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Ciência & Saúde Coletiva: scientific production analysis and collaborative research networks

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Abstract *The purpose of this metric and descriptive study was to identify the most productive authors and their collaborative research networks from articles published in Ciência & Saúde Coletiva between, 2005, and 2014. Authors meeting the cutoff criteria of at least 10 articles were considered the most productive authors. VOSviewer and Network Workbench technologies were applied for visual representations of collaborative research networks involving the most productive authors in the period. Initial analysis recovered 2511 distinct articles, with 8920 total authors with an average of 3.55 authors per article. Author analysis revealed 6288 distinct authors, 24 of these authors were identified as the most productive. These 24 authors generated 287 articles with an average of 4.31 authors per article, and represented 8 separate collaborative partnerships, the largest of which had 14 authors, indicating a significant degree of collaboration among these authors. This analysis provides a visual representation of networks of knowledge development in public health and demonstrates the usefulness of VOSviewer and Network Workbench technologies in future research.*

Key words *Knowledge development, Public health, Partnerships, Computer technologies*

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Introduction

The Revista Ciência & Saúde Coletiva, official journal edited by Associação Brasileira de Saúde Coletiva (Abrasco), completed twenty years of existence in 2015. In the editorial of its first issue, it is stated that its purpose is

to be an instrument for the dissemination and critical reflection of the history and memory of the field, of the analysis of the "state of the art" of the disciplines that are part of it, of the trends and perspectives of thought of the theories and practices of Collective Health[1].

In turn, with a view to the celebration of this date, the edition of July 2015 (vol.20, no.7) had as its theme "The importance of scientific publication in the development of public health", with an editorial signed by Prof. Dr. Mengistu Asnake, President of the World Federation of Public Health Associations. From this special issue, we highlight the article "The Ciência & Saúde Coletiva journal and the process of institutionalization of a field of knowledge and practices", Everardo Duarte Nunes authored. The author poses as the central objective of the work the analysis of the role of the Revista Ciência & Saúde Coletiva in the process of institutionalization of Public Health and says that

two decades are a short historical time, but it allow us to evaluate, in the field of publications, a successful experience that brings in its path a fundamental period in the field of public/collective health and is the bearer of a rich material that is open for many possibilities for research[2].

The Revista Ciência & Saúde Coletiva has a significant representation in the dissemination of the scientific production in the field of Public Health. In this context, under review by Minayo and Gomes[3] from data provided by SciELO, "the health area responds for 47.36% (47,364) of all articles published at SciELO database and the Public Health collection represents 19.03% (9,017) of this total. Within the collection, Ciência & Saúde Coletiva, a monthly journal since 2011, is the journal that most published in the period (2.009 documents), and is responsible for 22.29% of the total".

In alignment with the SciELO objectives of dissemination of scientific literature in other languages, the journal has recently also introduced online editions in English, thus contributing to the increased visibility of national scientific production. Currently, the journal in question is classified as category B1 in the Qualis System of Coordination for the Improvement of Higher Education Personnel (Capes) of the Ministry of Education. This system is used to classify the scientific production of postgraduate programs in relation to articles published in scientific journals, which are classified in strata indicative of quality – A1, the highest; A2; B1; B2; B3; B4; B5; C – with zero weight. The periodicity of the Revista Ciência & Saúde Coletiva was semi-annual until 2001, quarterly, from 2002 to 2006, and bimonthly from 2007 to 2009. From 2011, the journal became a monthly publication with 12 issues a year.

It is precisely the influence the Revista Ciência & Saúde Coletiva has on the development of public health science that makes this journal the best source for identifying the leaders in scientific production in public health and examining their collaborative networks. Network examination through bibliometric mapping is a broad topic that can include the mapping of citation networks or co-authorship networks[4]. Outcomes of the examination of co-authorship networks include insight on knowledge development in the field, and the social structure within academia, and between academia and non-academic partners[4]. Often such network examination is conducted by discipline. However, in recent years, there has been an increased emphasis on research conducted by interdisciplinary teams[5]. Examination of the co-authorship networks among authors who published articles in the Revista Ciência & Saúde Coletiva specifically has a couple of advantages: 1) it allows for interdisciplinary network examinations and 2) it provides insight to the structure of knowledge development by this journal.

This study was conceptualized within a recent framework whereby scientific communities are perceived as autopoietic systems[6]. The components of these systems, and items of interest to this study, references and citations, are considered communicative events[6]. The references and citations are viewed as the means by which the cognitive, intellectual and social dimensions of knowledge development within a discipline are communicated[6]. The autopoietic framework used here suggests that bibliographic maps are glimpses of the structuring process that roduces and perpetuates scientific communities[6].

The purpose of this article is to analyze the scientific production published in the Revista Ciência & Saúde Coletiva from 2005 to 2014 considering the publications of type Article (Theme), Free Theme and Review – according to the classification of this journal – with special

attention to co-authorship networks established in that period.

Methods

This is a metric and descriptive study for which data collection was carried out in April 2015, by consulting the electronic website of the Revista Ciência & Coletiva in the SciELO database, accessible on http://www.scielo.br/csc/. Delimiting the period 2005-2014, the query was restricted to Article/Theme, Free Theme and Review publications type. Thematic publications and the publications without thematic identification and not classified as Free Theme or Review were included in the category Article/Theme. For treatment of retrieved documents one of the investigators developed software that, from the data capture of the articles, stored and processed fields of interest (year of publication and authors) for mathematical/statistical analysis and visual representations. The authors' positions in each article (first author, second author or after second author) and the role of each author in the study were also considered. The names of the authors were normalized in a semi-automatic way to identify cases of the same author registered with different names – for example, Edinilsa Ramos de *Souza* and Edinilsa Ramos de *Sousa* are the same author; so is Deborah Carvalho Malta and Deborah *de* Carvalho Malta; also, Marcelo de Castro *Meneguim* and Marcelo de Castro *Meneguin*, among others – where names with the most frequent spellings in the registers were selected. In order to generate subsidies for the analysis of scientific literature, VOSviewer[7] and Network Workbench[8] technologies were used for visual representations of collaborative research networks involving the most productive authors in the considered period. VOSviewer is a free software created by Eck and Waltman[7] that allows the creation and visualization of bibliometric maps from a large volume of data. In scientific production analysis applications, this software can be used mainly to create maps of authors, keywords, title or abstract words, journals and articles. Network Workbench[8] is also a free software used for the generation and visualization of scientific collaboration networks. It also allows the explicitation of direct connections between researchers through several visualization algorithms. It has been established that the authors considered to be more productive are those with the minimum number of 10 articles published in the period of 2005 to 2014 in the Revista Ciência & Saúde Coletiva. This minimum quantity has been established to ensure that the identified authors have published, on average, at least 1 (one) article per year in the selected period. Considering that this work presents the exposition of the comparative production among researchers, for the case of the most productive authors a numeric coding was used instead of their names. In order to visualize the map of the collaborative networks, the remaining authors were generically represented by asterisks.

Results and discussion

With the consultation in the electronic website of the Revista Ciência & Saúde Coletiva in the SciELO database, accessible at http://www.scielo.br/csc/, 2529 articles were retrieved, and 18 of them were identified and considered repeated (because they were also published in supplements). Thus, 2511 different articles were identified and considered. The Revista Ciência & Saúde Coletiva had 10 volumes edited from 2005 to 2014 (v. 10 to v. 19), in addition to the supplements. Its periodicity has changed over the years, for this reason some volumes had more numbers published as seen in Table 1. Due to the increased periodicity, it is observed that in the second five-year period (2010-2014) the number of edited numbers (1773, 70.61%) is significantly higher than in the first five years (2005-2009). The increase of more than the double of the articles in the last 5 years of the 10-year study period is naturally a reflection of the increase in the journal production from quarterly, then bimonthly, to monthly production during the study period.

Regarding the number of authors, 6288 different authors and 8920 authors in the grand total were identified, corresponding to an average 3.55 authors by article. Table 2 presents the 24 authors with at least 10 articles in the selected period – in descending order of the number of articles, including the number of articles of each author more productive as first author, until second author or after second author. This first step in the analysis provides an overview of the most productive authors that contribute to the knowledge generation in public health. The next stages in the analysis allow further exploration of the level of engagement with the articles and networks of partnerships.

Considering only the production of authors with 10 or more articles in the analyzed period (2005-2014), 287 articles were counted with 616

Table 1. Number of publications in the total production and in the production of the most productive authors (from 2005 to 2014).

Year	Editions	Total production	
		Articles	%
2005	4 (+ 1 suppl.)	108	4,30
2006	4 (+ 1 suppl.)	89	3,54
2007	6 (+ 1 suppl.)	149	5,93
2008	6 (+ 2 suppl.)	194	7,73
2009	6 (+ 1 suppl.)	198	7,89
2010	6 (+ 3 suppl.)	341	13,58
2011	12 (+ 1 suppl.)	440	17,52
2012	12	294	11,71
2013	12	349	13,90
2014	12	349	13,90

different authors. However, if the overall total of authors (1237) is considered, then an average of 4.31 authors by article is identified. Reflecting the general trends of publication observed during the period of increased production of the journal, the number of articles published by more productive authors increased three and four times, along with an accompanying increase in the proportion of annual publications of the journal. In Table 2, it is observed that author "20" presents the highest index (70.00%) of occurrence as first author, followed by the author "18" (54.55%), author "14" (50.00%), and author "5". On the other hand, it is noted that five authors – "8", "10", "13", "24" and "19" – present no occurrence as first author. Specifically in the case of this last author cited, in all of her articles she appears only after the second author.

Table 2. Authors with at least 10 articles published.

Author	Articles	Average of authors by article	Co-authorships	Different co-authorships	First author	Until second author	After second author
1	31	4,10	96	61	10 (32,26%)	23 (74,19%)	8 (25,81%)
2	31	3,58	80	57	11 (35,48%)	25 (80,65%)	6 (19,35%)
3	28	5,11	115	64	5 (17,86%)	21 (75,00%)	7 (25,00%)
4	26	4,00	78	52	9 (34,61%)	20 (76,92%)	6 (23,08%)
5	23	6,43	125	71	11 (47,83%)	16 (69,57%)	7 (30,43%)
6	16	4,19	51	31	2 (12,50%)	9 (56,25%)	7 (43,75%)
7	16	3,81	45	32	4 (25,55%)	11 (68,75%)	5 (31,25%)
8	15	5,00	60	43	0 (0,00%)	3 (20,00%)	12 (80,00%)
9	15	3,40	36	24	4 (26,67%)	12 (80,00%)	3 (20,00%)
10	14	5,43	62	34	0 (0,00%)	2 (14,29%)	12 (85,71%)
11	14	5,93	69	48	4 (28,57%)	8 (57,14%)	6 (42,86%)
12	13	6,54	72	38	4 (30,77%)	9 (69,23%)	4 (30,77%)
13	13	7,08	79	47	0 (0,00%)	3 (23,08%)	10 (76,92%)
14	12	2,75	21	15	6 (50,00%)	10 (83,33%)	2 (16,67%)
15	11	3,45	27	20	2 (18,18%)	9 (81,81%)	2 (18,18%)
16	11	4,18	35	29	2 (18,18%)	9 (81,81%)	2 (18,81%)
17	11	5,45	49	34	3 (27,27%)	5 (45,45%)	6 (54,55%)
18	11	4,73	41	29	6 (54,55%)	7 (63,64%)	4 (36,36%)
19	11	5,82	53	32	0 (0,00%)	0 (0,00%)	11 (100,00%)
20	10	2,50	15	10	7 (70,00%)	9 (90,00%)	1 (10,00%)
21	10	5,60	46	24	1 (10,00%)	2 (20,00%)	8 (80,00%)
22	10	3,90	29	25	2 (20,00%)	6 (60,00%)	4 (40,00%)
23	10	6,10	51	42	3 (30,00%)	8 (80,00%)	2 (20,00%)
24	10	6,70	57	43	0 (0,00%)	3 (30,00%)	7 (70,00%)

This additional analysis provided explains very well the primacy of the roles of authors in the development of the article. Standards and authorship trends may identify central authors in research partnerships. Often, the authorship is traded on the establishment of study partnerships[9-11]. Ethically, researchers working with students or assistants encourage their mentees to be the first author to meet certain requirements (evaluation or career progression, for example) or to develop their curricula[9-11]. Without this step in the analysis, the discovery of the most productive authors who are not first authors would have been missed. In one case, author "19" was not first or second author in any of the 11 items to put in the list of the most productive authors. In such cases, the author of the paper identified in the study may provide additional insight. The experience of this author is in the area of nutrition and it operates in a highly reputable institution. She appears repeatedly as coauthor with a team of researchers who are also on the list of the most productive authors. Similarly, author "13", a member of the Ministry of Health at the time of her publications, can contribute with her experience in a political and institutional point of view. Using the bibliometric mapping methodology, ranking of the most productive authors may include authors who never appear as primary authors but consistently appear as a team member. Definitive conclusions cannot be drawn from the bibliometric mapping performed here. Riviera[6] would suggest that the inclusion of a highly cited author guarantees the reproduction of the scientific community. Bevc et al.[12] found that government and educational agency partnerships in public health collaborations are not surprising, allow for a sharing of resources and information, and increases the likelihood of effective outcomes.

Considering the types of publication – Article/Theme, Free Theme and Review – Table 3 shows the number of publications of each type, for each of the most productive authors. As specified in the Methods section, thematic articles and articles without identifying theme not classified as Free Theme or Review were included in the category Article/Theme. Note that authors "12" and "13" presented the highest index (100.00%) of Article/Theme type, followed by author "1" (96.77%). On the other hand, author "9" has the highest index (66.67%) of Free Theme articles type, followed by authors "18" and "19", both with a 63.64% index. Only four authors present the Review articles type. There are no specific conclusions that can be derived from the types of articles of the more productive authors. In general, very few articles were Review articles. Several authors have most of their published articles as Free Theme articles. Some authors published exclusively Thematic articles, although the data analysis in this study does not reveal if these manuscripts had been invited, or were published in the context of a specific thematic call. It should be noted that for several research partnerships one or more of the members work in the Revista Ciência e Saúde Coletiva, such as editors or reviewers. This membership highlights their experiences in public health area and can also indicate the value they place on this publication and the reason they often publish in the journal.

For visualization of the collaborative research networks (or co-authorships networks) involving the most productive authors, it was first necessary to identify each of these authors' partnerships. Then, using the investigator developed software for this stage and for the stage of formatting and preparing data according to the requirements of VOSviewer software, the resultant map of the network is illustrated in Figure 1, in the density vision mode. The VOSviewer allows one to create maps of authors based on a set of documents. This is a two-dimensional map in which the authors are located such that the distance between two authors can be interpreted as an indication of the relationship between them.

In this map, the distance between two authors indicates the degree of relationship between them, and the shorter the distance, the greater the relationship between these authors. Also, the close authors have greater similarity of their partnerships. Each point on the map has a color that indicates the author's density at that point. The greater the number of authors in the neighborhood of a point, and the greater the frequency of the neighboring authors, the more the color approaches red. Otherwise, the color approaches blue. It is observed that authors "3" and "5" - highlighted in Figure 1 in relation to the red intensity and the font size - present the largest number of partnerships in the total (respectively, 115 and 125) and of different partnerships (respectively, 64 and 71). In turn, authors "1" and "2" have significant proximity in the map provided by the 5 works in which they have a partnership, in addition to the similarity of their partnerships even in the works in which they are not partners. The visualization of this image should be done with caution. The font size of the printed name and color intensity do not infer the

Table 3. Publications by type of article.

Author	Type		
	Article/Theme	Free Theme	Review
1	30 (96,77%)	1 (3,23%)	0 (0,00%)
2	25 (80,65%)	4 (12,90%)	2 (6,45%)
3	12 (42,86%)	14 (50,00%)	2 (7,14%)
4	18 (69,23%)	6 (23,08%)	2 (7,69%)
5	20 (86,96%)	3 (13,04%)	0 (0,00%)
6	14 (87,50%)	2 (12,50%)	0 (0,00%)
7	13 (81,25%)	3 (18,75%)	0 (0,00%)
8	6 (40,00%)	9 (60,00%)	0 (0,00%)
9	3 (20,00%)	10 (66,67%)	2 (13,33%)
10	9 (64,29%)	5 (35,71%)	0 (0,00%)
11	11(78,57%)	3 (21,43%)	0 (0,00%)
12	13 (100,00%)	0 (0,00%)	0 (0,00%)
13	13 (100,00%)	0 (0,00%)	0 (0,00%)
14	8 (66,67%)	4 (33,33%)	0 (0,00%)
15	9 (81,82%)	2 (18,18%)	0 (0,00%)
16	5 (45,45%)	6 (54,55%)	0 (0,00%)
17	6 (54,55%)	5 (45,45%)	0 (0,00%)
18	4 (36,36%)	7 (63,64%)	0 (0,00%)
19	4 (36,36%)	7 (63,64%)	0 (0,00%)
20	6 (60,00%)	4 (40,00%)	0 (0,00%)
21	7 (70,00%)	3 (30,00%)	0 (0,00%)
22	6 (60,00%)	4 (40,00%)	0 (0,00%)
23	6 (60,00%)	4 (40,00%)	0 (0,00%)
24	5 (50,00%)	5 (50,00%)	0 (0,00%)

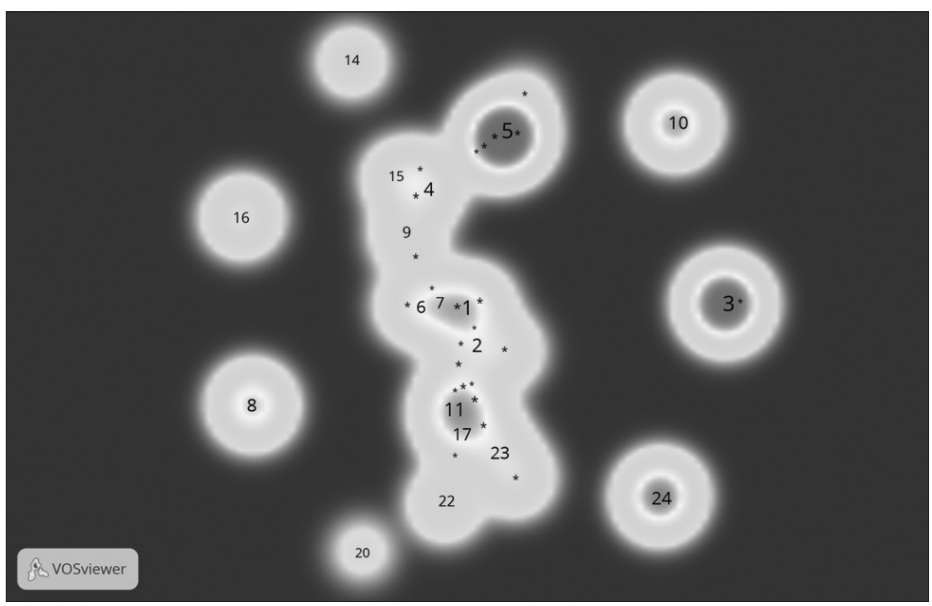


Figure 1. Map of collaborative research networks (or co-authorships networks).

role in the research team. Therefore, prominent researchers may not necessarily be the lead researcher or research team leader.

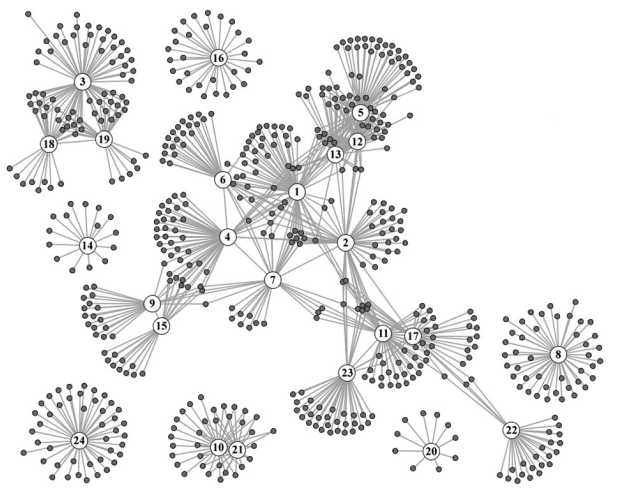
Considering the publications of the most productive authors, a graph (graphical representation of data elements and connections between some of these items) was elaborated for viewing of the direct links of these authors with each other and their different partnerships, as illustrated in Figure 2. The GraphML markup language, which was originally developed for computer representation of graphs, was used to construct this graph[13]. This language has specific tags for elements of a graph as nodes and edges. In this way, from the investigator developed software, the data processing was performed with the application of the Network Workbench software, in which the *Generalized Expectation-Maximization* (GEM) algorithm was used for image generation. Network Workbench is a network simulator software designed primarily for use in the academic-scientific environment and, among many other features, allows the performance of analysis and visualization of networks.

In this graph, there is the existence of eight collaborative research networks, involving the most productive authors and their co-authorship. These networks are disconnected in the sense that there are no common partnerships among the most productive authors that compose them. The largest network consists of 14 more productive authors, 8 of the 10 most productive authors being directly connected to each other or via common partnerships (involving authors from among the most productive or not) – which represents a significant degree of collaboration between these authors. Then, with their respective direct co-authorship, there is a network formed by three more productive authors, a network formed by two more productive authors, and finally, each of the others formed by a single more productive author. The identification of these eight collaborative research networks is valuable for the public health field. These networks can be considered as distinct and consistent aggregators of knowledge to the discipline within their original areas of study. In addition, the position of the authors within the co-authorship provides information about with whom they have published. The network structures shown in Figure 2 are numbered in descending order of the total number of articles in the respective network.

The Network 1, consisting of 14 most productive authors and its various partnerships, had the highest number of articles (180) accounting for 62.72% of the total articles of the universe of the most productive authors, followed by Network 2 with 35 (12.20%) articles. In the case of Network 4, all 10 articles of the author "21" were produced in direct partnership with the author "10". These quantities reflect a significant development of knowledge that can be attributed to the authors of Network 1. It is also important to highlight that this network has publications in each of the 10 years analyzed in this study. This illustrates the lasting contributions that researchers in this cluster are making in the area of public health. Since one of the authors of this network – author "13" – is associated with the Ministry of Health, it is likely that this group influences issues related to policy directives in public health. No other network presented articles in each of the 10 years under review.

Final considerations

Limitations of this study include the time period chosen. Bibliometric mapping occurs within the



Collaborative networks identification
•Network 1 (180 articles): author 1, 2, 4, 5, 6, 7, 9, 11, 12, 13, 15, 17, 22 and 23
•Network 2 (35 articles): authors 3, 18 and 19.
•Network 3 (15 articles): author 8.
•Network 4 (14 articles): authors 10 and 21.
•Network 5 (12 articles): author 14.
•Network 6 (11 articles): author 16.
•Network 7 (10 articles): author 20.
•Network 8 (10 articles): author 24.

Figure 2. Representation of the co-authorship graph of the most productive authors.

context of a time period. During the time period under examination for this study the number of issues published per year increased from 4 issues plus a supplement, to 6 issues plus 1 to 3 supplements, to 12 issues per year one with a supplement and the others without. This rendered a comparison of published articles per author, per year meaningless.

This study examined the publication productivity of authors within the context of Ciência & Saúde Coletiva. Therefore it is not possible to make conclusions about the productivity of the most prolific authors identified here within the context of all published works during the same time period. Riviera[6] suggests that scientific publication practices are constructivist. Knowing that a particular readership of a journal could produce a favorable citation history for authors may motivate them to continue to publish in a particular journal. The cycle of publication and citation then could influence the structure of research teams and the addition of new co-authors for future articles. Future studies could include linking time and co-authorship network development and changes among the most productive authors. Future studies should also compare the co-authorship networks within the context of a particular journal to the broader publication productivity for the same time period.

It is interesting to note that the most published author is the central figure in the network that contains 14 of the most productive authors in this study. In a similar study with Nobel Laureates and Non-Nobel Laureates, researchers found that although the laureates had a lower number of coauthors across their careers, they were as collaborative as non-laureates, and more likely to span a network to create a collaboration, positioning themselves for new discoveries[14]. The researchers posit that through their own visibility laureates can broker their network connections, and engage more frequently in activities that revel to them structural holes and opportunities for new knowledge development that keeps them on the forefront of scientific discovery[14]. Future research could include examination of productivity of networks and detailed examination of the specific partnerships within networks.

Within the discipline of nursing collaboration is understood as a property of scholarliness. Established disciplines need to collaborate both within and between disciplines in both research and publication to facilitate the development of knowledge[15]. The scientific community contributes to the body of collective knowledge, and it is the first step in the creation of research centers and works to build on the contributions of others[15]. Interdisciplinary research is an expectation in funded research, and the group involved is highly valued. Global partnerships where collaboration unites complementary skills and knowledge are needed to solve global health problems[16]. As public health problems quickly reach beyond the borders of countries, global partnerships will become important for tackling future pandemic conditions. Results of this study support the idea that partnerships are important for generating knowledge. While country of affiliation was not collected for this study, future studies should include this information to determine whether knowledge generation is geographically limited.

It is an expectation within the academic culture that faculty, and students publish so that their findings can be disseminated, and they can obtain funding for their research[17]. Traditionally, early career faculty have been encouraged to pursue publication as the sole author and co-authored publications are viewed less favorably[17]. This advice seems to run contrary to findings in this study which would suggest research and publication that takes place within a network has a synergistic effect on publication productivity. This would suggest the need for a paradigm shift within the academic culture, from the competitive, self-interest dominated research and publication activities to collaborative, interdisciplinary research and co-authored articles to facilitate the knowledge development that will be needed to solve current and future problems.

The technologies used in this study may help researchers to build more robust research teams with productive researchers. This study revealed the number and nature of research partnerships among the most productive authors who published in the Revista Ciência & Saúde Coletiva from 2005 to 2014. Of the 24 most productive authors (generating at least 10 articles), 8 collaborative networks were identified. The background fields of the authors covered numerous areas related to health, and some authors who work in government agencies. This information is valuable for education, since it demonstrates patterns of development of knowledge. Researchers will realize the usefulness of this technology as a methodology. Moreover, they can see the dominance of a group of partnerships in publications, and have an interest in knowing that a collaborative network most significantly influenced the science in public health in Brazil. Future studies could include additional variables such as key-

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words, affiliations, and network membership at initial data collection, if such data are available from the information provided by the journal. Additionally, statistical analysis of the relative strength of partnerships within a network could be examined. This technology could be applied in future studies to analyze publication practices and partnerships in scientific journals for articles published in public health. This could inform the science about the amplitude of publications by various partnerships.

Collaborations

N Conner, A Provedel, and ELN Maciel participated in all stages of preparation of the article, from conception through to the final writing of it.

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