally, we identified data collection methods that need to be in place to maximize the value of results from bibliometric analyses, and identified alternate sources of data that should be considered to enhance the assessment of scientific impact.

INTRODUCTION

The call to maintain health security has gained enormous global traction in the past decade[1-3] and several programs to address emerging infectious disease threats have been established.[4] The Department of Defense (DOD) Armed Forces Health Surveillance Center's Division of Global Emerging Infections Surveillance and Response System (GEIS) initiated in 1997 is one such federal program.[5] Over the past 15 years, GEIS has coordinated surveillance for emerging infections of military and public health importance through partnerships with DOD laboratories, academic partners, non-governmental organizations, and host nation collegues.[6]

To ensure programs which monitor and counter infectious disease threats are achieving their intended objectives, program evaluations must be conducted on a regular basis. The GEIS program has previously undergone a number of peer reviews to assess management of program activities.[7-11] However, while these evaluations have helped identify areas for programmatic improvement, measures to determine and quantify scientific impact have been lacking.

The field of bibliometrics offers an opportunity to measure scientific productivity and impact. It is also one of several methods suggested to evaluate federal research programs.[12] Bibliometrics is a set of methods that quantitatively analyzes academic literature. These analyses can be used to develop metrics to assess scientific productivity and impact. For example, counts of articles can indicate scientific activity and frequency of citation can indicate the importance (impact) of the article.[13, 14] Our aim was two-fold: 1) to determine the utility of conducting a bibliometric analysis to measure scientific productivity and impact of the GEIS program, and 2) identify additional or alternative methods to facilitate an improved evaluation of scientific productivity and impact.

METHODS

Definitions and indicators were developed to measure scientific productivity and impact of GEIS funded projects. Scientific productivity was defined as the number of scientific publications in peer-reviewed literature derived from GEIS-funded projects. All types of publications (original articles, reviews, letter to editor, etc.) were included. Indicators of scientific productivity were (a) the total number of GEIS supported projects, (b) the amount of funding awarded, (c) the total number of scientific publications, and (d) amount of funding spent per scientific publication. The impact of scientific publications was defined by the number of times a GEIS-funded research publication was cited by other peer-reviewed publications and the chosen indicators for measuring impact were: (a) the total number of citations of published articles, (b) the median number of citations per article, (c) the proportion of articles with zero citations, (d) the proportion of articles cited within one year of being published, and (e) the mean impact factor of journals where GEIS partners frequently published articles. Each indicator was evaluated by GEIS priority surveillance area and by calendar year. Additionally, to gauge the sphere of influence of GEIS partners in different regions of the world, the following indicators were used: (a) the number of articles published by country and (b) the number of publications in which institutions from two or more countries published together.

Publication and funding data from 2006 to 2012 were compiled from GEIS annual reports and program databases, respectively. All GEIS-funded investigators are asked to notify GEIS of any peer-reviewed publications resulting from GEIS support which is then published in the GEIS annual report. Since publication data is collected passively by GEIS from investigators, the data was supplemented by requesting investigators to provide a list of publications that were made possible from GEIS support from 2006 onward. After collecting publication and funding data, each project and publication was assigned to a GEIS priority surveillance area: respiratory infections (RI), gastrointestinal infections (GI), febrile and vector-borne infections (FVBI), antimicrobial resistance (AMR), sexually transmitted infections (STI), and capacity building and outbreak response (CB&OR). A total of nine projects and 13 publications which could not be assigned to the above listed surveillance areas were not included in the analysis.

Metrics necessary to conduct the bibliometric analysis were retrieved from the Web of Science (WoS) (accessed August 8, 2013) and Journal Citation Report (JCR). WoS has approximately

8,700 scientific journals indexed and provides comprehensive information about the editorial and publication characteristics of articles published from 1900 to present. Information retrieved for each scientific publication included: accession number, year of publication, title, the names and number of authors, the names and number of institutions that collaborated on the article, journal name, country of publication, other sources of funding, number of citations per article, type of article, and area of research. JCR was utilized to obtain journal 'impact factor' data which measures the overall influence of a journal. The impact factor values were assigned to each article using the journal title, the International Standard Serial Number, and year of publication.

To gather data on the network of international collaboration between GEIS partners, a database of countries was developed based on the locations of collaborating institutions appearing in each publication. Visualization of this collaboration was done by entering the data into the Pajek[15] program.

RESULTS

Scientific Productivity

~~On average~~ from 2006 to 2012, GEIS distributed 47M dollars (ranged from $43M to $53M) and supported 132 projects (ranged from 96 to 160), annually. The predominant focus of the GEIS project portfolio during this time was on RI which had a total of 317 projects and was funded at 225M. FVBI was the second largest focus (274 projects funded at 45M), followed by CB&OR (182 projects funded at 42M) (Table 1). The number of annual RI-related projects peaked twice-once in 2006, again in 2009 (around 60 projects each time), and declined thereafter. The number of FVBI projects grew over time, doubling from 29 projects in 2006 to just over 58 in 2012. The number of CB&OR projects ranged between 20 and 36 projects annually while the number of AMR, STI and GI projects increased slowly during the time period ~~(Figure 1)~~.

A total of 651 articles derived from DOD-GEIS funding were published in peer-reviewed journals indexed in the WoS database. An average of 93 articles were published per year, and ranged between 67 (2008) and 117 (2011) articles. Over the study period, FVBI had the largest number of published articles (287), followed by RI (167) and GI (73). When broken down by type of publication, 581 (89.3%) were classified as original articles, 29 (4.5%) as review articles, 24 (3.7%) as letters to editor and 17 (2.6%) as editorials. The amount of funds awarded per resulting publication was highest for RI and CB&OR (1.35M and 1.31M respectively) and lowest for STI (0.05M). The average amount of funds per publication was 0.51M (Table 1).

<u>Impact</u>

Of the articles published, 89.9% of articles were cited at least once in manuscripts also indexed in WoS, and the number of citations per article ranged from 1 to 1405. Overall, the median number of citations per article was 6, and ranged from 2 (CB&OR) to 7 (RI and STI). Approximately 73.9% of the articles were first cited within one year of being published. The distribution of the impact indicators by GEIS pillar and calendar year is shown in Table 2.

Over the study period, GEIS articles were published in 147 different journals. The five journals in which GEIS articles were most frequently published were *The American Journal of Tropical Medicine and Hygiene* (Impact Factor (IF) 2012=2.5), *Emerging Infectious Diseases* (IF 2012=5.9), *Plos One* (IF 2012=3.73), *Journal of Clinical Microbiology* (IF 2012=3.28), and

Military Medicine (IF 2012=0.77). The journals' IFs ranged from 0.3 to 53.5 with an average of 4.2. The majority of publications (71%) were published in journals with IFs between 1 and 5, 7% of publications were in journals with an IF <1 and 22% had an IF greater than 5 (Figure 2). Table 3 shows the top two journals by IF category.

Network of Collaboration

Institutions from 90 countries located in all six WHO regions have engaged in at least one study funded by GEIS. The number of countries increased steadily from 30 countries in 2006 to 50 in 2011. Overall, the five countries with the highest scientific production were the US (475 publications, 72.9%), Egypt (103, 15.8%), Peru (82, 12.6%), Thailand (80, 12.3%) and South Korea (42, 6.4%). Institutions located in the U.S. worked collaboratively with institutions from 74 other countries. Egypt, Thailand, and Peru had 43, 34, and 30 collaborating countries, respectively. The pairs of countries with the highest number of publications were: US-Egypt (61 articles), US-Peru (50), US-Thailand (44) and US-South Korea (27).

The network of collaboration among countries by GEIS surveillance area is shown in Figure 3. Institutions from the US participated in each GEIS priority surveillance area and also had the greatest number of scientific publications in each area compared to any other country. RI and FVBI had the greatest number of countries working conjointly in GEIS-funded studies (60 countries), followed by GI (36 countries), STI (19 countries), CB&OR (16 countries) and AMR (8 countries). Countries of the 6 WHO regions engaged in the areas of CB&OR, GI, FVBI, while 5 and 4 WHO regions engaged in the areas of STI and AMR, respectively.

DISCUSSION

To the best of our knowledge, bibliometrics are not used routinely for assessment of surveillance program productivity and impact. The metrics developed for this study drew attention to a number of interesting findings which demonstrate the utility of using such metrics for future program evaluations. However, the data also identified a need for development of alternate metricsfor instances in which our metrics were not adequate in capturing productivity and impact.

The metrics were able to demonstrate the GEIS program's responsiveness to significant public health events. The large number of RI projects funded in 2006 and 2009 is reflective of the supplemental funds received by GEIS in 2006 through the National Defense Authorization Act to expand surveillance and response capabilities with respect to avian/pandemic influenza[8], and the GEIS response to pandemic H1N1 in 2009. Beginning in 2011, GEIS emphasized expansion for other growing global and military infectious disease threats[16] such as artemisinin-resistant malaria[17] and the spread of antimicrobial resistant wound/healthcare-associated infections. This led to an increase in the number of projects pertaining to FVBI, AMR and STI. The scientific impact of these programmatic changes can be studied further by analyzing the types of articles published in these surveillance areas.

Analyzing the impact factors of journals in which GEIS partners published, reflects the GEIS programs' timeliness and ability to address topics of interest to the public health community. For the surveillance areas excluding CB&OR, GEIS management can now use this baseline data to determine which journals to target to reach appropriate audiences and achieve wider dissemination of data. Determination of where to publish should take into consideration the audience that will utilize the data and caution must be exercised if targets are set to publish only in higher impact journals. For GEIS, a targeted audience (e.g. military members) may be best reached through specialized journals which have "low" impact factors (e.g. Military Medicine has a lower impact factor compared to the New England Journal of Medicine). Also, if the publication data is to benefit individuals in resource-constrained areas where GEIS conducts surveillance, access to open-source publications can be very valuable for in-country partners.

Using bibliometrics to look at the sphere of influence of GEIS labs around the world allowed visualization of known attributes of the GEIS network but also identified areas where global linkages could be created. Countries in which there was an overseas US military research presence (Peru, Southeast Asia, Egypt, Kenya and Thailand) showed high productivity which was expected given that in order to for these labs to develop strong surveillance networks, they need to develop partnerships with national and academic institutions in their respective geographic regions. The US has especially high productivity which is positively biased as many GEIS funded partners, and reach-back support for GEIS overseas laboratories, are based in the US. Figure 3 shows the extensive partner network GEIS has in place particularly for RI and FVBI related activities with room for development across the other surveillance areas should GEIS determine there is a need to do so. GEIS has a strong presence in the Southeast Asia and Americas regions, with potential to improve collaboration in the African and Eastern Mediterranean regions. This analysis has identified potential areas for growth and these metrics can be used as a measure by other programs as well.

I think it would be helpful to have a brief paragraph on the existing DoD laboratories that are the primary GEIS funding recipients and project implementors in the introduction. Would help to comprehend the trends in

Above, were situations in which bibliometrics was found to be useful. Below, we describe instances in which the use of bibliometrics was either inadequate or inappropriate. The amount of funding spent per publication in each of the surveillance areas allowed comparison of productivity across the different areas. Five times as much was spent on RI compared to FVBI; however, there were almost twice as many publications for FVBI compared to RI. Also, the ratio of FVBI publications to CB&OR publications was 9:1 even though almost the same amount was spent for both CB&OR and FVBI. The opposite was true for STI; despite being the lowest funded area, STI had a large number of publications for the amount spent compared to all the other areas. The data identified the areas of RI and CB&OR as needing improvement since productivity was low when measured by the number of publications.

Early RI activities focused on building and coordinating an extensive network of partners (see Figure 3) to support the collection of data and specimens. This platform now helps inform vaccine policy[8] and is also leveraged by several other GEIS and DoD program activities, driving down costs of future projects. Despite the fact that these RI activities have a scientific impact, they are not captured by metrics which depend on output of scientific publications. For CB&OR, most projects pertained to providing personnel training and the development of tools that simplify surveillance in resource-constrained settings. The impact of these activities cannot be measured using indicators in the peer-reviewed literature, since peer-review literature is not the venue to disseminate noteworthy CB&OR accomplishments/ findings. Alternate metrics to quantify productivity and impact should be developed to complement (or replace bibliometric data) when appropriate. Participation in conferences and high profile meetings, establishment of agreements with countries to advance surveillance objectives, and contribution to media stories and to nation- and world-wide databases programs (e.g. PulseNet, GENBANK, WHO Collaborating Centers) can all have high scientific impact. Unfortunately these activities are not captured through the metrics developed for this study. An effort must be made to capture such scientific contributions as they add value to scientific knowledge. Metrics to help capture the impact of surveillance and capacity building activities currently in development by institutions working on the Global Health Security Agenda (a partnership launched by the US government in coordination with international partners in 2014), should also be considered for incorporation into evaluation of surveillance and capacity building programs.

Publications and projects for this study were linked together based on their respective surveillance areas; publications were not linked directly to the project which supported its publication as this information was not available. Also, the degree to which projects leveraged non-GEIS funding was not captured. The high number of STI articles published despite the low amount of GEIS funding for STI from 2006 through 2008 could have resulted from leveraging projects funded previously or in collaboration with other groups. Similarly, the networks and platforms established through GEIS RI or CB&OR funding may have also been leveraged to conduct other surveillance activities. If bibliometrics are to be used to measure productivity and impact, an algorithm needs to be developed to capture publications systematically and capture leveraged efforts. This will improve accountability of any surveillance program.

The study provides insight into the GEIS surveillance portfolio and has shown to be a helpful tool in demonstrating scientific productivity, influence, and responsiveness in a given area. The data from this study provide a good baseline that can be used to strategically plan what scientific changes should be made to the program. The data can also be used in a future study to compare the effects of modifications made to the program. For example, a future scientific productivity and evaluation study can measure changes in the number of publications per year by surveillance area, the percentage of publications being published in high impact journals, and publication in specific journal types. Should other surveillance programs wish to use a similar bibliometric method to measure productivity and impact, the following are considerations that should be given: 1) Develop a data collection tool with the ability to link publications to specific projects and funding; 2) Recognize that bibliometric indicators do not account for all of the scientific contributions made by a project and that alternative metrics may need to be developed. The alternative metrics should take into consideration the venues for dissemination of findings, audiences being targeted, leveraging of other projects, ~~etc.~~; 3) Bibliometric data can be biased (e.g. self/organizational citation) and bibliometric targets (e.g. to publish in high impact journals) may not accurately reflect a program's objectives.

17. Noedl H, Se Y, Schaecher K, Smith BL, Socheat D, Fukuda MM. Evidence of artemisinin-resistant malaria in western Cambodia. *N Engl J Med.* Dec 11 2008;359(24):2619-2620.

18. Centers for Disease Control and Prevention. Guidelines for evaluating surveillance systems. *MMWR Morb Mortal Wkly Rep.* May 6 1988;37 Suppl 5:1-18.

FIGURE LEGENDS

Figure 1. Number of proposals and publications over time by GEIS surveillance priority

Figure 2. Percentage of articles published between 2006 and 2012 grouped by journal impact factor (IF)

Figure 3. Network of collaboration among countries in GEIS-funded studies by GEIS surveillance priority

Note: For most journals the order preferred here is:
- Tables
- Figures (without legends)
- Figure legends

Countries that belong to the same WHO region are denoted by the same color node: Regional Office for Africa (gray), Regional Office for the Americas (red),Regional Office for South-East Asia (light blue), Regional Office for Europe (yellow), Regional Office for the Eastern Mediterranean (green), and Regional Office for the Western Pacific (magenta). Number of articles published by country is represented by the size of node and the number of publications in which institutions of two countries published together is represented by the thickness of line connecting nodes. Countries with only one publication in collaboration for AMR(6), CB &OR (9), GI(23) and STI(10) ;and countries with less than three publications in collaboration for FVBI(44) and RI(44) ~~have been excluded from the figure~~. are not shown.

Space Space

TABLES

Table 1.Scientific production of GEIS studies, 2006-2012.

	Number of accepted projects	Amount of funding awarded (in millions)	Number of scientific publications	Amount of funding per scientific publication (in millions)
GEIS Surveillance Priority				
Antimicrobial resistance	57	6.71	47	0.14
Capacity building & Outbreak response	182	41.77	32	1.31
Febrile and vector borne infections	274	45.24	287	0.16
Gastrointestinal infections	58	9.03	73	0.12
Respiratory infections	317	225.31	167	1.35
Sexually transmitted infections	33	2.45	45	0.05
Fiscal year				
2006	137	45.10	86	0.52
2007	96	45.36	88	0.52
2008	103	45.44	67	0.68
2009	148	51.63	89	0.58
2010	160	52.82	116	0.46
2011	117	43.10	117	0.37
2012	160	47.07	88	0.29

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Table 2. Impact of GEIS studies, 2006-2012.

	Number of citations	Median of citation per article	% of articles with no citation	% of articles cited within one year of being published	Average of Impact factor
GEIS Surveillance Priority					
Antimicrobial resistance	534	4	23.4	65.9	3.7
Capacity building & outbreak response	221*	2*	25.0	53.1	5.8
Febrile and vector borne infections	3535	6	8.0	76.3	3.5
Gastrointestinal infections	1098	6	10.9	73.9	3.8
Respiratory infections	5324	7	9.6	80.2	5.9
Sexually transmitted infections	481	7	0	57.8	2.9
Fiscal year					
2006	1918	15	0	76.7	4.1
2007	18065	16	1.1	76.1	4.2
2008	1374	7	1.5	67.2	4.3
2009	3451	8	1.1	77.5	5.6
2010	1517	6.5	3.5	81.9	4.1
2011	580	2	17.1	75.2	3.9
2012	143	1	42.1	57.9	3.8

*A single article cited 15855 times was excluded from the analysis.

See comments in text.

Table 3. Top two journals by journal impact factor (IF), GEIS publications 2006-2012

IF	Top two journals in IF Category
IF<1	Military Medicine Journal of Vector Ecology
1<IF≤5	American Journal of Tropical Medicine and Hygiene Plos One
5<IF≤10	Emerging Infectious Diseases Journal of Infectious Diseases
IF>10	New England Journal of Medicine Journal of the American Medical Association