Female scholars' contribution to research topics in microbiology (2012-2016) and its relationship with the Gross Domestic Product (GDP) index

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Introduction

- There is an absolute divergence in Gross Domestic Product (GDP) between developed and developing countries, which has an impact on what they can devote to research (Bloom, et al. 2006).

- High income countries allocate more capital to investment and have better infrastructure for research and development (R&D) activities. R&D investment can be linked to academic output (Diacon & Maha, 2015).

- However, in low income countries, the funding gender gaps are often larger (Fox, 2015), and women may have less access to financial resources for R&D than in high income countries.

- Additionally, as females and male researchers choose different research topics, this has an important impact on their research performance (Pan & Kalinaki, 2015).

Research objectives

- To study the number of female and male scholars in microbiology.
- To study female scholars' contribution to research topics in microbiology.
- To examine whether there is a relationship between the average Gross Domestic Product (GDP) index and the female relative proportion per paper (FRP):

    i. In general
    ii. In the identified topics.

Methodology

Data collection and processing

- The dataset of this study comprised 167,874 articles and reviews in the field of microbiology from 2012-16, retrieved from the Web of Science Medline.
- To identify and visualize the topics addressed during the studied period, VOSviewer was used. The construction and visualization of the term map was done based on 5,918 MESH subject headings.
- GDP (current US$) data was gathered from the World Data Bank website and an average value calculated for the five-year study period (2012-2016) for each paper.
- Gender API was used in order to detect the gender of authors.
- Female relative proportion per paper (FRP) was also calculated for each paper.

Methodology

Data analysis and procedures

- To compare the number of male and female authors in the field of microbiology, a chi-square test was performed.

- To study the contribution of female scholars to research topics in microbiology, a Kruskal-Wallis test was used.

- To study the relationship between average GDP and female relative proportion per paper in topics and in the entire dataset, Spearman correlations were used.

Results

- In terms of frequency, the analysis of the data showed that of 86,212 authors, 55,807 (65%) were male and 30,405 (35%) were female.

- Additionally, the results of the chi-square test showed that the number of female authors was significantly lower compared to their male counterparts ($x2 = 7484.59$, $P < 0.0001$).

Identified topics in microbiology

- Six topics were identified in the field of microbiology between 2012-2016.

Table 1. Identified topics in the field of microbiology between 2012-2016, their corresponding description and number of papers

Cluster	Name	Description	No. of papers
1	Metabolic engineering in biofuel production	The approach offered by Metabolic engineering in which synthetic pathways are engineered into user-friendly hosts to produce fuel molecules (Atsumi and Liao 2008).	28,985
2	Isolation and purification methods in microbiological analysis of foods	Methods used in microbiological examination of foods. The isolation, purification and identification of microorganisms in different foods.	19,156
3	Animal models and cell culture for the investigation of human viruses (diseases)	The detection of viruses by the novel cell culture, methods which is considered as a gold standard for virus isolation and identification (Hematin, et al., 2016).	25,289
4	Computational microbiology and algorithms in genetics	The development and application of data-analytical algorithms and computational simulation techniques in the analysis and modelling of genetic data.	15,635
5	Bacterial physiology and pathogenesis	It is a scientific discipline that concerns the life-supporting functions and processes of bacteria, which allow bacterial cells to grow and reproduce.	11,322
6	Phylogenetics and microbial ecology	Phylogenetics is used in evolutionary microbiology to study the patterns and processes of evolution in microbes. Microbial ecology is the study of microbes in the natural environment, such as soil, plant microbial ecosystems, water, sediments, etc.	16,208

Females' contribution to different topics: comparison

- The result of the Kruskal-Wallis test showed a statistically significant difference between the mean ranks of *female relative proportion per paper* for the six studied topics ($H=1862.23$, $p < 0.0001$, $\eta 2=0.01$).

Pairwise comparison of topics in terms of FRP

To evaluate pairwise differences among the six topics, Dunn's pairwise tests (adjusted using the Bonferroni correction) and Nemenyi's tests were carried out. The results indicated a significant difference between all pairs of topics (except between 2 and 3; 5 and 3).

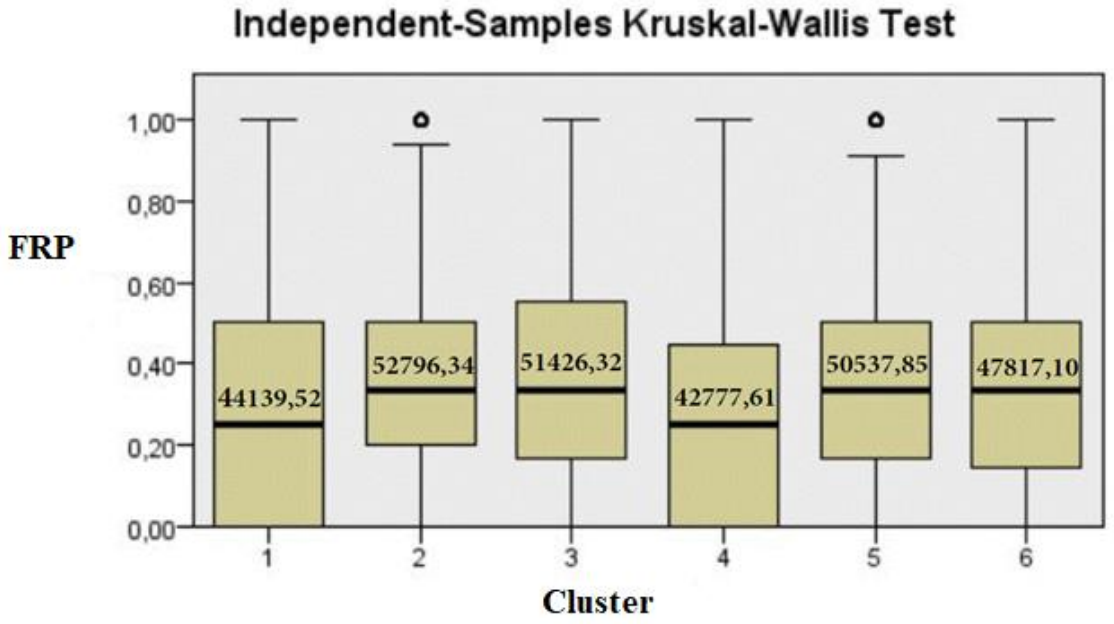
Table 2. Nemenyi's test of multiple comparisons for independent samples (tukey)

Pairs	**mean.rank.diff**	***P* value**
2-1	8656.8254	< 2e-16 ***
3-1	7286.7996	< 2e-16 ***
4-1	-1361.9051	7.5e-06 ***
5-1	6398.3355	< 2e-16 ***
6-1	3677.5797	< 2e-16 ***
3-2	-1370.0258	0.0812 .
4-2	-10018.7305	< 2e-16 ***
5-2	-2258.4899	4.6e-11 ***
6-2	-4979.2457	< 2e-16 ***
4-3	-8648.7047	< 2e-16 ***
5-3	-888.4641	0.5655
6-3	-3609.2198	5.8e-11 ***
5-4	7760.2406	< 2e-16 ***
6-4	5039.4849	< 2e-16 ***
6-5	-2720.7557	8.0e-14 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Females' contribution to different topics: a comparison

- Topic two (2) showed the highest mean rank followed by topics three (3) and five (5), respectively.
- The topic with the lowest mean rank FPR was topic (4).
- In other words, women provided the **highest** contribution to "*Isolation and purification methods in microbiological analysis of foods"* and the **lowest** contribution to "*Computational microbiology and algorithms in genetics*".



Correlation between GDP and FRP

- The results showed a negative significant correlation between GDP and FRP in all topics as well as in the entire data set. This means as GDP increases, female proportion relative per paper decreases.

Table 3.Spearman's rho correlation coefficients for the relationship between GDP and FRP

Topic	Spearman's rho correlation coefficients	***P value***
1	-0.07	P<0.001
2	-0.14	
3	-0.14	
4	-0.08	
5	-0.10	
6	-0.12	
All	- 0.11	

Conclusions

- The number of female scholars was significantly lower compared to their male counterparts.

- Women showed the highest contribution to "*Isolation and purification methods in microbiological analysis of foods*".

- Women showed the lowest contribution to "*Computational microbiology and algorithms in genetics*". This result is in line with Bonham and Stefan's (2017) study which found that computational biology papers have fewer female authors compared to biology in general.

Conclusions

- There was a significant negative correlation between GDP and FRP per paper.

- It seems that in countries with higher GDP (high income countries), females' contribution to the field of microbiology is lower compared to their male counterparts. This result is in line with a study on research labs at 24 top US research institutions. The findings reveald a gender gap in the biology labs (Gibney, 2014).

- According to Fox (2015), economic growth alone will have only a minor effect on gender inequality; other complementary measures are needed, especially in specific areas where non economic factors such as laws, norms, traditions or culture may reduce opportunities. Gender-science stereotypes are robust even in nations where the gender gap in STEM fields is narrow (Brown Jarreau, 2014).

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Thank you!