



Network analysis to support research management: evidence from the Fiocruz Observatory in Science, Technology and Innovation in Health

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ABSTRACT

Brazil has been encouraging the establishment of research networks to address strategic health issues in response to social demands, creating an urgent need to develop indicators for their evaluation. The Oswaldo Cruz Foundation (Fiocruz), a national research, training and production institution, has initiated the development of an “Observatory in Science, Technology and Innovation in Health” to monitor and evaluate research and technological development for the formulation of institutional policies. In this context, we are proposing the use of social network analysis to map cooperation in strategic areas of research, identify prominent researchers and support internal research networks. In this preliminary study, co-authorship analysis was used to map the cooperative relations of Fiocruz in tuberculosis (TB) research, an important public health issue for which diagnosis and adequate treatment are still challenging. Our findings suggest that Brazilian research organizations acting in TB research are embedded in highly connected networks. The large number of international organizations present in the Brazilian network reflects the global increase in scientific collaboration and Brazil’s engagement in international collaborative research efforts. Fiocruz frequent cooperation with high-income countries demonstrates its concern in benefiting from the access to facilities, funding, equipment and networks that are often limited in its research setting. Collaboration with high burden countries has to be strengthened, as it could improve access to local knowledge and better understanding of the disease in different endemic contexts. Centrality analysis consolidated information on the importance of Fiocruz in connecting TB research institutions in Brazil. Fiocruz Observatory intends to advance this analysis by looking into the mechanisms of collaboration, identifying priority themes and assessing comparative advantages of the network members, an important contribution to help bridging the translational gap in TB research.

INTRODUCTION

The analysis of science and technology (S&T) networks can provide useful information for research monitoring and evaluation, decision-making processes and for the development of the institutions involved (Fonseca et al., 2016). Collaborative networks for health innovation are particularly important in developing countries where resources are scarce and research capacities are fragmented (Morel, 2005).

Brazil has been encouraging the establishment of research networks to address strategic health issues in response to social demands, creating an urgent need to develop indicators for their evaluation. The Oswaldo Cruz Foundation (Fiocruz), a national research, training and production institution linked to the Ministry of Health, has initiated the development of an “Observatory in Science, Technology and Innovation in Health” to monitor and evaluate research and technological development for the formulation of institutional policies. In this context, we are proposing the use of social network analysis (SNA) to map cooperation in strategic areas of research, identify prominent researchers and support internal research networks. SNA has been previously used to map and measure relationships between researchers and institutions, providing input for research policy (Vanderleist, 2015).

In this preliminary study, co-authorship analysis was used to map the cooperative relations of Fiocruz in tuberculosis (TB) research, an important public health issue for which diagnosis and adequate treatment are still challenging. The paper aims to contribute to the discussion of the following questions: i) How is Fiocruz engaged in the Brazilian TB research networks?; ii) What is its pattern of collaboration?; iii) Can SNA be step stone for supporting S&T organizational management?

METHOD

Scientific articles on TB published by Brazilian organizations were retrieved from the Web of Science database for the period 2005 to 2014. The unit of analysis consisted of S&T institutions where Brazilian-based authors and their national and international collaborators were affiliated at the time of publication. Multiple affiliations were all used in the analysis. As in the health sciences is common to researchers to be affiliated to both university or research institute and hospital or clinic in order to access clinical data and patients (Mattson, 2016), we assumed that these individuals provide a collaboration link between these institutions. In the network, each node is an institution and two institutions were considered connected if its members shared the authorship of a paper.

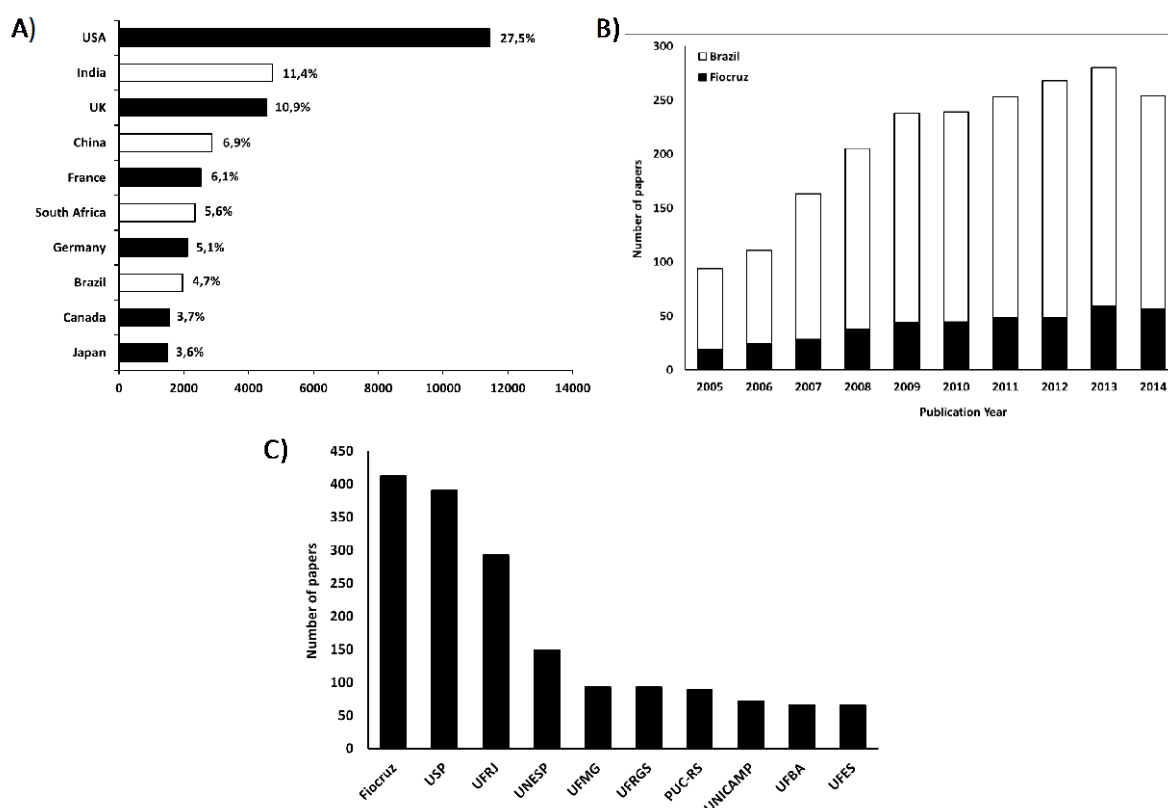
Network connectivity was assessed by the following indicators (Wasserman & Faust, 1994): i) number of nodes and links, corresponding to the number of organizations and their connections; ii) size of the giant component, indicating the maximal subset of fully connected nodes; iii) average degree, indicating the mean number of collaborators the nodes have; iv) average path length, estimating the average smallest number of connections to reach any node in the network; and v) average clustering coefficient, measuring the extent to which the nodes establish a fully connected cluster. Organizations that had prominent roles were identified by their degree centrality - which indicates the number of node’s direct connections -, and by betweenness centrality - which reflects the extent a node acts as a “bridge” between other nodes (Freeman, 1979).

RESULTS

Brazilian organizations accounted for approximately 5% of the world’s scientific production on TB and ranked 4th when compared to other countries with high disease burden (Figure 1A). Fiocruz and Brazil had the same publication trend overall, with a growth until 2009 followed

by a relatively stable production (Figure 1B). Fiocruz was the most productive institution in the country and accounted for approximately 24% of TB publications during the study period (Figure 1C). Although Fiocruz has units in different states in the country, the one located in Rio de Janeiro was responsible for 79% of all Fiocruz publications (n=326), still above the second most productive institution, the University of São Paulo (n=246). Other units involved in TB research were located in the states of Amazonas (2.9%), Bahia (5.3%), Pernambuco (8.2%), Mato Grosso (0.2%), Minas Gerais (4.1%) and Paraná (0.2%). Inter-unit collaboration is modest, with a maximum of five papers in co-authorship between different units.

Figure 1: Tuberculosis research publications by Fiocruz (2005-2014). A) Ten most productive countries and relative contributions (%). White bars indicate high TB burden countries. B) Annual evolution of Brazil's scientific production. B) Top ten most productive Brazilian institutions¹.



The Brazilian organizational network for TB research is composed of 442 national and 670 international institutions from 87 countries (Figure 2).

The United States, United Kingdom and France are Fiocruz most frequent partners, accounting for 18%, 13% and 7%, respectively, of all papers published. Fourteen high disease burden countries have collaborated with Fiocruz, but their association is less frequent. Among

¹ Fiocruz: Oswaldo Cruz Foundation; USP: University of São Paulo; UFRJ: Federal University of Rio de Janeiro; UNESP: São Paulo State University; UFMG: Federal University of Minas Gerais; UFRGS: Federal University of Rio Grande do Sul; PUC-RS: Pontifical Catholic University of Rio Grande do Sul; UNICAMP: State University of Campinas; UFBA: Federal University of Bahia; UFES: Federal University of Espírito Santo.

these countries, South Africa was Fiocruz most frequent partner with 13 papers (3%) in co-authorship.

Figure 2: Institutional network for tuberculosis research involving Brazilian organizations. Nodes are color coded - dark gray for Brazil and light gray for foreign organizations. The size of the nodes is proportionate to their degree centrality. For visualization purposes only the giant component is shown. The top three Brazilian organizations with highest degree centrality are labeled.



The connectivity indicators of the Brazilian TB research network are presented in Table 1

Table 1: Connectivity indicators of TB research networks involving Brazilian organizations.

Indicator	Value
Number of nodes (organizations)	1,112
Number of links	9,138
Giant component size	97.8%
Average degree	16.8
Average clustering coefficient	0.836
Average path length	2.71

The large size of the giant component together with the high average clustering coefficient and average degree, and a low average path length suggest that the network structure is potentially very effective in knowledge generation (high connectedness) and knowledge sharing and diffusion (low distance).

Centrality analysis allowed the identification of the most influential Brazilian organizations (Table 2). Central organizations usually have greater access and control over resources, leading knowledge exchange and preventing many groups from isolation and, in consequence, are more likely to be associated with innovative activities.

Table 2: Top three central organizations of the Brazilian TB research network²

Rank	Organization	Degree centrality	Organization	Betweenness centrality
1	Fiocruz	0,358	Fiocruz	0,249
2	UFRJ	0,260	USP	0,184
3	USP	0,228	UFRJ	0,155

Fiocruz has the highest degree and betweenness centrality values, indicating its prominent role in connecting TB research institutions in Brazil. The Federal University of Rio de Janeiro (UFRJ) and the University of São Paulo (USP) also have important participation in the network.

Fiocruz most frequent national partners are universities, including UFRJ and the Federal University of Pernambuco (UFPE), with 131 (32%) and 32 (7%) papers in collaboration. Frequent international collaborators include the Johns Hopkins University and the University of London.

DISCUSSION

In this preliminary study the evaluation of co-authorship networks identified structural and organizational patterns of TB research involving Brazil and Fiocruz. Our findings suggest that Brazilian research organizations are embedded in highly connected networks.

The large number of international organizations present in the Brazilian network reflects the global increase in scientific collaboration and Brazil's engagement in international collaborative research efforts. Fiocruz frequent cooperation with high-income countries demonstrates its concern in benefiting from the access to good laboratory facilities, funding, equipment and networks that are often limited in its own research setting. Collaboration with high burden countries has to be strengthened, as it could improve access to local knowledge and better understanding of the disease in different endemic contexts.

Centrality analysis consolidated information on the importance of Fiocruz to TB research in Brazil. As a central organization, it has a large number of connections (degree) and is likely to control knowledge flow in the network (betweenness), helping to both disseminate knowledge and facilitate access to resources and research opportunities. Together with UFRJ and USP, they probably had a vital role in maintaining the connection between the overall research

² Fiocruz: Oswaldo Cruz Foundation; USP: University of São Paulo; UFRJ: Federal University of Rio de Janeiro.

network and in ensuring that less well connected or peripheral organizations gained access to new knowledge and information, reducing network vulnerability.

Fiocruz Observatory intends to advance this analysis by looking into the mechanisms of collaboration, identifying priority themes and assessing comparative advantages of the network members, an important contribution to help bridging the translational gap in TB research.

The identification of Fiocruz individual researchers who are most likely to sustain scientific productivity and networking is yet to be evaluated. Such leading authors are expected to be important opinion makers and could assist in guiding the formulation of institutional policies and the promotion of research for public health and development.

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