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Application of Growth Models to Research Literature of All India Institute of Medical Sciences: An Analysis

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ABSTRACT

In this study linear and non – linear growth models are applied to 10 years of medical literature published by the faculties of All India Institutes of Medical Sciences (AIIMS) to determine goodness of fit. The curve fitting methodology is used to fit the growth of the research literature of AIIMS. It is found that exponential growth model fits at $y = 989.21e^{0.0648x}$ which is comparatively best among other models. The study evinced mean relative growth rate as 1.915 and doubling times as 5.5999. Multiple linear regression analysis is also used to evaluate the effect of faculty strength and department on the research output of AIIMS. The t statistics prove that faculty strength is the significant independent variable compared to department, but it does not reach the statistical significance ($p = 0.344$) hence, the faculty strength and the department does not have a remarkable effect on the productivity of AIIMS.

Keywords: Growth models; Multiple linear regression analysis; Chi square test; Medical educational institutions; All India Institute of Medical Sciences; Curve fitting methodology.

1. INTRODUCTION

Bibliometric and scientometrics statistics are used to evaluate the research productivity and its impact on any institution. Assessment of medical research literatures published by the institutions supports to built a healthy nation. India is the second most populated country in the world with high proportionate disease burden. The Government of India has allocated INR 69,000 crore for the year 2020-2021 to upgrade existing medical centers and to set up 12 more All India Institute of Medical Sciences (AIIMS) across the country[14].

AIIMS is a group of medical educational institutions established by an Act of Parliament to serve as a nucleus for nurturing excellence in all aspects of healthcare. It is recognised as an Institute of National Importance by the Government of India. AIIMS, New Delhi has been the forerunner of the medical educational institution since 1956[13].

Under PMSSY, during the year 2012 six new AIIMS are started in the under-served places of Patna, Bhopal, Raipur, Bhubaneshwar, Jodhpur and Rishikesh and four more AIIMS is started during 2018 with the objectives of correcting regional imbalances in the availability of affordable and reliable tertiary health care services, augmenting facilities for quality medical education, offering paramedical courses at under graduate and post-graduate level and undertakes research on common disease, prevention and treatment of national health problems.

There is a common assumption that publication literature is the output of research activities of an institution which help to evaluate the quality of education and clinical care. Application of growth models to the research literature published by the faculties of AIIMS, the curve fitting methodology to the data and identifying the best fitting unveils literature growth pattern of institutions, predict the growth of literature in the near future and helps the administrators, policy makers to strengthen the research activity and to reduce the disease burden and ensure well being of the people of India.

Several studies[1,6,8,9,12] analysed the research publication of AIIMS from a different perspective. But no attempt was made to study the trajectory growth of medical literature published by AIIMS. Hence, linear and non-linear growth models are applied to the medical literature to reveal trajectory growth by revisiting the data collected in the earlier study[8].

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2. OBJECTIVES

This study aims to investigate trajectory growth of medical literature of AIIMS during the year 2007-2016. The specific aims of this study are:

- To delve the relative growth rate and doubling time of the medical literature of AIIMS
- To ascribe the curve fitting methodology to the medical literature in terms of different growth models
- To evaluate effects of faculty strength and department on the research literature of AIIMS.

3. SCOPE AND METHODOLOGY

The bibliographical dataset is retrieved from the Scopus database by providing keywords AFFIL ("All India Institute of Medical Sciences" or "AIIMS") AND PUBYEAR > 2007 AND PUBYEAR < 2016. Totally 14410 records retrieved on 13th December 2017 are distributed in MS Excel worksheet for statistical analysis. Annual reports of AIIMS are used

Table1. Relative growth rate (RGR) and Doubling time (Dt) of Medical literature published by AIIMS

Output	Cum. Output	ARoG	W1	W2	RGR	Mean RGR (5 Years)	Dt	Mean Dt (5 Years)
1087	1087	1		6.991	6.99		0.099	
1182	2269	1.087	6.991	7.727	0.736		0.942	
1216	3485	1.029	7.727	8.156	0.429	1.742	1.615	1.543
1281	4766	1.053	8.156	8.469	0.313		2.214	
1313	6079	1.025	8.469	8.713	0.243		2.848	
1350	7429	1.028	8.713	8.913	0.201		3.455	
1444	8873	1.07	8.913	9.091	0.178		3.902	
1703	10576	1.179	9.091	9.266	0.176	0.173	3.947	4.056
1693	12269	0.994	9.266	9.415	0.148		4.667	
2141	14410	1.265	9.415	9.576	0.161		4.308	
14410						1.915		5.599

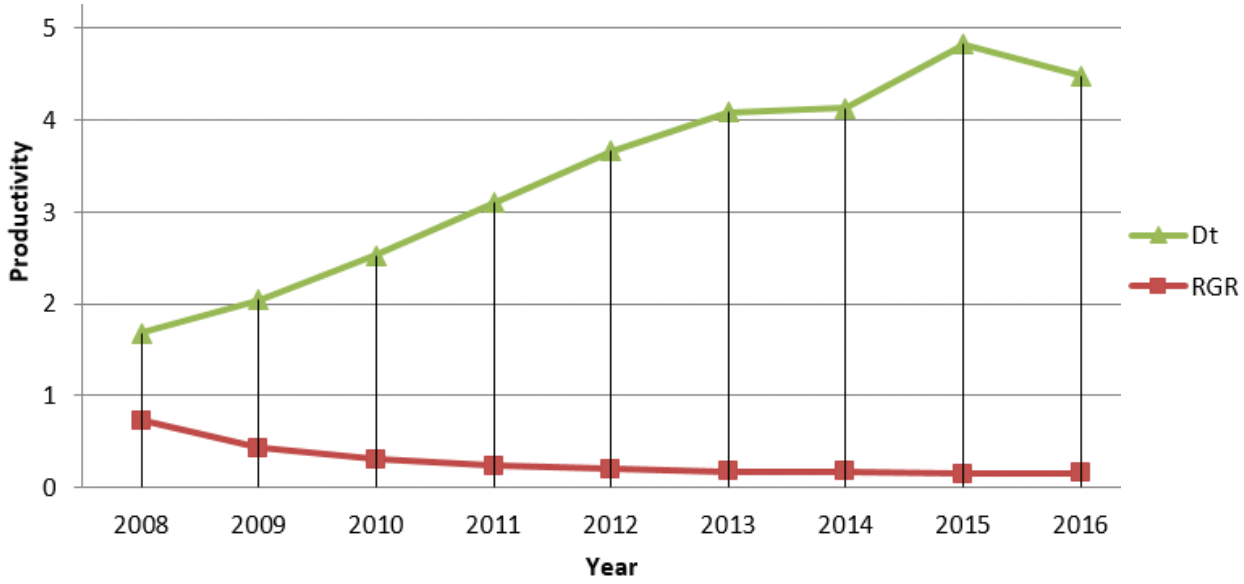

Figure 1. Inverse relationship between relative growth rate & doubling time.

to determine the faculty strength and size of the department. Scientific productivity of seven AIIMS is studied, but statistical inferences are drawn only for the six. AIIMS, Patna has been eliminated because of unavailability of annual report on their website. Newly emerging AIIMS are also eliminated from the growth study.

In this study linear and non-linear growth models are applied to the medical research literature of AIIMS to reveal the trajectory of growth. A multiple linear regression analysis is also used to evaluate the effect of faculty strength and department on the research literature of AIIMS.

3.1 Growth Models

A statistical technique used in structural equation to estimate growth trajectory is known as growth model. It is a longitudinal analysis technique to calculate growth over a period of time. There are enormous growth models available in science and social science discipline & broadly classified into linear and non-linear growth models[2]. (Annexure 1)

3.2 Multiple Linear Regression Analysis

It is used to study the relationship between two or more explanatory variables and a response variable by fitting linear equation to observed data. The formula for multiple linear regression is,

$$y_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots + \beta_p x_{ip} + \epsilon$$

Where y_i is the dependent variable; xi =explanatory variables; β_0 = y intercept (constant term); βp = slope coefficients for each explanatory variable ϵ = the model's error term (also known as the residuals) and i = number of observations[11].

4. DATA ANALYSIS AND INTERPRETATION

4.1. Relative Growth Rate and Doubling Time of Medical Literature Published by AIIMS:

Relative growth rate (RGR) is computed by the following equation propound by Mahapatra[7].

$$\overline{R}(1-2)=\frac{W_2-W_1}{T_2-T_1}$$

Where $\overline{R}$ (1-2) = mean relative growth rate over the specified period of interval.

W_1 = LogW1: (Natural log of initial number of Publications/pages)

W_2 = LogW2: (Natural log of final number of Publications/pages)

T_2-T_1 = The unit difference between the initial time and final time.

Doubling Time: Doubling Time (Dt) for publication is calculated by

$$Dt=\frac{0.693}{\overline{R}}$$

0.693 is obtained from the value of Log e[2]

The study period from 2007-2016 have evinced a mean relative growth rate as 1.915 and doubling time as 5.599. A diminishing rate of relative growth is identified in medical literature. During the year 2007-2011 RGR 1.742 is reduced to 0.175 in the span period of 2012-2016. Correspondingly the Dt of the medical literature escalated from 1.543 to 4.056. But in the year 2016 RGR increased from 0.148 to 0.161with a decreased Dt from 4.667 to 4.308 as shown in Table 1.

It is evident from the Fig.1 that the RGR and Dt are inversely proportional in the medical literature.

4.2 Application of Growth Models to Medical Literature Published by AIIMS.

Table 2 evaluates the goodness of fit of the growth model using R^2 value to the medical literature. The coefficient of determination (R^2) for the exponential growth model is 0.91 indicates that 91 per cent of the variance in the growth of medical literature best fits the data compared to other growth models. The remaining 9 per cent is unexplained by exponential growth model. The R^2 value of the linear growth model is 0.85 which is the second best fit model and statistically significant at the 0.05 critical alpha level t(8) = 6.73>2.306 with the p value = 0.000148 < α. The t statistics for the slope of power model is significant at α t (8) = 4.73 > 2.306 and the p value = 0.000148 < α. The logarithmic growth model is the least fit to the growth of medical literature with 65 per cent of variance and statistically significant as the two tailed t test critical alpha value is lesser than the calculated t value 3.87.

4.3 Fitness of Growth Models to the Medical Literature Using Chi Square Test

Table 3 depicts the fitness of growth models to the medical literature using chi square test. The following hypothesis is drawn to evaluate the fitness of growth models to the medical literature of AIIMS.

Table 2. Evaluation of fitness of the growth model using R^2

Growth Models	R^2 Value	df	t Statistics	F Statistics
Linear	0.85	8	6.73	45.32
Exponential	0.91	8	8.91	79.36
Power	0.73	8	4.73	22.38
Logarithmic	0.65	8	3.87	14.97

Table 3. Evaluation of fitness of growth models to the medical literature using Chi Square test

Growth Models	Calculated Chi Square Value	Goodness of Fit
Linear	85.06	Not fit
Exponential	226.17	Not fit
Power	173.83	Not fit
Logarithmic	210.9	Not fit

Table 4. Chronological distribution of productivity, faculty strength and departments

Year	Productivity	Faculty Strength	Departments
2007	1087	543	23
2008	1182	453	57
2009	1216	446	57
2010	1281	434	57
2011	1313	434	59
2012	1350	498	61
2013	1444	619	81
2014	1703	811	142
2015	1693	917	229
2016	2141	1232	224

"The growth of medical literature published by AIIMS follows any one of the growth models: linear, exponential, power and logarithmic"

In order to test the data, growth rate and expected output are computed separately for the growth models (Annexure 2). The table value of chi square for one degree of freedom at the 5 percent level of significance is 16.919. The calculated value of chi square for growth models is provided in the Table 4 is much higher than the table value which means that the calculated value cannot be said to have arisen just because of chance. It is significant. Hence, the hypothesis does not hold good.

4.4 Linear and Non Linear Curve Fitting to Medical Literature Published by AIIMS

The curve fitting is used to find the best fit curve to the

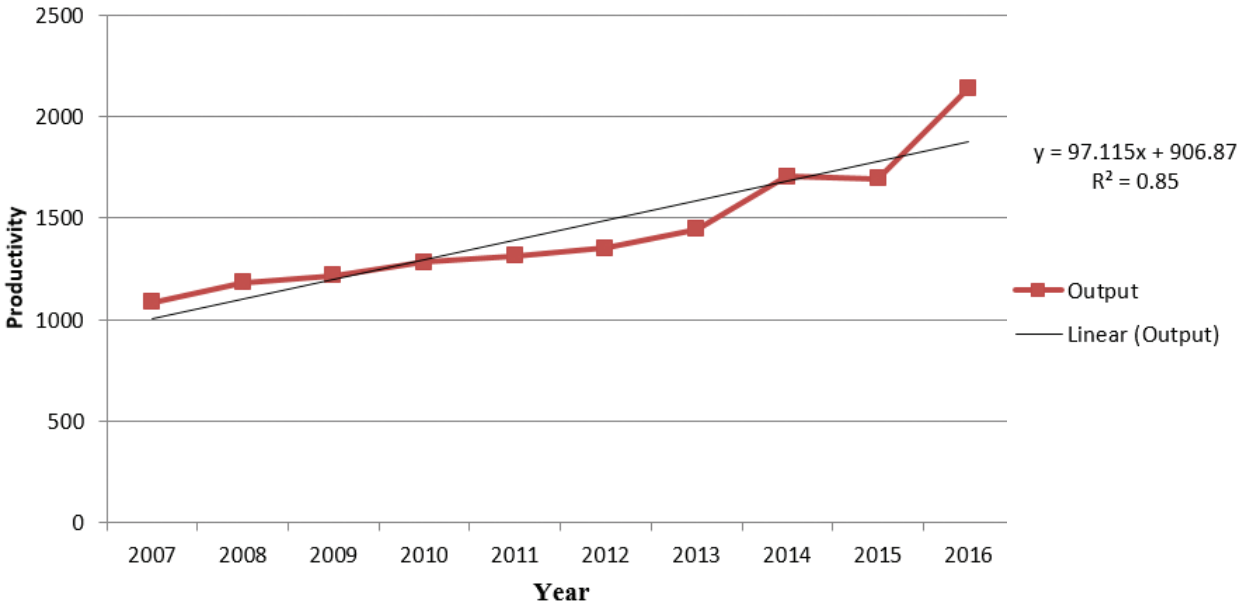

Figure 2. Linear curve fitting to medical literature published by AIIMS.

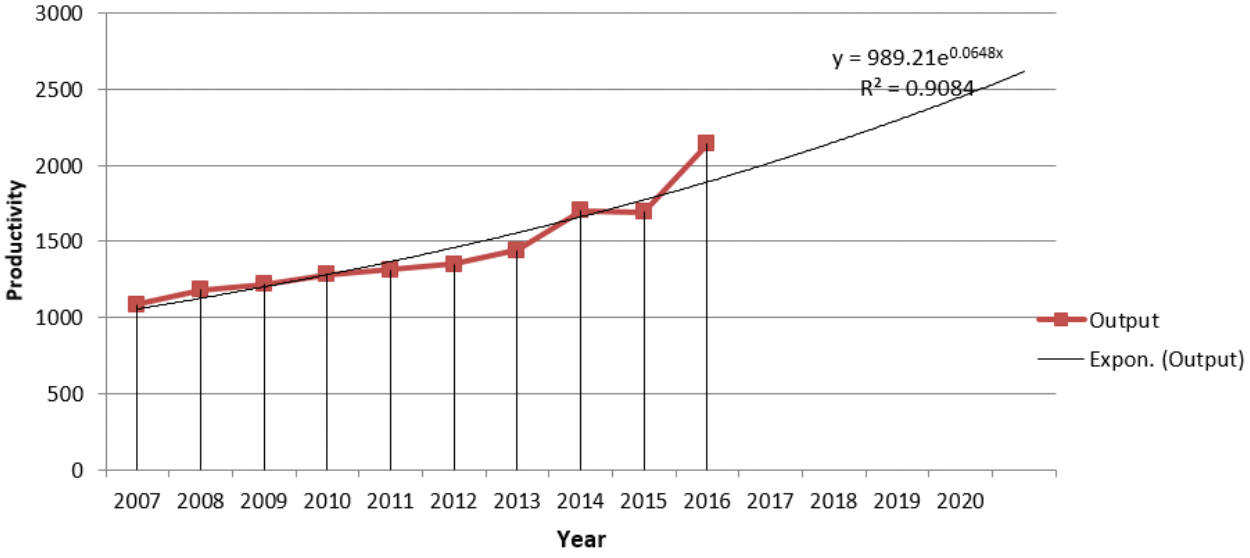

Figure 3. Exponential curve fitting to medical literature published by AIIMS.

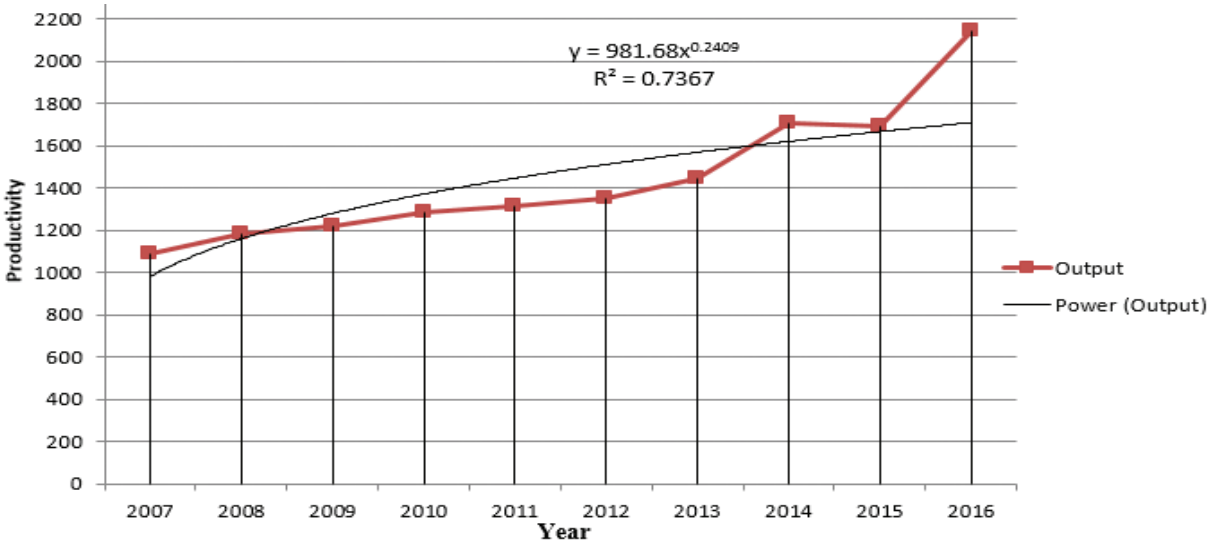

Figure 4. Power curve fitting to medical literature published by AIIMS.

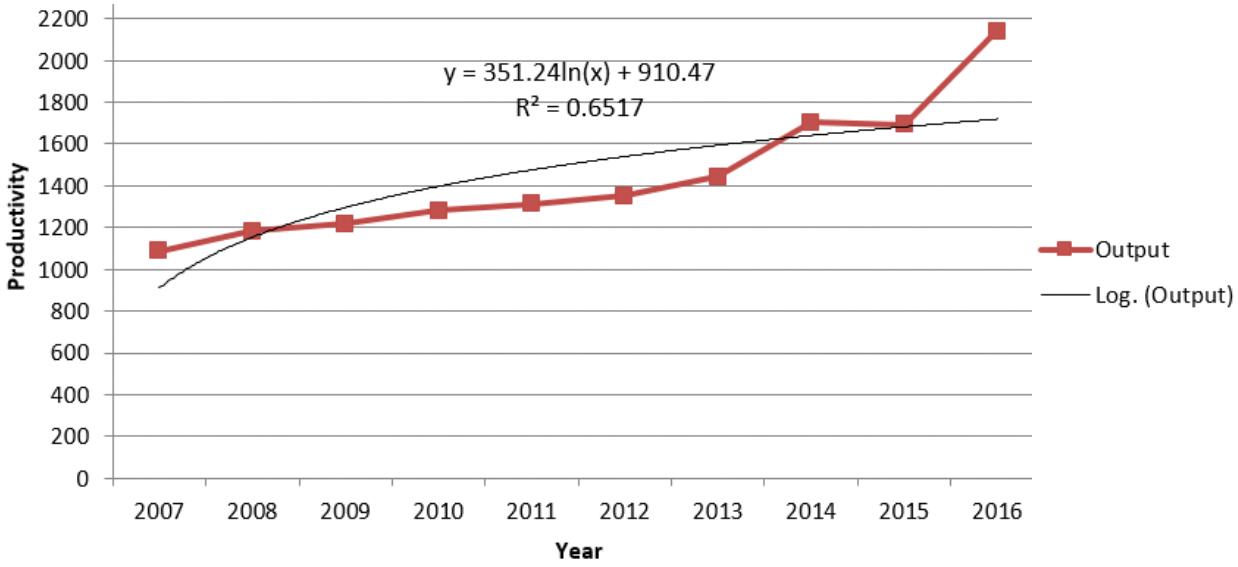

Figure 5. Logarithmic curve fitting to medical literature published by AIIMS.

Table 5. Regression coefficient of medical literature published by AIIMS

	Coefficients	Standard Error	t Stat	P-value
Intercept	799.6487137	121.7229408	6.569417	0.000313099
Faculty strength	0.80664875	0.346287387	2.32942	0.052658857
Departments	1.274189188	1.257749674	1.013071	0.344755771

trajectory growth of the medical literature. The different growth equations discussed in Annexure 1 are used to find points to plot in the graph. Figure 2,3,4,5 represents different growth curves and reveals that exponential growth curve fit best compared to other curves.

4.5 Effect of Faculty Strength and Department on Medical Literature of AIIMS

It is evident from the Table 5 that the faculty strength is diminished till 2011 from 543 to 434 with an increased productivity. While the number of departments at AIIMS shows an increasing trend throughout the study period, the additional faculty strength shows an increasing trend from the year 2012 corresponding increase in productivity except in the year 2015.

Multiple linear regression analysis is used to evaluate the effect of faculty strength and department on the research output of AIIMS. From the Table 5, multiple regression equation is fitted as,

y = published medical literature = 799.6487 + 0.806649 (Faculty strength) + 1.274189 (Department).

It suggests that each unit increase in faculty strength is associated with a 0.806649 unit increase in published medical literature. For each unit increase in department size, publication of medical literature increases with 1.274189 units. Coefficient describes the mathematical relationship between published medical literature and the faculty strength and departments. The coefficient of faculty strength is estimated standard error of 0.346, t statistics of 2.329 and p value of 0.0526. It is therefore statistically significant at significance level α =0.05 as p = 0.05. The coefficient of the department is estimated standard error of 1.258, t statistics of 1.013 and p value of 0.344. Hence statistically insignificance level α =0.05 as p > 0.05. The magnitude of t statistics proves that faculty strength is the significant independent variable compared to department and it does not reach the statistical significance (p = 0.344) in the multiple regression model. Hence, no sufficient evidence to conclude that there is effect on the medical literature.

The overall goodness of fit measures R^2 = 0.91 indicates that 91 per cent of the variation in medical literature published is explained by the independent variables faculty strength and department size. The closer to 1, the better the regression line fits the data.

5. DISCUSSION AND CONCLUSIONS

This study investigate the trajectory growth of medical literature published by AIIMS from 2007-2016 indicates an exponential growth with an average annual growth rate of 6.7 per cent is compared to an average annual publication growth rate of 11.57 per cent in medical literature published from India.

Bala and Gupta[1] revealed AIIMS, New Delhi have published highest research output than other medical colleges in India with 7850 research papers in the span of 12 years (1996 – 2007). In continuation, the present study explored the research output burgeoned to 14410 during ten years (2007 – 2016) would be the outcome of establishment of six AIIMS institution across India, introduction of new departments and budget sanctioned to research cells in AIIMS. This was supported by the work of Hendrix[4] at Association of American Medical Colleges and Medical Schools. The study shows a significant positive effect on the number of papers published by US Medical Schools and their annual budget. On the contrary,

Yazdani et al[16] found that there was an inverse significant correlation between the age of the research centers affiliated to Tehran University of Medical Sciences and a number of published papers.

The mean relative growth rate for medical literature published by AIIMS is (RGR 1.915 which is relatively low compared to the mean relative growth rate of research publication by IGCAR (Indra Gandhi Centre for Atomic Research, Kalppakam) (RGR = 4.2)[5].

It is observed that the decrease (543 to 434 during 2007 – 2011) or increase (498 to 1232 during 2012 – 2016) in the faculty strength resulted in increased productivity. This may be due to the most prolific authors of that institution. Study by Bala and Gupta[1], Kumar A of AIIMS has published 161 articles and occupied seventh place in the most productive Indian authors in medicine during the year 1999–2008. It is noteworthy from the study of Nishavathi and Jeyashankar[8] that the productivity of the same author Kumar A has increased to 619 and secured second place in the productivity of top 20 prolific authors. Thus the faculty strength and department does not have remarkable effect on the productivity of AIIMS.

As per the Medical Council of India (MCI) 2015 guidelines[15], at least 4 research publications for the post of an associate professor and 8 for the post of professor is required as promotional avenues for the faculties of medical educational institution in India. Though research work does not affect their promotion which is mainly governed by seniority and their practice, faculties are interested in research and obtained over Rs.100 crores as extramural grants in a year and committed to serve humanity by advancing knowledge, providing important Information about disease trends and risk factors for improving health and health care of the people.

The present study offers a broad panorama of the trajectory growth of medical literature published by AIIMS. The data for study period is limited to 10 years may not be sufficient to study the growth pattern. Future work should cover at least 30 years retrieved from specialised database such as PubMed would be more appropriate for the trajectory growth study. Similarly, more growth rates[3] and models like logistic can also be tested with the data along with different time slices unveil the productivity of AIIMS. In addition, more explanatory variables like age of the department, annual budget, intrium and extrium funds sanctioned for each AIIMS can be integrated into a multiple linear regression analysis to reveal the effect on the productivity of AIIMS. A scientometrics and social network approach[10] would bring insights about the medical literature of AIIMS.

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In the current study, she conceived the idea, applied statistical tools and conceptualised the data.