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Assessment of public health research output by Bangladeshi authors: A scientometric study

Md. Nazmul Islam, Md. Shariful Islam*, Partha Biplob Roy

Department of Information Science and Library Management, University of Rajshahi, Rajshahi, Bangladesh

ABSTRACT

The main objective of the study is to assess the growth and expansion of public health (PH) research works by Bangladeshi authors from various perspectives such as quantum of growth, patterns of collaboration, and productivity of authorship, among others. The present research uses a scientometric technique to examine secondary literature. Between 2000 and 2015, 871 literature by Bangladeshi writers and 3,71,389 literature by worldwide authors on PH were retrieved from the Scopus database and evaluated using quantitative indicators to study growth and development from various perspectives. The highest growth in terms of the number of publications has been observed in the year 2015 (133) and the lowest in 2001 (10). The PR (Percent of Growth Rate) shows that 2001 was the deepest decreasing year (-38%) whereas 2002 was the most increasing year (90%). During the study, RGR (Relative Growth Rate) values of Bangladeshi contributions to PH literature varied from 0.16 to 0.55, with an average of 0.27. The CC (Collaborative Coefficient) value indicates that during the research period, there was a substantial amount of collaboration among the authors. At the same time, the PPA (Productivity Per Author) value (0.31) denotes that throughout the era, each Bangladeshi author produced less than half of a publication per year. The mean Activity Index (AI) during 2000-2015 was 89.14, which reflects lower activity than the world's average in PH literature. It was also observed that research productivity in public health of Bangladesh follows Lotka's inverse rule of author production. According to the findings, there is a strong link between public health research output in emerging and developed nations.

KEYWORDS

Scientometric study; Bibliometric study; Public Health (PH); Bangladesh; Scopus database

1 Prelude

The concept of scientific measurement derives from the term "Statistical bibliography" introduced by Hulme in 1923. The use of statistics in library operations was also observed in Ranganathan's era, which was then referred to as "Librarmetry". In 1969, Pritchard introduced the term "Bibliometrics" instead of "Statistical Bibliography". In the same year, Nalimov and Mulchenko coined the word 'Naukometriya' (Scientometrics is referred to by a Russian term). Tibor Braun founded the "Scientometrics" journal in 1978, since before the

* Corresponding Author: sharif6islam@yahoo.com

name "Scientometrics" became widely recognized (Zahedi et al., 2014; Islam, 2013; Garfield, 2009; Hood & Wilson, 2001).

However, the technique of scientometric or bibliometric analysis is extensively utilized in the Library and Information Science field to discover the effect of a subject, importance of a researcher, or the impact of a particular publication (for example, a journal). It assists in identifying the types of writing, authorship trends, and selection of secondary publications in order to gain in-depth information in any given field, which is essential for effective organization of information resources. All major collections of scientometric or bibliometric indicators rely heavily on statistics of publication and citation information (Thanuskodi, 2010; Glänzel, 2003).

There are several laws of Bibliometrics/scientometrics used to assess the applicability of different disciplines. Among them, Lotka's inverse square law, Bradford's scattering law, and Zipf's word frequency law are widely used globally. According to Lotka, the number of authors and the number of articles are inversely proportional. Lotka stated that approximately 1\n_{2} of individuals who make a single publication are writers who make "n" contributions (Friedman, 2015; Tague-Sutcliffe, 1992; Pao, 1985). On the other hand, Bradford described a quantitative relationship between journals and the published articles. According to Bradford, if the articles of journals on a given subject are arranged in decreasing order, they are grouped into three zones, out of which zone-1 contains one-third of the total articles, and the number of articles in the remaining zones will be proportional to $1:n:n^2$ (Sudhier & Abhila, 2011; Sudhier, 2010; Tague-Sutcliffe, 1992; Bradford's Law, n.d.). For the distribution of word tokens across kinds, Zipf devised a word frequency and rank frequency arrangement. According to Zipf, a term's frequency is inversely proportional to its rank (Tague-Sutcliffe, 1992; Fedorowicz, 1982; Wyllys, 1981).

Public health refers to actions aimed at preventing illnesses, promoting good health, and extending people's lives. As a result, the scope of public health research has broadened to cover a number of academic fields, such as health economics and health-society connections (Merigo & Nunez, 2016). Bangladesh has a long history of public health services dating back to the eighteenth and nineteenth centuries when the British East India Company ruled undivided India. Formerly, the health service was limited to urban areas, and subsequently, the services were extended to rural areas by establishing hospitals with a few beds. At that time, the most emphasis was given to sanitation. Later on, due to the recommendation of the Plague commission in 1904, a few research laboratories were established for the development of immunizations and serum. The 'Health Survey and Development Committee' was formed in 1946 to create graduate doctors and establish rural health centers. In 1967, the Thana (sub-district) health center framework was developed to offer all people effective and holistic health care. After the liberation war of Bangladesh, the Ministry of Health and Welfare, which has two directorates, one for health and another for family planning, is in charge of establishing and implementing national health and population policies. The Health and Welfare administration is decentralized into seven divisions, which are divided into sixty-four districts, which are further divided into 545 thanas/upazilas (sub-districts) and yet more divided into more than a thousand union (the lowest tier of local government in Bangladesh) sub-centers responsible for local health and family planning activities including home services. After attaining the Millennium Development Goals, the government of the People's Republic of Bangladesh is currently aiming to achieve the Sustainable Development Goals (SDGs). Three of the eight Millennium Development Goals (child mortality, maternal health, HIV/AIDS, and malaria) are health-related (Ministry of Health and Family Welfare, 2016;

Bangladesh national portal, 2016; Amin et al., 1999).

2 Literature review

In the case of Bangladesh, BIWS (Bibliometric, Informetric, Webometric, and Scientometric) research is still a new phenomenon. Only two doctoral theses and a few research articles on such topics were accomplished in the country. Therefore, the products of neighboring India are often treated as the local giants (Mahbuba & Rousseau, 2010) in BIWS research. The nature, types, and quality of research conducted by the Indian researchers is very similar to that of research conducted by Bangladeshi researchers. Several studies were identified in India that used a scientometric technique to quantify growth and development of various disciplines based on the country's research output, such as, biomedical research (Duraisingam, n. d.), lead-zinc resources (Paliwal et al., 1986), solar power research (Garg & Sharma, 1991), alkaloid chemistry research (Karki & Garg, 1997), laser research (Garg, 2001), health sciences (Krishnamoorthy, 2003), social science research (Keshava, 2004), biomedical research (Jeyaseeli, 2011), nanotechnology (Karpagam, 2011), genetics literature (Arali, 2014), public health research (Kalita et al., 2015), diabetes and allied diseases (Karuilancheran, 2015), biochemistry research (Kumar, 2015), bioinformatics research (Kandpal, 2016), etc.

The review of related literature focuses primarily on scientometric and related works published by Bangladeshi authors in any format, such as doctoral theses, journal articles, reports, and so on, because the current study is based on Bangladeshi authors' scientometric analysis of public health literature.

Ahmed and Rahman (2008) explored the growth and development of the nutrition literature in Bangladesh. Between 1972 and 2006, 636 papers by 998 authors were published in 100 local and international journals on nutrition. The result suggested that Lotka's law could apply to the nutrition literature in Bangladesh. The following year, Ahmed and Rahman (2009) used K-S goodness-of-fit to investigate the validity of Lotka's law in the area of nutrition research, concluding that Lotka's inverse square rule was not relevant to Bangladeshi nutrition research. In the field of library and information science literature of Bangladesh, Ahmed and Shuva (2009) validated Lotka's law, Price's square root law, and Pareto's 80/20 rule. The findings showed that, while Lotka's law could be applied to this field, the other two laws could not be applied to author productivity data. On diarrhoeal literature collected from PubMed, Web of Science, and Scopus databases, Khatun and Ahmed (2011) evaluated the literature growth, authorship pattern, collaboration, and journal distribution. The result of the study suggested the core journals for diarrhoeal research using Bradford-Zipf's distribution.

Mahbuba and Rousseau (2010) compared research indicators related to India, Bangladesh, Pakistan, and Sri Lanka using "Web of Science" and "Scopus" data. The result of the study indicated that Sri Lanka was the best performer in terms of the country's h-indices among these four countries. In another work, Mahbuba et al. (2010) compared two health and population research organizations in Bangladesh and India in terms of scientometric indicators from 1979 to 2008 using the "Web of Science". The study presented the evolution of publication activities from various aspects, including time series of the institutional h- and R-indices, trends in the yearly received citations, types of publications, international collaboration, top scientists, and most cited articles. In another study, Mahbuba and Rousseau (2012) proposed a new standard and real-valued h-index of two different types. In 2012, Mahbuba proposed new variations on the standard and the real-valued h-index in her doctoral thesis. She noticed the expansion of Bangladeshi publications by tracking collaborative efforts with

surrounding nations, with a particular focus on Bangladesh's ICDDRB and India's NICED. Mahbuba and Rousseau (2016) extended the notion of year-based h-indices and the corresponding h-scores by providing a real-life example of a Bangladeshi scientist. The result of the study also showed the year-based h-indices for all Bangladeshi publications.

Islam (2013) described some early history of citation indexing techniques along with some modern contributions to this field by showing the inadequacies of Google Scholar and Thompson ISI Web of Science (WoS) in computing true citation impact. Islam (2016) also examined library and information science literature published in Rajshahi University's Social Science Journal. 21 papers by 28 writers were recognized as library and information science literature from 187 articles by 238 authors published in the Social Science Journal. Results of the study indicated that solo research dominated over collaborated authors. From 2000 to 2015, Islam (2018) undertook a scientometric research of public health literature to examine global and Bangladeshi growth and development. The average productivity per author (PPA) for all authors globally was 0.49 throughout the study period, meaning that public health writers produced less than half a publication each year. Islam et al. (2021) showed that the average Collaborative Coefficient (CC) value for global public health research writers was 0.37, indicating that there was no notable scale of collaboration across global authors. This study also suggested using a Collaborative Coefficient (CC) value to measure the extent of collaboration.

3 Objectives and research questions

The present research was carried out to examine the development and advancement of public health research by Bangladeshi authors using data extracted from the Scopus database. More specifically, there are also three special objectives:

i) To assess the growth of research on public health by Bangladeshi authors indexed by the Scopus database during 2000-2015;
ii) To investigate the patterns, collaborations, and productivity of authorship in Bangladeshi public health literature.
iii) To study Bangladeshi contributions to public health literature.

The following research questions were constructed to meet the objectives of the study:

a) Is there any mean relationship between public health research performances of Bangladeshi researchers and the researchers of other countries?
b) Does research productivity in public health in Bangladesh conform to Lotka's inverse law of author productivity?
c) Is there a significant relationship between developing and developed countries' research productivity?

4 Research Methodology

A scientometric technique was used to investigate the secondary literature on public health published by Bangladeshi writers from a variety of perspectives, including growth rate, authorship pattern, cooperation rate, author productivity, and the implications of fundamental bibliometric law, among others. As a results, from the 2000 to 2015, the literatures on public health by Bangladeshi writers (871) were obtained from the Scopus database. During this time, the worldwide research outputs on public health (3,71,389) were also retrieved to provide a comparison. The search strategies applied to get the results from the Scopus database were: i) *(TITLE-ABS-KEY (Public health) AND PUBYEAR > 1999 AND PUBYEAR < 2016 AND*

(LIMIT-TO (AFFILCOUNTRY, "Bangladesh") for the literature of Bangladeshi authors, ii) "(TITLE-ABS-KEY (Public Health) AND PUBYEAR > 1999 AND PUBYEAR < 2016)" for the literature of global authors. A search was launched on November 23, 2016.

The Scopus database search results were obtained using two methods: one was year-wise search results containing subfields including year, number of results, author name, subject area, document type, source title, keyword, affiliation, country, source type, language; and another one was detailed search result with citation information containing subfields including author, title, year, source title, volume, issue, pagination, citation information etc. Various statistical tools, such as arithmetic mean, percentage, regression coefficient, correlation, t-test, correlation test, etc. were used for the study. MS-Excel and SPSS (version-24.0) were used to evaluate the data statistically. Arithmetic mean, percentage, regression coefficient, correlation, t-test, correlation test, and other statistical techniques were used in the study. Quantitative indicators were used to count scientific publications from various standpoints. Table 1 shows the scientometric indicators and bibliometrics laws that were used in this study.

Table 1 List of indicators/laws used in scientometric and bibliometrics research

Name of Indicators/Laws	Description
A. Analysis of growth and development of literature	
Average Annual Growth Ratio (AAGR)	Compare between values of specific period of interval
Percent Growth Ratio (PR)	Compare the growth rate with previous year
Compound Annual Growth Rate (CAGR)	Shows exact amount of growth than previous year
Relative Growth Rate (RGR)	Calculate mean growth rate over a specific period of time
Doubling time (Dt)	Calculate how long it will take for a measurement to be doubled
B. Analysis of the collaborative pattern and author productivity of literature	
Collaborative Index (CI)	Compute mean number of authors per paper
Degree of Collaboration (DC)	Estimate the proportion of multi–authored papers
Collaborative Coefficient (CC)	Measure for collaboration of authors
Revised Collaborative Coefficient (RCC)	Revised version of Collaborative Coefficient (CC)
Average Author Per Paper (AAPP)	Calculate number of author per paper
Productivity Per Author (PPA)	Calculate number of paper per author
Activity Index (AI)	Compare one country´s research output with world´s average research output
C. Analysis of the citation of literature	
Average Citation Per Paper (ACPP)	Compute proportional number of citations per published paper of an author
Average Citation Per Cited Paper (ACPCP)	Compute proportional number of citations per cited paper of an author
D. Analysis of the index score of authors of literature	
h–index	Measure the productivity of an author
g–index	Modify the measure of h–index
hI, norm	Normalize h–index
hI, annual	Measure of h–index at different career stage
E. Analysis of the literature using fundamental laws of bibliometrics	
Lotka´s Inverse Square Law	Relate the authors of papers to the number of papers written by each authors

5 Results

5.1 Growth of public health literature by Bangladeshi authors

Different authors from various countries have published the literature on public health. The Bangladeshi authors also played an important role in publishing articles on public health. The growth of public health literature by Bangladeshi authors has been determined here using several growth rate indices, such as Average Annual Growth Ratio (AAGR), Percent Growth Ratio (PR), Compound Annual Growth Ratio (CAGR), Relative Growth Ratio (RGR), etc.

The summation of the values of the specific period of interval divided by the number of period intervals yields the **Average Annual Growth Ratio (AAGR)**. **The percent (straight-line) growth rate (PR)** is determined by subtracting the current year's number of publications from the previous year's number of publications, then dividing by the previous year's number of publications (Parker, 2002).

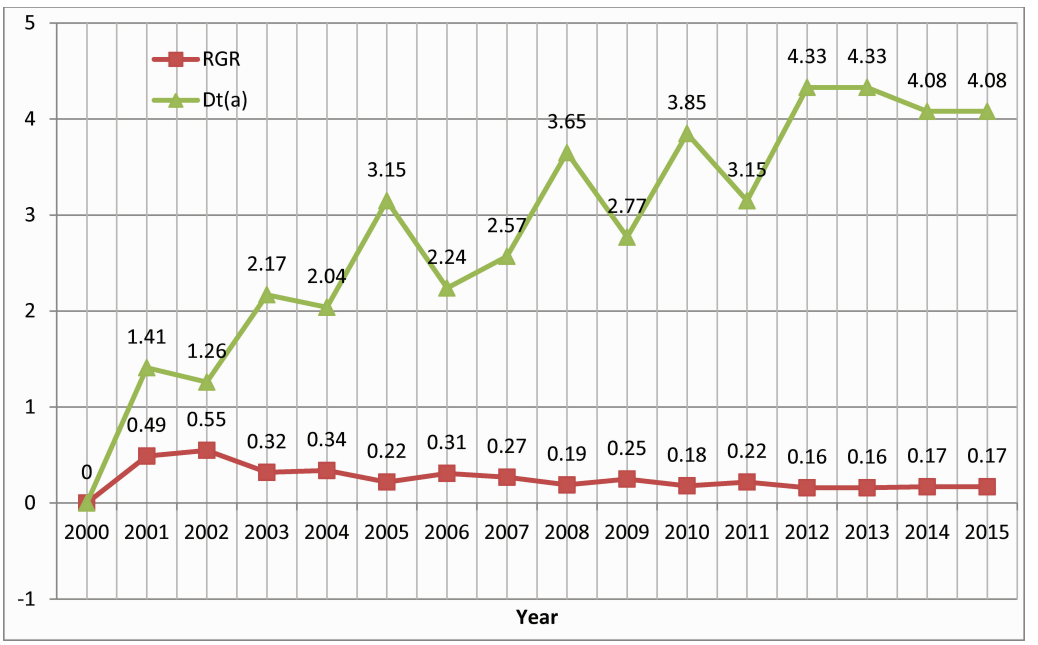
The **CAGR (Compound Annual Growth Rate)** is computed by dividing the current year's number of publications by the prior year's number of publications to the power of one divided by the period length and subtracting one from the result (Murphy, 2019). In terms of literature, the **Relative Growth Ratio (RGR)** refers to the increase in the number of articles or pages per unit of time. The log difference of two values divided by the time interval yields RGR (Hunt, 1982). If the RGR stays unchanged, the **Doubling time (Dt)** is the time it takes for a given quantity to double in size. Doubling time can be computed directly from RGR and the larger the RGR, the faster the doubling time (Boucher, 2017). Dt is calculated as the natural logarithm (loge2) of 2 (0.693) divided by the value of RGR (Keshava, 2004).

Table 2 Growth of literature by Bangladeshi authors on Public Health (PH)

Four Yr. Block	Year	Records	Cum	Difference	AAGR	PR	CAGR
2000–2003	2000	16	–	1	1.12	7%	0.07
	2001	10	26	–6		–38%	–0.38
	2002	19	45	9		90%	0.90
	2003	17	62	–2		–11%	–0.11
2004–2007	2004	25	87	8	1.32	47%	0.47
	2005	22	109	–3		–12%	–0.12
	2006	40	149	18		82%	0.82
	2007	45	194	5		13%	0.13
2008–2011	2008	42	236	–3	1.21	–7%	–0.07
	2009	65	301	23		55%	0.55
	2010	62	363	–3		–5%	–0.05
	2011	88	451	26		42%	0.42
2012–2015	2012	75	526	–13	1.12	–15%	–0.15
	2013	95	621	20		27%	0.27
	2014	117	738	22		23%	0.23
	2015	133	871	16		14%	0.14
Total		871	Average	7.38	1.2	20%	0.20

Note: There were 15 publications of Bangladeshi authors in 1999 (Source: Scopus)

From 2000 to 2015, Table 2 highlights the contributions of Bangladeshi authors in the field of public health. Bangladeshi authors produced 871 publications during that time. The highest growth in terms of the number of publication has been observed in the year 2015 (133) and the lowest in 2001 (10). The average increasing rate of publications between two years is above seven. The PR (Percent of Growth Rate) shows that 2001 was the deep decreasing year (-38%) whereas the following year was the most increasing (90%). The highest AAGR has been observed in block period 2004-2007 and the lowest in 2000-2003 and 2012-2015. The Compound Annual Growth Rate (CAGR) varies from -0.38 to 0.90 with an average of 0.20 during the study period.



Note: Dt(a)= Double time value for articles.

Figure 1 RGR and Dt(a) value of public health literature

Figure 1 depicts the RGR values of Bangladeshi contributions to PH literature during the study, which range from 0.16 to 0.55, with an average of 0.27. Dt(a) values, on the other hand, also vary from 1.26 to 4.33, with an average of 3.00. That means the literature of public health by Bangladeshi authors, with a 0.27 growth rate, would have a doubling time of 3 years. The year 2002 was the peak year of the period under survey if we consider the RGR values of the Bangladeshi authors, whereas the years 2012 and 2013 had the lowest RGR values.

5.2 Measures for pattern, collaboration, and productivity of Bangladeshi contributors

It is vital to study authorship patterns and productivity in order to evaluate research contributions in any subject field. As a result, scientometric studies must include authorship patterns and research output, which is something that the current study does.

5.2.1 Collaboration and authorship pattern of Bangladeshi authors

Collaborated works entail several researchers working together to conduct research and publishing the results of their efforts as a research publication. Various indices have been

used throughout the world to calculate the degree of collaboration, for example, the Collaborative Index (CI), Degree of Collaboration (DC), Collaborative Coefficient (CC), Revised Collaborative Coefficient (RCC), or Modified Collaborative Coefficient (MCC), etc.

Lawani (1980) created the **Collaborative Index (CI)** to determine the average number of authors per publication. The complete data was classified into total authors of single-authored articles, total authors of two authored papers, total authors of three authored papers, and total authors of more than three written papers in order to compute the CI value for Bangladeshi authors. Subramanyam (1983) devised the **Degree of Collaboration (DC)** to represent the proportion of multi-authored articles. The value of DC always remains within a range of 0.01 to 0.99. The higher DC value means maximum collaboration.

The value of the **Collaborative Coefficient (CC)** developed by Ajiferuke et al. (1988) is always between '0' and '1', indicating single authorship and multi authorship, respectively. Each publication's CC credit point is shared among the writers. As a result, a value of CC greater than 0.5 suggests a higher likelihood of collaboration, while a value of CC less than half indicates that the authors do not have a multiple authorship pattern. A normalized version of CC is called **Revised Collaborative Coefficient (RCC)**, which was devised by Egghe (1990). Later on, Savanur and Srikanth (2010) also made the same modification of CC, renamed as **Modified Collaborative Coefficient (MCC)**, which was similar to what was devised by Egghe (1990).

Table 3 Year-wise authorship pattern and collaboration indices for Bangladeshi authors on PH

Year	1	2	3	3+	Total
2000	5	2	3	6	16
2001	1	0	3	6	10
2002	4	1	1	13	19
2003	5	3	3	6	17
2004	4	4	3	14	25
2005	5	3	1	13	22
2006	3	2	4	31	40
2007	4	9	3	29	45
2008	4	9	4	25	42
2009	8	6	10	41	65
2010	2	7	6	47	62
2011	6	10	11	61	88
2012	4	4	11	56	75
2013	2	11	16	66	95
2014	7	14	15	81	117
2015	4	11	18	100	133
Total	68 (7.81%)	96 (11.02%)	112 (12.86%)	595 (68.31%)	871

Note: 1= Single authored paper, 2= Double authored paper, 3=Triple authored paper, 3+=More than three authored paper; The maximum and minimum values are shown in the highlighted cells.

Table 3 reveals the year-wise authorship pattern together with several indices of collaboration for Bangladeshi authors in public health literature. Researchers in Bangladesh prefer working together in publishing public health literature. An increasing trend has been observed in the case of multi-authored papers. There were only 11 multi-authored papers in 2000, but that number increased dramatically in the following years, and by 2015, there were 129. Additionally, more than 92% of the total contributors are collaborative authors. Less than 8% of literature is single-authored. That is, Bangladeshi authors prefer collaborative works when publishing public health research papers.

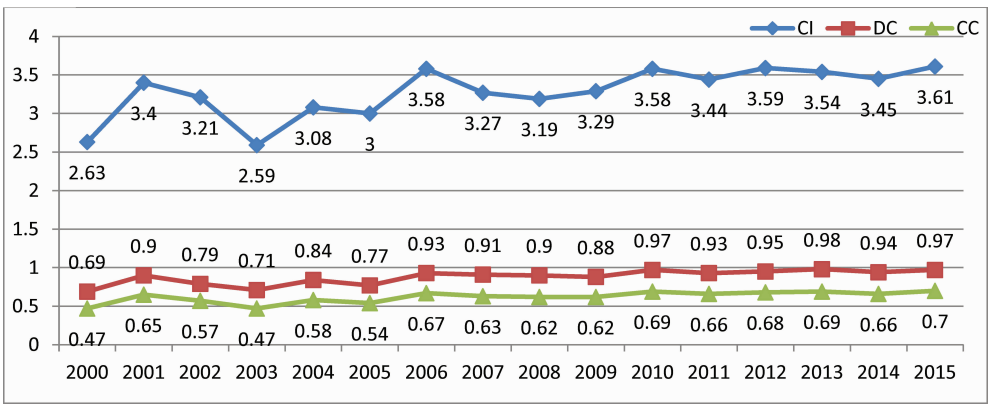


Figure 2 Collaboration indices for Bangladeshi authors on PH

Figure 2 shows that the CI spans from 2.59 to 3.61 over the study period, with an average CI value of 3.28, indicating that Bangladeshi researchers have a favorable attitude toward collaborative work. The DC, on the other hand, ranges from 0.69 to 0.98, indicating a significant level of author collaboration among Bangladeshi writers across the time. Multi-authored articles are more prevalent than single-authored publications, as indicated by the average DC value of 0.88.

CC reflects a high level of collaboration among Bangladeshi public health authors during this time period. In 2015, the highest CC was recorded (0.70), while the lowest was recorded in 2000 and 2003. (0.47). The authors' CC for public health writers varied from 0.47 to 0.70, with an average of 0.62, indicating that they collaborated closely throughout the study.

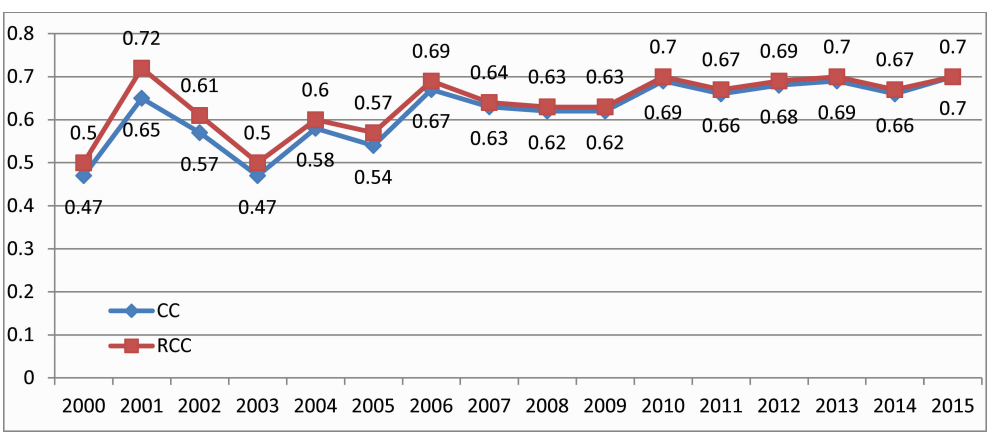


Figure 3 A comparison between CC and RCC

For several years, there were some variances in the values of CC and RCC. It's obvious that the more literature there is, the smaller the disparities between CC and RCC values become (Figure 3).

5.2.2 Productivity by Bangladeshi authors on PH

5.2.2.1 AAPP and PPA of Bangladeshi authors on PH

Yoshikane et al. (2009) and Mamdapur et al. (2014) have devised Average Author Per Paper (AAPP) and Productivity Per Author (PPA) to measure the author's productivity. The value of AAPP is equivalent to that of Collaborative Index (CI).

Table 4 AAPP and PPA of Bangladeshi Authors

Year	Authors	Publications	AAPP	PPA
2000	42	16	2.63	0.38
2001	34	10	3.40	0.29
2002	61	19	3.21	0.31
2003	44	17	2.59	0.39
2004	77	25	3.08	0.32
2005	66	22	3.00	0.33
2006	143	40	3.58	0.28
2007	147	45	3.27	0.31
2008	134	42	3.19	0.31
2009	214	65	3.29	0.30
2010	222	62	3.58	0.28
2011	303	88	3.44	0.29
2012	269	75	3.59	0.28
2013	336	95	3.54	0.28
2014	404	117	3.45	0.29
2015	480	133	3.61	0.28
Total	2976	871	3.28	0.31

Note: The maximum and minimum values are shown in the highlighted cells.

Table 4 depicts the year-by-year distribution of public health literature by Bangladeshi contributors as well as the value of AAPP and PPA. The AAPP values vary from 2.59 to 3.61, with an average of 3.28, indicating that each publication had more than three authors throughout the research period. The PPA values vary from 0.28 to 0.39, with an average of 0.31, implying that throughout the period, each Bangladeshi author-produced less than half of a publication each year. For Bangladeshi writers, the greatest AAPP value (3.61) was recorded in 2015, while the lowest AAPP value (2.59) was recorded in 2003. Bangladeshi writers had a high output rate (0.39) in 2003, whereas the years 2006, 2010, 2012, 2013, and 2015 had the lowest PPA production rates.

5.2.2.2 Activity Index (AI) of Bangladeshi contributions

The Activity Index (AI) measures a country's relative research activities in a certain field. Karki and Garg (1997) and Frame (1977) suggested Activity Index (AI) first as:

$$\mathrm{AI} = \frac{Country's\ publication\ output\ on\ a\ given\ field\ in\ particular\ year}{world's\ publication\ output\ on\ a\ given\ field\ in\ particular\ year} \times 100$$

To compare Bangladeshi research output with the world's output on public health during the period 2000-2015, AI can be defined mathematically in the following way:

$$\mathrm{AI} = \frac{\frac{B_i}{B_o}}{\frac{W_i}{W_o}} \times 100$$

Where,

Bi denotes Bangladeshi research output in the year i. Bangladeshi research production is abbreviated as Bo. Wi denotes global research output in the year i. Wo denotes Worldwide Research Production. AI = 100 implies that a country's research efforts on a particular issue are identical to the global average, whereas AI > 100 suggests a greater activity rate than the global average, and AI 100 indicates a lower effort rate than the global average (Karki & Garg, 1997).

Table 5 World output vs. Bangladeshi output on public health

Year	World output Including Bangladesh	Bangladeshi Output	World output excluding Bangladesh
2000	11594	16	11,578
2001	13325	10	13,315
2002	14683	19	14,664
2003	16818	17	16,801
2004	18329	25	18,304
2005	19668	22	19,646
2006	20845	40	20,805
2007	21752	45	21,707
2008	22750	42	22,708
2009	24289	65	24,224
2010	26222	62	26,160
2011	28367	88	28,279
2012	31044	75	30,969
2013	32297	95	32,202
2014	35430	117	35,313
2015	34847	133	34,714
Total	372260	871	371,389

Between 2001 and 2008, Bangladeshi academics' efforts on PH publications were lower than the global average productivity, according to Table 5. Over the next seven years, from 2009 to 2015, Bangladesh's research activities were more than the global average.

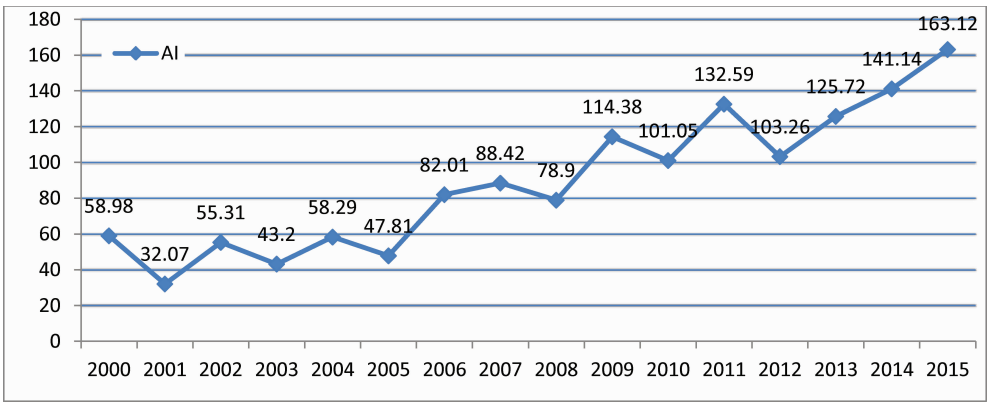


Figure 4 Activity Index of Bangladeshi authors

Figure 4 shows that the Activity Index (AI) peaked in 2015 and peaked at its lowest point in 2001. The average Activity Index (AI) in the PH literature was 89.14 between 2000 and 2015, suggesting lower activity than the worldwide average.

The research question (RQ-1) was evaluated using the "t-test" to examine the mean association between existing public health research performances of Bangladeshi academics and researchers from other nations. Due to the quantitative character of the two dependent variables (values of Bangladeshi researchers and researchers from other countries excluding Bangladesh) and the qualitative nature of the independent variable, this test was conducted (year). As a result, the significance of the mean difference between two dependent variables (research output of Bangladeshi researchers and research output of other regions of the globe excluding Bangladesh) was examined.

Table 6 t-Test: Paired Two Sample for Means

	Variable–1 (Bangladesh)	Variable–2 (Rest part of the world)
Mean	54.4375	23211.8125
Variance	1461.995833	56513199.36
Observations	16	16
Pearson Correlation	0.958618053	
Hypothesized Mean Difference	0	
Df	15	
t Stat	–12.38216578	
P (T<=t) one–tail	1.40649E–09	
t Critical one–tail	1.753050325	
P (T<=t) two–tail	2.81298E–09*	
t Critical two–tail	2.131449536	

Note: *significant at p<0.01

The mean of the two dependent variables for Bangladeshi researchers is 54.43, whereas the mean for the rest of the globe is 23211.81. Table 6 shows that the p-value is significantly lower than 0.01, indicating a strong positive mean relationship between Bangladeshi academics' public health research performance and that of researchers from other nations. As a result, there is a statistically significant mean link between the world and Bangladeshi

scholars' research output.

5.2.2.3 Applicability of Lotka's law to the production of Bangladeshi authors

Alfred J. Lotka suggested an Inverse-Square Law connecting the number of articles authored by each author to the number of authors. According to him, the number of writers who publish a specific number of articles is proportional to the number of authors who publish a single article. Authors that publish a large number of articles become less frequent as the number of articles published grows. 60 percent of all writers in a field will have just one publication, 15 percent will have two publications each (1/4), 7% will have three publications each (1/9), and so on (Potter, 1988; Lotka's law, n.d.). The following formula was used to compute this:

$$Y = \frac{C}{X^n}$$

Where, Y = relative frequency of authors with 'X' publications.
C = Constants depending on the specific field
X = Number of publications/papers
n = Constants depending on the specific field

In general, author productivity is measured by the number of articles that the authors have contributed in a certain subject. The influence of Lotka's rule on Bangladeshi writers' productivity on public health is extremely important to investigate. Standardized in this regard, has been calculated in the following way:

$$\text{Standardized} = \frac{Value\ of\ Y * Total\ number\ of\ actual\ unique\ author}{Total\ number\ of\ calculated\ unique\ author}$$

Based on Lotka's law, Table 7 shows the output of Bangladeshi authors. 408 (62.01%) of the 658 Bangladeshi writers published one paper, 123 (18.69%) wrote two articles, and so on. There aren't many authors who have written more than ten articles (2.74%).

Table 7 Calculation of Bangladeshi authors' productivity based on Lotka's law

Number of Papers (x)	X Log of x	Number of Authors (y)	Y Log of y	%	Expected (n=2)	Standardized	%
1	0	408	6.011267	62.01	408	415.269488	63.11
2	0.693147	123	4.812184	18.69	102	103.817372	15.78
3	1.098612	48	3.871201	7.29	45.33333	46.14105423	7.01
4	1.386294	23	3.135494	3.50	25.5	25.954343	3.94
5	1.609438	14	2.639057	2.13	16.32	16.61077952	2.52
6	1.791759	11	2.397895	1.67	11.33333	11.53526356	1.75
7	1.94591	3	1.098612	0.46	8.326531	8.474887511	1.29
8	2.079442	8	2.079442	1.22	6.375	6.48858575	0.99
9	2.197225	2	0.693147	0.30	5.037037	5.126783803	0.78
10	2.302585	3	1.098612	0.46	4.08	4.15269488	0.63
11	2.397895	2	0.693147	0.30	3.371901	3.43197924	0.52
12	2.484907	1	0	0.15	2.833333	2.883815889	0.44
13	2.564949	5	1.609438	0.76	2.414201	2.457215906	0.37
14	2.639057	1	0	0.15	2.081633	2.118721878	0.32
18	2.890372	3	1.098612	0.46	1.259259	1.281695951	0.19
20	2.995732	1	0	0.15	1.02	1.03817372	0.16
23	3.135494	1	0	0.15	0.771267	0.785008484	0.12
31	3.433987	1	0	0.15	0.424558	0.432122256	0.07
Total		658		100	646.4814	657.9999856	100.00

Based on the study's goals, we hypothesized that public health research production in Bangladesh did not follow Lotka's inverse rule of author productivity (***RQ –2***). Regression analysis was applied here, where the numbers of papers were dependent variables and the numbers of authors were independent variables. A t-test was carried out to test the significance of the regression coefficient.

Table 8 Summary output for conformation of Lotka's inverse law into the author's productivity

Regression Statistics	
Multiple R	0.944737754
R Square	0.892529424
Adjusted R Square	0.885812513
Standard Error	0.602861062
Observations	18

Table 9 Regression Coefficient for conformation of Lotka's inverse law into the author's productivity

	Coefficients	Standard Error	t Stat	P–value*	Lower 95%	Upper 95%
Intercept	5.71595	0.373405073	15.3076	5.6E–11	4.924368	6.507535?
Log of X	–1.9032	0.165103253	–11.527	3.7E–09	–2.25319	–1.553187

Note: *significant at $p<0.01$

Accordings to Cohen et al. (2003), the multiple R (0.9447) suggests a high correlation (0.50 or greater = strong) between the number of authors and their outputs. The R square value is 0.8925, which implies that the regression line or the regression of the number of articles on the number of authors can explain 89 percent of the variability in the number of authors (Table 8). The regression coefficient is statistically significant since the p-value in this test is less than 0.01 (Table 9). We may say that Bangladesh's public health research productivity follows Lotka's inverse rule of author productivity.

5.3 Assessment of Bangladeshi contributions to PH literature

5.3.1 Top ten Bangladeshi authors on PH

The only authors who are either affiliated with or originated from Bangladesh were selected for the current analysis. Rank is made based on the highest number of publications on public health and is arranged in an ascending order of rank.

Table 10 Top ten Bangladeshi authors with affiliations

Authors	Affiliated Institution	Total Publications	Publications on PH	Rank
Yunus, M.	ICDDR,B	283	21	1
Ahsan, H.	University of Chicago	267	18	2
Noor, R.	Stamford University Bangladesh	47	16	3
Parvez, F.	Columbia University Medical Center	119	16	3

Authors	Affiliated Institution	Total Publications	Publications on PH	Rank
Rahman, M.	Bangladesh Rural Advancement Committee	74	16	3
El Arifeen, S.	ICDDR,B	119	15	4
Islam, T.	UChicago Research Bangladesh	79	15	4
Haque, R.	ICDDR,B	243	14	5
Nahar, N.	ICDDR,B	82	14	5
Ahmed, S.M.	Mymensingh Medical College	81	13	6

Table 10 demonstrates that among the Bangladeshi authors, Mr. Yunus of ICCDDR,B ranked 1st position which means he had the maximum number of publications on public health in the list. He had 21 publications on public health out of his total 283 publications. Mr. Ahsan had the 2nd highest number of publications (18), which placed him in the 2nd position on the list. Mr. Parvez and Mr. Rahman had an equal number of publications on public health (16), which placed them third in rank. It is interesting to note that out of the top 10 authors, four were affiliated with ICDDR,B and two were affiliated with foreign institutions.

Average Citation Per Paper (ACPP) denotes the proportional number of citations per published paper of an author, whilst Average Citation Per Cited Paper (ACPCP) indicates the proportional number of citations per cited paper of an author. Table 11 lists the top ten Bangladeshi authors, along with their citation number, cited document, ACPCP, ACPP, and rank.

Table 11 Top ten Bangladeshi authors with ranking and criteria

S.N.	Authors	Total Publications	Citation Number	Cited Document	ACPCP	ACPP	Rank			
							1	2	3	4
1.	Yunus, M.	283	9548	6972	1.37	33.74	2	2	7	4
2.	Ahsan, H.	267	12110	8498	1.43	45.36	1	1	6	2
3.	Noor, R.	47	222	102	2.18	4.72	10	10	1	10
4.	Parvez, F.	119	5009	2751	1.82	42.09	4	5	2	3
5.	Rahman, M.	74	3731	2527	1.48	50.42	6	6	5	1
6.	El Arifeen, S.	119	3778	2939	1.29	31.75	5	4	8	5
7.	Islam, T.	79	1575	1058	1.49	19.94	7	8	4	7
8.	Haque, R.	243	7559	4584	1.65	31.11	3	3	3	6
9.	Nahar, N.	82	764	600	1.27	9.32	9	9	9	9
10.	Ahmed, S.M.	81	1371	1136	1.21	16.93	8	7	10	8

Note: ACPCP = Average Citation Per Cited Paper; ACPP = Average Citation Per Paper; 1= Based on citations; 2= Based on cited document; 3= Based on ACPCP; 4 = Based on ACPP

Table 11 examines the top ten Bangladeshi authors based on citation number, cited document, average citation per cited paper (ACPCP), and average citation per paper (ACPP). Mr. Ahsan placed 1st rank based on citation and cited document. He has received 12,110

citations from 8,498 cited documents. Mr. Noor got the first place based on ACPCP (2.18), and Mr. Rahman placed first in position based on ACPP (50.42). To assess the productivity and effect of published work, many citation indices have been developed across the world. Hirsch (2005) suggested the h-index, while Egghe (2006) proposed the g-index to assess and describe a researcher's scientific output. Due to some differences remaining in calculating the h-index between senior and junior academics across disciplines and career stages, hI, norm and hIa (hI, annual) were introduced (Harzing, 2017).

Table 12 indicates that Mr. Ahsan had the highest h-index (62) and g-index (101) scores compared to others. All of the topmost Bangladeshi authors had low hI, norm index value means most of their articles were co-authored with at least three other academics. All of the authors listed failed to produce at least one article per year as all of their hI, values are below 1.0. Anyway, Mr. Yunus was the most experienced author, as he had the maximum year of experiences in the publication (47 years).

Table 12 Top ten Bangladeshi authors with various indices

S.N.	Authors	h–index	g–index	hI, norm	hI, annual	Tenure	Citation Years
1.	Yunus, M.	52 (2)	86 (2)	17 (1)	0.36 (8)	1970–2016	47 (1970–2016)
2.	Ahsan, H.	62 (1)	101 (1)	16 (2)	0.7 (1)	1994–2017	23 (1994–2017)
3.	Noor, R.	9 (10)	11 (10)	4 (9)	0.29 (10)	2003–2017	14 (2003–2017)
4.	Parvez, F.	39 (4)	69 (4)	11 (5)	0.65 (2)	2000–2017	17 (2000–2017)
5.	Rahman, M.	28 (6)	61 (5)	14 (3)	0.64 (3)	1995–2017	22 (1995–2017)
6.	El Arifeen, S.	35 (5)	58 (6)	10 (6)	0.53 (6)	1998–2017	19 (1998–2017)
7.	Islam, T.	20 (8)	38 (7)	8 (7)	0.38 (7)	2000–2017	17 (2000–2017)
8.	Haque, R.	49 (3)	76 (3)	16 (2)	0.59 (4)	2004–2017	13 (2004–2017)
9.	Nahar, N.	14 (9)	25 (9)	6 (8)	0.18 (9)	1984–2017	33 (1984–2017)
10.	Ahmed, S.M.	23 (7)	34 (8)	12 (4)	0.57 (5)	1996–2017	21 (1996–2017)

Note: The number inside the bracket indicates rank based on indices

5.3.2 Top ten affiliated institutions and collaborated countries by Bangladeshi authors

Various institutes where Bangladeshi researchers affiliated with were also ranked based on a higher number of research outputs published in the field of public health. The researchers from Bangladesh worked together with the researchers from various countries around the world. Table 13 lists the top ten most productive institutes and countries with the most collaborations with Bangladeshi authors.

The International Centre for Diarrhoeal Disease Research Bangladesh (ICDDRB) produced the maximum research output (362) on public health and placed 1st in ranking which was followed by the University of Dhaka with 82 contributions, placed 2nd in the ranking. The BRAC and its sister organization produced 81 research outputs, which placed them as 3rd and 4th respectively in the ranking. The University of Rajshahi was positioned in 5th place in producing public health literature as a Bangladeshi institute.

Table 13 Top 10 institutions and collaborated countries affiliated by Bangladeshi authors

Affiliated Institutes	Records	Rank	Collaborated Countries	Records	Rank
International Centre for Diarrhoeal Disease Research Bangladesh (ICDDRB)	362	1	United States of America	310	1
University of Dhaka	82	2	United Kingdom	119	2
BRAC	42	3	Australia	80	3
BRAC University	39	4	Japan	78	4
Rajshahi University	34	5	India	71	5
Jahangirnagar University	31	6	Sweden	59	6
Bangabandhu Sheikh Mujib Medical University	28	7	Switzerland	50	7
National Institute of Preventive and Social Medicine (NIPSOM)	21	8	Canada	42	8
Stamford University Bangladesh	20	9	Malaysia	30	9
Bangladesh University of Engineering and Technology	19	10	Thailand	29	10

The researchers from Bangladesh preferred most to work together with the researchers from the United States of America. The joint efforts by the researchers from Bangladesh and the USA produced 310 records, which is the top in the collaboration ranking. The second most preferred country, with which the researchers of Bangladesh working together, is the United Kingdom (119). Australia, Japan, and India are the third, fourth and fifth in ranking as most collaborated countries gradually preferred by Bangladeshi researchers.

5.3.3 Research productivity of developed and developing countries

It was anticipated that there was no substantial degree of research productivity link between developed and developing nations, with Bangladesh serving as a developing country (***RQ–3***). The country-wise research productions for each category of countries were arranged in order of decreasing productivity in public health literature during 2000-2015. The first ten countries were then selected from each category of the list. The research output of the top ten developed and developing countries on public health is presented in Table 14.

Table 14 Publication number of top 10 developed and developing countries on PH

Developed countries		Developing countries	
United States	116418	Brazil	12953
United Kingdom	38313	India	9159
Canada	18692	China	8586
Australia	18002	South Africa	4637
France	12431	Mexico	3024
Germany	11466	Turkey	2801
Italy	8305	Iran	2726
Spain	8217	Taiwan	2690
Netherlands	7229	Thailand	2167
Switzerland	6889	Nigeria	2059
Total Output	245962	Total output	50802

Note: Cut-off country-wise research production was set based on the top ten highest number of literature producer countries

In the present study, there are two set variables each, i.e., two independent variables (developing and developed countries) and two dependent variables (production of public health literature of in developing and developed countries). The correlation coefficient was used to measure the degree of relationship between two variables, which always varies between -1 and +1. Table 15 shows the result of the correlation coefficient between developing countries and developed countries.

The result of Pearson's correlation is 0.87, which is close to +1, indicating a positive relationship in the production of public health literature between developing countries and developed countries. Therefore, the production of developing countries in terms of public health literature is correlated with that of developed countries. The correlation test was performed using SPSS version 24.0, and the correlation was found to be significant at the 0.01 level and there is a substantial connection between emerging country research productivity and developed country research productivity (***RQ–3***).

Table 15 Correlation test for the significant level of relationship

		Developed countries	Developing countries
Developed countries	Pearson Correlation	1	.870**
	Sig. (2–tailed)		.001
	N	10	10
Developing countries	Pearson Correlation	.870**	1
	Sig. (2–tailed)	.001	
	N	10	
**Correlation is significant at the 0.01 level (2–tailed)			

6 Findings and further study

871 publications (0.23%) counted as publications by Bangladeshi authors out of 3,72,260 documents during the period 2000-2015, 2015 being the most productive year (15.27%) and 2001 the least productive year (1.15%) in terms of the number of publications. The Percent (Straight-Line) Growth Rate (PR) of Bangladeshi productions was 20%, with an average CAGR of 0.20. The period from 2004 to 2007 was the highest block of years in terms of AAGR (1.32). During the study period, RGR values of Bangladeshi contributions to public health literature varied from 0.16 to 0.55, with an average RGR value of 0.27. Dt(a) values, on the other hand, also varied from 1.26 to 4.33, with an average Dt(a) values of 3.00. That means the literature on public health by Bangladeshi authors, with a 0.27 growth rate, would have a doubling time of 3 years.

More than 68% of the total Bangladeshi productions have more than three authors per paper whilst near about 8% of papers are single-authored papers. More than 92% of total publications produced by Bangladeshi authors are collaborative works, dominating single-author works. The CI values were found to range from 2.59 to 3.61, with an average of 3.28, which means there are 3.28 authors per paper. The average DC value is 0.88, which indicates the proportion of multi-authored papers is greater than single-authored papers. The mean value of CC is 0.62, which indicates better collaboration among Bangladeshi authors. Some variations of values have been observed between RCC (the normalized version of CC) and CC, as the number of literature by Bangladeshi authors is quite smaller than

public health literature published globally in general.

The AAPP, which is equivalent to CI values, was more than 2.5, which means there are 2.5 Bangladeshi authors per paper. The PPA values range from 0.28 to 0.39 with an average of 0.31, which means during the research period, each author produced less than half of a publication each year. From 2009 to 2015, the research efforts of Bangladeshi authors were lower than the world's research efforts. The Activity Index (AI) was at its maximum in 2015 (163.12) and the lowest in 2001 (32.07). Of the 658 unique Bangladeshi authors' names, 408 (62.01%) had produced one article, 123 (18.69%) had produced two articles, and 48 (7.29%) had produced three articles, which is a similar finding to Lotka's law of productivity.

Based on the highest number of publications on public health, Mr. Yunus was placed first in the ranking among Bangladeshi authors. Mr. Ahsan was ranked first in terms of citations and cited documents, and his h-index (62) and g-index (101) were the highest of any researcher. Mr. Noor was the first rank based on ACPCP. Mr. Rahman stood first in the ranking based on ACPP.

An ACPP (Average Citation Per Paper) is a widely used tool for assessing an author's cited publications. This is necessary in order to determine the number of referenced articles among the author's publications. However, an issue occurs when a document mentions more than one publication by the same author; the traditional indication does not account for this. To address this issue, ACPCP (Average Citation Per Cited Paper) has been proposed as a method of determining an author's multiple citation rate based on a single publication.

More citations received by the cited document from more than one publication of an author (source author) is called the Average Citation Per Cited Paper (ACPCP). For calculating ACPCP, the following formula was proposed by the present researchers:

$$\text{ACPCP} = \frac{Total\ number\ of\ citations\ received\ by\ a\ researcher}{Total\ number\ of\ cited\ publications\ acknowledge\ to\ the\ source\ author}$$

The citation rate for an author's works from the perspective of cited publications is known as the average citation per cited publication (ACPCP). The value of ACPCP equal to 1 indicates that the author of the cited article used citations from just one publication by the same source author. When the ACPCP value is greater than 1, it signifies that the author of the referenced publication cites more than one publication by the same source author. More research is required to build a solid foundation of this new proposition.

7 Conclusion

Using scientometric approaches, the current study focuses on crucial features of Bangladeshi writers' research production on public health. The study's scope is limited to bibliographic data collected from the "Scopus" database for a 16-year period from 2000 to 2015. As sources of public health literature, the study comprises research papers, reviews, conference proceedings, and reviews, editorial comments, letters, brief surveys, books, book chapters, press pieces, erratum, business articles, and abstract reports.

The researchers or authors of Bangladesh made a 0.23% contribution (871) to the world (3,71,389) in public health literature during the period from 2000 to 2015. Author's productivity of the world's researchers (0.49) based on Productivity Per Author (PPA) is slightly greater than the productivity of Bangladeshi authors (0.31). The number of cited documents acknowledged in the world's literature on public health (70.66%) is lower than the number of cited documents in Bangladeshi literature (85.30%). During the study period,

the average Bangladeshi research output was lower than the world's average (89.14). The h-index and g-index of top Bangladeshi authors on public health (62 and 101) are near the indices of the world's top author (75 and 132). The average double-time value of the world's literature (4.16) is nearly equal to the double-time value of Bangladeshi literature on public health (3.00). The collaboration rate of Bangladeshi researchers (92.19%) is far greater than the collaborative rate of the world's researchers (53.35%).

Regardless of country, document type, author, subject, or source, the current study analyses the essential features of public health research in terms of output quantity and growth. This research examines the country's progress in terms of public health research production. It shows how the literature has changed through time by presenting contributions from various affiliated institutions. It assigns a ranking to countries based on their research contributions. It aids in identifying the country's top writers in this discipline based on the number of times their work has been mentioned by others. It compares the contributions of other countries' research output to show the scope of public health research in Bangladesh.

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