Aesth Plast Surg (2023) 47:1644–1657
https://doi.org/10.1007/s00266-022-03223-9

ISAPS

ORIGINAL ARTICLE SPECIAL TOPIC

Human Capital and Productivity in Plastic Surgery Research Across Nations

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Received: 5 October 2022 / Accepted: 3 December 2022 / Published online: 29 December 2022

Abstract

Background Understanding country differences in production and human capital in plastic surgery research is crucial in identifying current and future leaders in the field. In this study, we document each country's human capital and productivity in plastic surgery research.

Methods A web scraping algorithm was deployed on PubMed to retrieve information on every publication and every first author in 10 major research outlets in plastic surgery between 2015 and 2021. Each country's human capital in the field is proxied by the number of first authors affiliated with that country. We compare aggregate patterns and volume trajectories of publications affiliated with 110 countries in the context of their human capital.

Results We find that over the studied period, two countries, the USA and China, are represented in roughly 50% and 45% of global research output and first authors, respectively, in plastic surgery. Specifically in the USA, California has the highest number of affiliated first authors and publications compared with other States.

Conclusions Our findings reveal the clear dominance of the USA in plastic surgery research production. No specific US State stands out in the nation as much as the USA does in the global ranking of plastic surgery publications. This suggests that US plastic surgeons across the nation aim to publish. Our global analysis also suggests that countries with a higher share of first authors relative to their research output may have greater capacity to expand their research output in the future.

Level of Evidence IV This journal requires that authors assign a level of evidence to each article. For a full description of these Evidence-Based Medicine ratings, please refer to the Table of Contents or the online Instructions to Authors www.springer.com/00266.

Keywords Human capital · Research productivity · First authors · Publications · Plastic surgery · Web scraping

Introduction

Plastic surgeons treat an ever-expanding number of patients across the globe [1–4]. Countries like the USA, Brazil and Japan seem to dominate the field, in financial terms, since the majority of the procedures were performed in those countries [1, 2]. Thus, Plastic Surgery holds tremendous financial benefits for healthcare systems worldwide [5]. The global plastic surgery market is projected to grow from $46.02 billion in 2021 to $58.78 billion in 2028 [6].

Even though we have a clear view of the increasing market in the field, there are scarce data regarding plastic surgery research. In this study, we investigate the level and trajectory of national contribution in the global production of plastic surgery research.

Previous research examined publications in 6 plastic surgery outlets between 2005 and 2009 [7]. More recently, a study analyzed manuscripts published in the Plastic and Reconstructive Surgery (PRS) journal from 2010 to 2019 to

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Table 1 Research articles in plastic surgery by outlet

Journal	2015	2016	2017	2018	2019	2020	2021	Total	IF
Annals of Plastic Surgery (AnPS)	353	387	349	397	380	335	412	2613	1.4
Aesthetic Plastic Surgery (APS)	153	131	234	251	262	484	659	2174	2.3
Aesthetic Surgery Journal (ASJ)	229	263	277	261	335	293	462	2120	4.3
Dermatologic Surgery (DS)	343	318	356	349	343	420	652	2781	2.9
Facial Plastic Surgery and Aesthetic Medicine (FPSAM)	99	105	116	119	121	101	147	808	3.2
Journal Cosmetic Dermatology (JCD)	51	82	95	218	285	796	751	2278	2.2
Journal of Craniofacial Surgery (JCS)	998	859	844	707	824	779	1058	6069	1.0
Journal of Plastic Reconstructive and Aesthetic Surgery (JPRAS)	412	357	314	360	427	577	635	3082	3.0
Plastic and Reconstructive Surgery (PRS)	792	882	821	918	940	846	1027	6226	4.7
Plastic Reconstructive Surgery - Global Open (PRSGO)	314	447	398	388	521	720	650	3438	1.6

This table reports the number of publications retrieved from each outlet in plastic surgery between 2015 and 2021. Each journal's impact factor was obtained from their respective publisher. Prior to January 1st of 2020, Facial Plastic Surgery and Aesthetic Medicine was called JAMA-Facial Plastic Surgery (JAMA-FPS)

uncover trends in each nation's representation in plastic surgery research [8]. However, having only one journal as the basis for studying national contributions in plastic surgery can bias the results, as there are other outlets with significant readership in the field.

Our study goes beyond previous research in three important ways. First, we include in our analysis manuscripts from the 10 most highly cited journals of the field based on the Google Scholar classification for the "Plastic and Reconstructive Surgery" category [7, 9]. Our approach achieves higher inclusivity as well as a more precise estimation of each nation's representation in the knowledge production in plastic surgery.

Second, we examine the aggregate and over-time research contribution of each country from 2015 to 2021, a more recent time frame than previously examined [8]. Our timespan allows us to document changes in research productivity related to the timing of the COVID-19 pandemic.

Third, we identify every first author from each country to estimate its human capital in plastic surgery research. First authors are likely to be researchers of sufficient expertise to publish again in the future. Thus, a country's human capital reflects its capacity to produce new knowledge in plastic surgery [10]. This study is the first one to present each nation's research productivity in relation to its human capital. Lastly, we discuss global trends in research productivity and human capital in plastic surgery to identify current and future leaders in the field.

Methods

We used a web scraping algorithm to obtain title, author, affiliation, and country information from PubMed for every manuscript published in 10 major plastic surgery outlets, shown in Table 1 [11]. Each publication was assigned to a country based on the first author's designated institutional affiliation. In cases of a first author with many affiliations, only the first affiliation was used. In cases where the first author's affiliated country was not immediately discernible, the original publication was reviewed to retrieve the country of affiliation. In the remaining cases where the primary author's affiliation was not automatically identified, a manual PubMed search for the author was performed and the most recent country of affiliation was used. When the primary author's country of affiliation was not immediately available and the affiliation was not possible to retrieve from the original manuscript or the PubMed search, then the publication was excluded. In cases of co-first authorship, the first listed author's country was used. The result of any manual investigation of author affiliation was corroborated by two investigators (GK and SG) and any conflict was resolved by consensus.

Financial context and country size are crucial for research productivity as they impact re- sources available for new knowledge production. The classification for each country's economic development from the World Bank was used [12]. We stratify countries based on their economic prosperity and compare research productivity and human capital across this financial classification. Population data were also retrieved from the World Bank for the 20 most productive countries [13].

Results

Reviewed published research included a total of 32.851 Publications from the 10 most highly cited journals in the field from 2015 to 2021. Figure 1 provides a flowchart of the articles included in the analysis. Overall, we were able

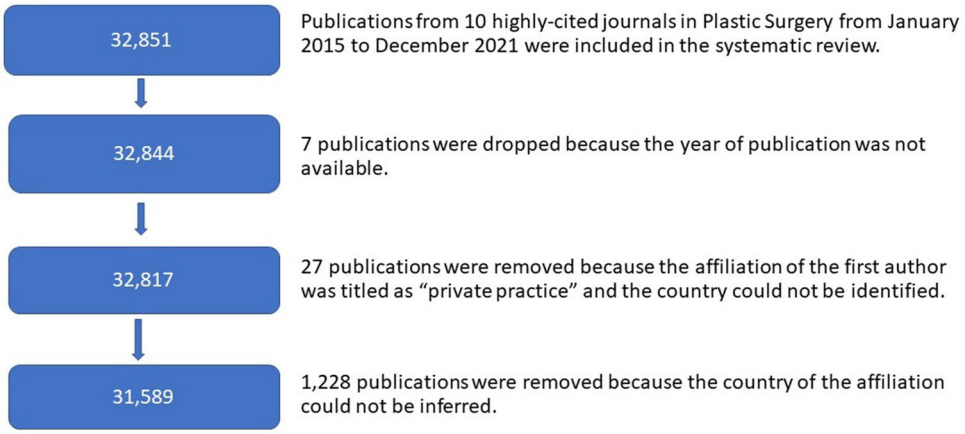

Fig. 1 Flowchart of articles included in the study

to identify the affiliated country of the first author for 96.65% of the extracted publications.

Worldwide

Table 1 presents the number of extracted articles from each journal by year. Two outlets, PRS and JCS, account for 38.92% of the total research productivity over the studied period.

The number of published research has been rising between 2015 and 2021. The increase in publications has been exponential since 2020 onward. Manuscripts published in 2020 or later represent more than one third (37.4%) of the total number of publications in the sample. The year with the higher research productivity was 2021. The number of publications in 2021 was 72% higher than that in 2015 and accounts for more than 20% of the research productivity over the seven-year period under study.

The number of countries producing research in plastic surgery grows from 67 in 2015 to 82 in 2021. Figure 2 plots a map of publications by country. The unwavering leader in the number of publications across the world every year and overall is the USA. US publications represent steadily between 39 and 42% of global publication production every year. Figure 3 plots the US contribution in research production relative to the rest of the world over time. Other substantial contributors to global research production include China (9.12% of total publications), South Korea (5.61%), Turkey (5.14%), and the UK (4.79%).

Table 2 shows the top 20 countries with the highest research contribution. We benchmark the research production of each country to their respective population. We find that among the top 20 countries, the USA has the highest number of publications per 100K of populations (3.86). In contrast, China, the second greatest producer of plastic surgery research, has only 0.21 publications per 100K of population.

It is crucial to represent each country's research production in plastic surgery in the context of each capacity to do so. Human capital is the major driver of new knowledge production. We proxy each country's human capital in plastic surgery by the number of first authors identified between 2015 and 2021. We identified 17,947 first authors across the world. US first authors represent 34.8% of first authors. Other leading countries include China (1883 authors), Turkey (1021), UK (999), and South Korea (980). Figure 4 plots a map of first authors by country. Detailed counts of publications and first authors per country are reported in Table 3.

We find that on average each author produces 1.8 publications. The ratio of publications per author ranges between 1.0 and 4.0. We report each country's number of publications per author in Table 3. We compare the share of publications and the share of first authors by country in Figure 5. Our results show that the USA produces a higher percentage of global knowledge in plastic surgery than its share of first authors. At the same time, top 10 countries such as China, Turkey, the UK, Brazil, and Germany produce a lower share of publications compared to their human capital. This suggests substantial potential for increased future knowledge production in these countries.

North America

Countries in North America account for 13,676 (43.3%) publications and 6739 (37.5%) first authors over the studied period. Between 2015 and 2021, the countries producing publications increased from 4 to 7 out of 11 countries in the region having ever produced publications. The USA dominates the world in the research output (12,798 or 40.5%) and first authors (6238 or 34.8%) across the world. After the USA, Canada, and Mexico are the most research-productive countries. Every author in North America produces 2.0 publications over the studied period on average (ranging between 1.0 and 4.0).

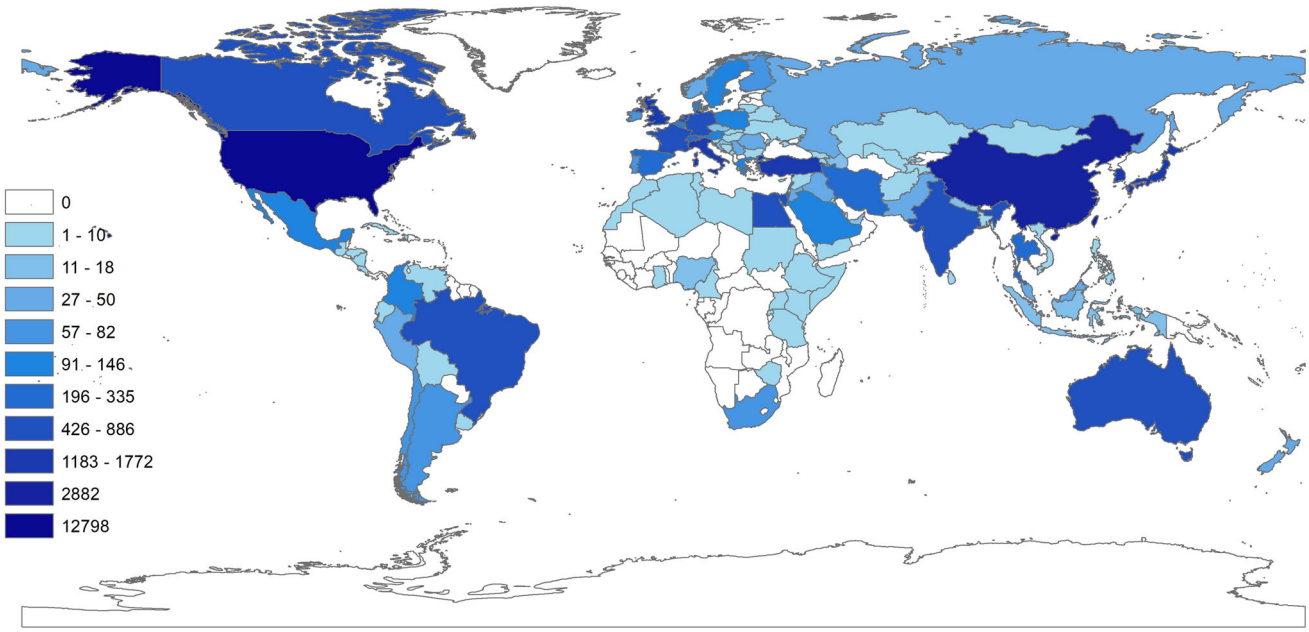

Fig. 2 Research productivity in plastic surgery across countries. *Notes*: This map plots the number of publications by country, a measure of knowledge produced in plastic surgery between 2015 and 2021. Each value level is represented by a different shade

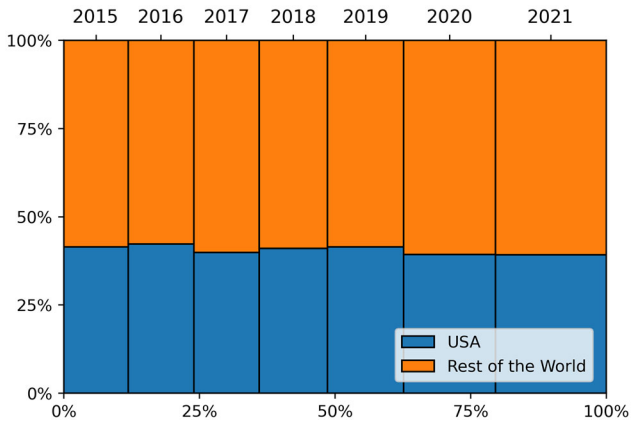

Fig. 3 US share of research productivity over time. *Notes*: This mosaic plot shows the US contribution in research production relative to the rest of the world from 2015 to 2021

USA

Due to the great volume of published research, we conducted a dive-in analysis of the US articles identified. Our dive-in analysis follows and builds on previous studies of US state-specific contributions to plastic surgery research [7, 14, 15].[1] We find substantial differences in the output and human capital between States. Figures 6 and 7 show the variation in research output and human capital, respectively, across States. California-CA (1813), New York-NY (1436), Texas-TX (1336), Massachusetts-MA (861) and Pennsylvania-PA (791) are the most productive states. No single State produces more than roughly 14% of the national publications. The States with the greatest numbers of first authors follow a similar ranking. The top five States represent 48.7% of US research output and 46.8% of human capital in plastic surgery. Table 4 shows a detailed ranking of all States contributing to research. The average author in the USA produces 2.1 articles, with a range between 1.0 and 4.5. We compare each State's share of national output to its human capital in plastic surgery research in Figure 8. Texas has a research output share noticeably higher than its share of first authors in the nation.

Europe

Countries in Europe produce 6069 (19.2%) publications and 3805 (21.2%) first authors over the studied period. Between 2015 and 2021, the countries producing publications increased from 26 to 29 out of 36 countries in the region having ever produced publications. The UK has the highest number of publications (24.9%) and first authors (26.3%) in the region. After the UK, Italy, Germany, France, and the Netherlands follow. The average author in Europe publishes 1.6 papers with a range between 1.0 and 3.5.

[1] Unlike other countries in the top 5 of research productivity in the plastic surgery, the US represents a federation of states, with varying institutional settings contributing to research productivity in plastic surgery [16]. Thus, the US constitutes a compelling case for a state-specific analysis.

Table 2 Country ranking by research productivity in plastic surgery

Country	Total	Percentage	Cumulative	Rank	Per 100K population
USA	12,798	40.51	40.51	1	3.86
China	2882	9.12	49.64	2	0.21
South Korea	1772	5.61	55.25	3	3.42
Turkey	1625	5.14	60.39	4	1.91
UK	1512	4.79	65.18	5	2.25
Italy	1371	4.34	69.52	6	2.32
Japan	1183	3.74	73.26	7	0.94
Brazil	886	2.8	76.07	8	0.41
Canada	745	2.36	78.43	9	1.95
Germany	524	1.66	80.08	10	0.63
France	518	1.64	81.72	11	0.77
Taiwan	494	1.56	83.29	12	2.07
Netherlands	447	1.42	84.7	13	2.55
India	446	1.41	86.12	14	0.03
Egypt	439	1.39	87.51	15	0.42
Australia	426	1.35	88.85	16	1.66
Spain	335	1.06	89.91	17	0.71
Iran	276	0.87	90.79	18	0.32
Switzerland	226	0.72	91.5	19	2.60
Thailand	198	0.63	92.13	20	0.28

This table shows 20 countries with the highest contribution to plastic surgery research between 2015 and 2021

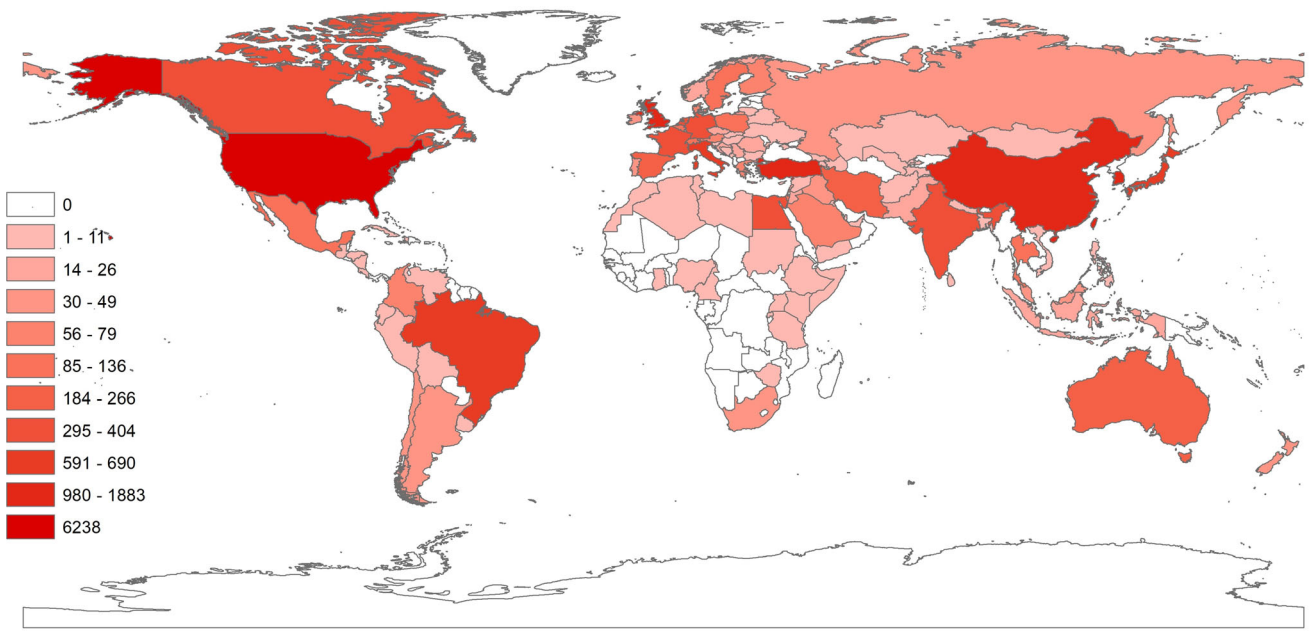

Fig. 4 Human capital in plastic surgery research across countries. *Notes*: This map plots the number of first authors by country between 2015 and 2021 to gauge its capacity to produce new knowledge in plastic surgery. Each value level is represented by a different shade

Asia

Countries in Asia represent 30.7% of global research production and 33.2% of first authors. Asian countries' production of research increased 66.6% between 2015 and 2021. China is the most research-productive country (29.8%) and holds the highest number of first authors (31.5%). After China, South Korea, Turkey, Japan, and

Table 3 Research productivity in plastic surgery by country

	2015	2016	2017	2018	2019	2020	2021	Total	Average (SD)	First Authors	Papers/Author	Country Income
Africa	25	34	54	74	81	113	171	552	4.64 (17.81)	379	1.5	
Algeria	0	0	2	1	0	0	0	3		1	3.0	LMI
Cameroon	0	0	0	0	0	0	1	1		1	1.0	LMI
Egypt	17	23	34	60	67	98	140	439		310	1.4	LMI
Ethiopia	0	0	0	0	1	1	1	3		3	1.0	LI
Ghana	1	0	0	1	0	0	1	3		3	1.0	LMI
Kenya	0	0	1	1	2	0	0	4		4	1.0	LMI
Libya	0	0	1	2	1	1	1	6		2	3.0	UMI
Morocco	1	0	2	0	0	1	3	7		4	1.8	LMI
Nigeria	1	5	2	2	0	0	5	15		11	1.4	LMI
Rwanda	1	0	0	0	0	0	0	1		1	1.0	LI
Somalia	0	0	0	0	0	0	1	1		1	1.0	LI
South Africa	2	4	11	6	7	11	16	57		30	1.9	UMI
Sudan	1	0	0	0	1	0	1	3		1	3.0	LI
Tanzania	0	0	1	0	0	0	0	1		1	1.0	LMI
Tunisia	1	0	0	1	2	1	1	6		4	1.5	LMI
Uganda	0	1	0	0	0	0	0	1		1	1.0	LI
Zimbabwe	0	1	0	0	0	0	0	1		1	1.0	LMI
Asia	1223	1150	1138	1122	1324	1692	2038	9687	40.70 (94.36)	5973	1.6	
Afghanistan	1	0	0	0	0	0	0	1		1	1.0	LI
Bahrain	0	0	0	0	0	0	1	1		1	1.0	HI
Bangladesh	0	0	0	0	2	0	0	2		2	1.0	LMI
China	320	264	296	341	394	538	729	2882		1883	1.5	UMI
India	38	39	43	42	67	100	117	446		307	1.5	LMI
Indonesia	1	0	0	3	4	4	4	16		14	1.1	LMI
Iran	27	31	21	39	44	53	61	276		184	1.5	LMI
Iraq	5	4	5	8	4	6	8	40		32	1.3	UMI
Israel	18	22	12	26	35	37	46	196		136	1.4	HI
Japan	158	158	168	132	174	195	198	1183		616	1.9	HI
Jordan	2	2	3	2	4	7	8	28		19	1.5	UMI
Kazakhstan	0	0	0	0	0	1	1	2		2	1.0	UMI
Kuwait	0	0	1	1	2	0	3	7		7	1.0	HI
Lebanon	4	4	11	12	9	9	50	99		38	2.6	LMI
Malaysia	4	4	4	2	7	8	8	37		33	1.1	UMI
Mongolia	0	0	0	0	0	2	0	2		1	2.0	LMI
Nepal	0	0	0	2	2	3	4	11		7	1.6	LMI
Pakistan	1	3	2	8	12	16	8	50		21	2.4	LMI
Philippines	2	0	1	0	0	1	2	6		6	1.0	LMI
Qatar	0	0	0	0	3	2	5	10		6	1.7	HI
Russia	2	5	0	2	8	7	18	42		35	1.2	UMI
Saudi Arabia	5	12	11	12	23	20	36	119		79	1.5	HI
Singapore	12	21	11	14	20	16	20	114		86	1.3	HI
South Korea	294	254	254	212	216	275	267	1772		980	1.8	HI
Sri Lanka	0	0	0	1	0	1	0	2		2	1.0	LMI
Syria	0	0	0	0	1	0	0	1		1	1.0	LI
Taiwan	48	70	70	65	74	79	88	494		327	1.5	HI
Tajikistan	0	0	0	1	0	0	0	1		1	1.0	LMI
Thailand	16	15	13	27	28	51	48	198		104	1.9	UMI

Table 3 continued

	2015	2016	2017	2018	2019	2020	2021	Total	Average (SD)	First Authors	Papers/ Author	Country Income
Turkey	264	240	212	167	188	257	297	1625		1021	1.6	UMI
UAE	1	0	0	3	3	3	3	13		11	1.2	HI
Uzbekistan	0	0	0	0	0	0	1	1		1	1.0	LMI
Vietnam	0	1	0	0	0	1	7	9		8	1.1	LMI
Yemen	0	1	0	0	0	0	0	1		1	1.0	LI
Europe	684	732	792	787	824	1027	1223	6069	24.08 (50.60)	3805	1.6	
Armenia	0	0	0	1	0	0	1	2		2	1.0	UMI
Austria	14	14	16	14	11	10	12	91		72	1.3	HI
Azerbaijan	1	0	0	0	5	3	5	14		6	2.3	UMI
Belarus	0	0	0	0	1	2	0	3		1	3.0	UMI
Belgium	18	21	9	15	10	25	41	139		102	1.4	HI
Bosnia and Herzegovina	1	0	4	0	1	1	0	7		2	3.5	UMI
Bulgaria	0	1	2	0	3	1	1	8		4	2.0	UMI
Croatia	2	1	2	2	4	4	3	18		15	1.2	HI
Cyprus	0	0	1	2	2	2	2	9		9	1.0	HI
Czech Republic	2	0	3	1	4	1	6	17		14	1.2	HI
Denmark	10	12	15	9	13	17	20	96		63	1.5	HI
Finland	8	7	10	13	12	15	17	82		56	1.5	HI
France	64	79	89	71	51	78	86	518		339	1.5	HI
Georgia	1	0	0	0	1	0	1	3		3	1.0	UMI
Germany	49	69	55	75	76	97	103	524		348	1.5	HI
Greece	8	14	16	17	9	18	16	98		64	1.5	HI
Hungary	1	1	3	0	0	1	1	7		7	1.0	HI
Ireland	19	9	15	7	10	9	7	76		49	1.6	HI
Italy	168	161	181	168	188	246	259	1371		690	2.0	HI
Lithuania	0	0	1	2	0	1	0	4		3	1.3	HI
Luxembourg	0	0	0	0	1	0	0	1		1	1.0	HI
Montenegro	0	1	0	0	0	0	0	1		1	1.0	UMI
Netherlands	47	60	61	71	62	65	81	447		295	1.5	HI
North Cyprus	0	0	1	0	0	0	0	1		1	1.0	UMI
Norway	1	6	9	10	9	5	7	47		26	1.8	HI
Poland	7	8	8	19	27	29	28	126		85	1.5	HI
Portugal	4	10	13	5	7	13	14	66		43	1.5	HI
Romania	1	4	1	3	3	8	7	27		15	1.8	HI
Serbia	4	3	3	4	4	3	10	31		18	1.7	UMI
Slovakia	0	0	1	0	0	0	3	4		3	1.3	HI
Slovenia	0	0	0	0	1	0	3	4		3	1.3	HI
Spain	33	32	55	42	49	48	76	335		240	1.4	HI
Sweden	15	18	28	19	20	22	24	146		87	1.7	HI
Switzerland	24	37	36	28	40	26	35	226		133	1.7	HI
UK	181	162	153	188	199	275	354	1512		999	1.5	HI
Ukraine	1	2	1	1	1	2	0	8		6	1.3	LMI
North America	1632	1708	1628	1749	1982	2249	2728	13,676	177.61 (536.56)	6739	2.0	
Canada	69	77	92	102	118	116	171	745		404	1.8	HI
Costa Rica	0	0	0	0	1	0	0	1		1	1.0	UMI
Cuba	0	0	0	0	0	0	1	1		1	1.0	UMI
Dominica	1	0	3	0	0	0	0	4		1	4.0	UMI

Table 3 continued

	2015	2016	2017	2018	2019	2020	2021	Total	Average (SD)	First Authors	Papers/ Author	Country Income
Grenada	0	0	0	0	0	2	1	3		2	1.5	UMI
Guatemala	0	0	0	0	0	0	1	1		1	1.0	UMI
Haiti	0	0	0	0	0	0	1	1		1	1.0	LMI
Honduras	0	0	1	0	0	0	0	1		1	1.0	LMI
Mexico	9	10	13	15	22	27	23	119		87	1.4	UMI
Nicaragua	0	0	0	2	0	0	0	2		2	1.0	LMI
USA	1553	1621	1519	1630	1841	2104	2530	12,798		6238	2.1	HI
Oceania	59	59	56	62	81	75	78	470	22.38 (28.45)	305	1.5	
Australia	55	55	51	55	75	67	68	426		266	1.6	HI
Kiribati	0	0	0	0	0	1	0	1		1	1.0	LMI
New Zealand	4	4	5	7	6	7	10	43		38	1.1	HI
South America	121	148	136	174	146	195	215	1135	18.02 (39.71)	746	1.5	
Argentina	4	5	10	14	7	9	9	58		33	1.8	UMI
Bolivia	0	1	0	0	0	0	0	1		1	1.0	LMI
Brazil	95	119	111	129	118	155	159	886		591	1.5	UMI
Chile	4	9	5	16	5	10	18	67		40	1.7	HI
Colombia	12	9	7	13	13	16	21	91		67	1.4	UMI
Ecuador	0	1	0	0	0	0	1	2		2	1.0	UMI
Peru	5	4	3	1	2	5	7	27		9	3.0	UMI
Uruguay	1	0	0	0	0	0	0	1		1	1.0	HI
Venezuela	0	0	0	1	1	0	0	2		2	1.0	UMI
Grand total	3744	3831	3804	3968	4438	5351	6453	31,589	41.02 (185.60)	17,947	1.8	

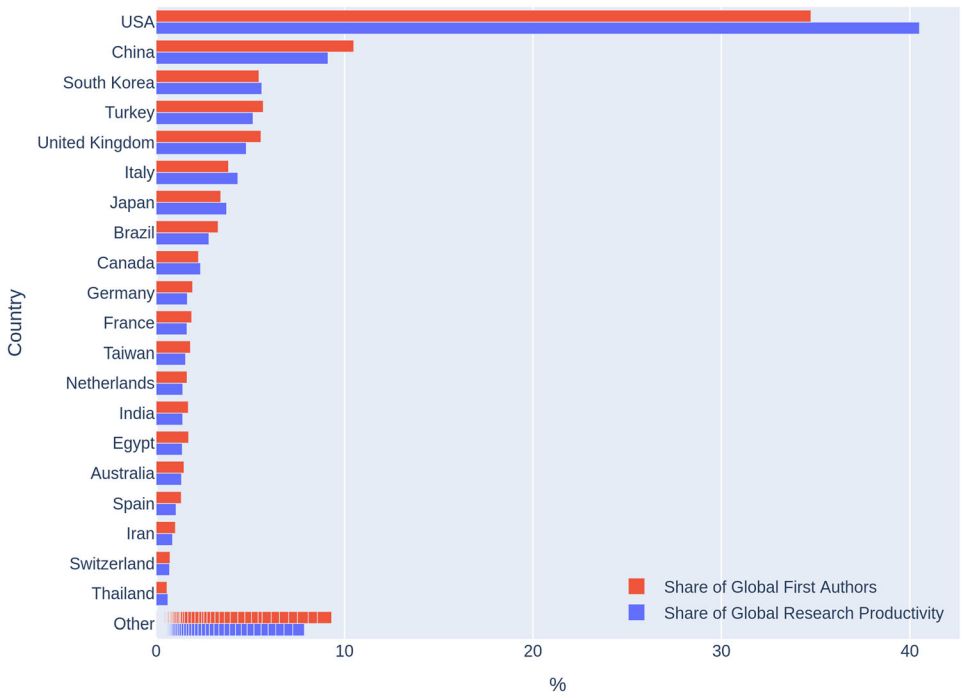

Fig. 5 Comparison of human capital and productivity in plastic surgery research across countries. *Notes*: This figure plots the share of global research output and global research-producing human capital for each of the top 20 most research-productive countries

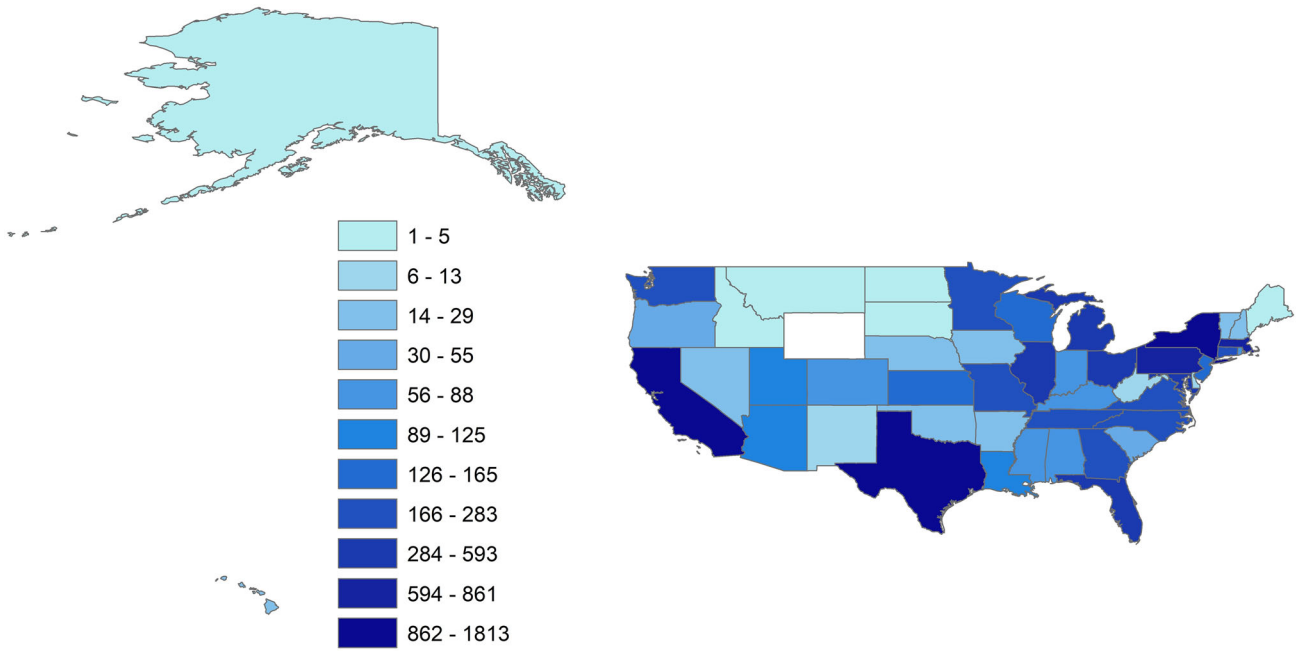

Fig. 6 Research productivity in plastic surgery across US States. *Notes*: This map plots the number of publications by State, a measure of knowledge produced in plastic surgery between 2015 and 2021. Each value level is represented by a different shade

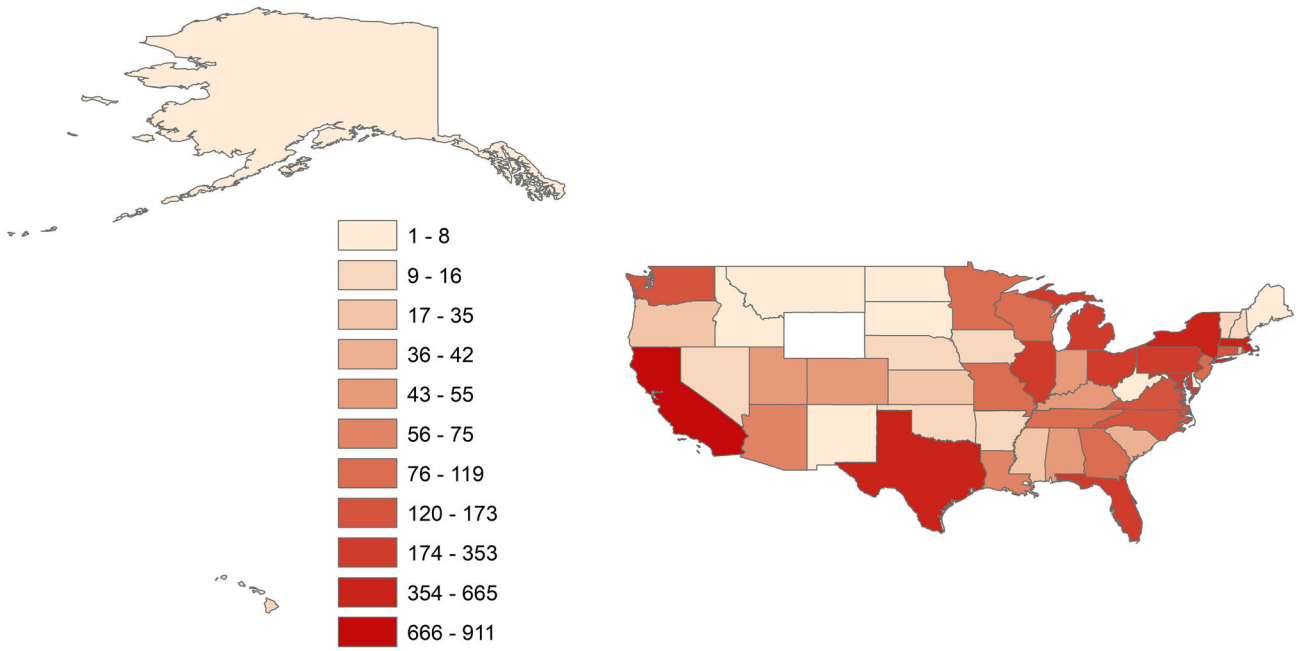

Fig. 7 Human capital in plastic surgery research across US States. *Notes*: This map plots the number of first authors by State between 2015 and 2021 to gauge its capacity to produce new knowledge in plastic surgery. Each value level is represented by a different shade

Taiwan follow. China is the country with the greatest increase in annual manuscript production from 2015 to 2021. The number of Asian countries contributing to research production increased from 21 in 2015 to 27 in 2021 out of 34 countries having ever produced any publication in the studied period. The average first author in Asia produces 1.6 publications, with a range between 1.0 and 2.6.

Table 4 Research productivity in plastic surgery by US State

State/Territory	2015	2016	2017	2018	2019	2020	2021	Total	Rank	First Authors	Papers/Author
CA	237	258	240	237	258	275	308	1813	1	911	2.0
NY	185	166	197	180	220	233	255	1436	2	665	2.2
TX	126	156	136	174	198	220	326	1336	3	564	2.4
MA	110	123	85	114	136	139	154	861	4	424	2.0
PA	94	102	88	98	97	149	163	791	5	353	2.2
IL	83	74	68	78	82	93	115	593	6	267	2.2
FL	83	81	70	67	70	91	117	579	7	311	1.9
OH	62	60	71	72	84	106	125	579	8	277	2.1
MI	80	74	58	41	63	72	79	467	9	223	2.1
MD	49	55	48	59	75	63	79	428	10	219	2.0
NC	43	41	24	31	41	45	58	283	11	173	1.6
WA	30	31	22	42	43	50	62	280	12	136	2.1
CT	32	27	24	38	47	39	68	275	13	130	2.1
DC	33	27	28	26	26	56	49	245	14	99	2.5
MN	25	23	19	24	52	54	48	245	15	116	2.1
GA	18	31	40	38	24	35	57	243	16	119	2.0
VA	18	31	32	39	39	42	38	240	17	133	1.8
TN	23	18	22	36	38	42	56	235	18	94	2.5
MO	18	26	37	37	34	34	32	218	19	109	2.0
NJ	11	17	20	28	19	37	33	165	20	96	1.7
WI	27	28	20	23	16	28	23	165	21	91	1.8
KS	36	30	16	11	21	19	26	159	22	35	4.5
AZ	15	18	13	11	11	20	37	125	23	75	1.7
LA	12	13	17	18	16	14	19	109	24	63	1.7
UT	12	4	15	12	17	18	21	99	25	54	1.8
IN	16	7	10	14	11	13	17	88	26	55	1.6
AL	10	16	14	8	6	12	20	86	27	52	1.7
KY	7	13	10	15	15	10	16	86	28	49	1.8
CO	9	11	19	4	11	12	14	80	29	51	1.6
MS	8	16	14	7	7	11	11	74	30	33	2.2
RI	2	6	12	6	10	14	19	69	31	38	1.8
SC	8	2	6	8	10	8	13	55	32	42	1.3
OR	3	6	6	5	10	9	10	49	33	31	1.6
AR	2	3	2	1	3	7	11	29	34	16	1.8
IA	2	5	1	3	3	4	6	24	35	14	1.7
VT	1	4	1	4	5	3	6	24	36	15	1.6
NH	7	0	2	2	2	5	4	22	37	13	1.7
NV	6	3	2	1	1	6	3	22	38	13	1.7
OK	0	3	3	7	2	4	3	22	39	15	1.5
NE	3	3	1	1	4	1	8	21	40	16	1.3
HI	0	2	4	2	2	2	6	18	41	12	1.5
PR	3	2	0	2	4	1	2	14	42	8	1.8
NM	0	1	0	1	2	3	6	13	43	8	1.6
WV	2	3	1	2	0	0	0	8	44	3	2.7
DE	0	1	0	0	3	0	3	7	45	3	2.3
ME	1	0	0	0	2	1	1	5	46	3	1.7
SD	0	0	1	2	0	0	1	4	47	3	1.3
MT	0	0	0	1	1	1	0	3	48	2	1.5

Table 4 continued

State/Territory	2015	2016	2017	2018	2019	2020	2021	Total	Rank	First Authors	Papers/Author
ID	0	0	0	0	0	0	2	2	49	2	1.0
ND	0	0	0	0	0	2	0	2	50	2	1.0
AK	1	0	0	0	0	0	0	1	51	1	1.0
GU	0	0	0	0	0	1	0	1	52	1	1.0
Grant total	1553	1621	1519	1630	1841	2104	2530	12,798		6238	2.1

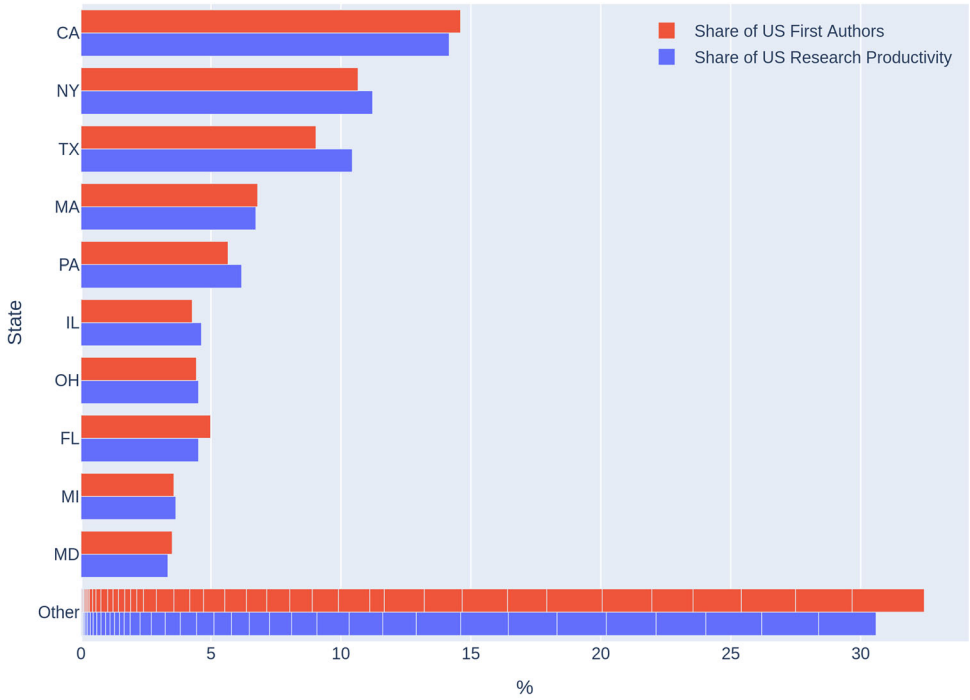

Fig. 8 Comparison of human capital and productivity in plastic surgery research across US States. *Notes*: This figure shows the share of national research output and national research-producing human capital for each of the top 10 most research-productive states.

South America

South American countries have 1135 (3.6%) publications and 746 (4.2%) first authors. Over the examined period, the number of South American countries contributing to research did not change between 2015 and 2021 (6 out of 9 ever having produced plastic surgery publications). Brazil dominates in the region in the number of publications (78.1%) and first authors (79.2%). The average author in South America publishes 1.5 papers with a range between 1.0 and 3.0.

Africa

African countries have only 1.7% of publications and 2.1% first authors globally. Between 2015 and 2021, the number of countries in Africa producing plastic surgery research increased from 8 to 11, out of 17 countries ever having produced plastic surgery publications. Egypt is the leader in plastic surgery research in the region in terms of both publications (79.5%) and first authors (81.8%). First authors in Africa publish 1.5 papers, on average, with a range between 1.0 and 3.0.

Oceania

Countries in Oceania represent 1.5% of output and 1.7% of human capital globally. Australia is the regional leader, producing 90.7% of the publications and having 87.2% of the first authors. The average first author produces 1.5 manuscripts, with a range between 1.0 and 1.6.

World Bank Income Classification

We report research output and human capital by country income in Table 5. We find that high-income (HI) countries represent 75.9% of research production and 72.4% of first authors globally. The remainder of output and human capital originates from lower-middle income (LMI) and upper-middle income (UMI) countries. The research

Table 5 Research productivity in plastic surgery by country income

Country Income	2015	2016	2017	2018	2019	2020	2021	Total	First Authors	Papers /Authors
High income (HI)	2898	3028	2980	3056	3403	3946	4669	23,980	12,997	1.8
Upper middle income (UMI)	748	691	702	735	820	1111	1375	6182	3996	1.5
Lower middle income (LMI)	95	110	122	177	212	293	406	1415	944	1.5
Low income (LI)	3	2	0	0	3	1	3	12	10	1.2

This table shows the research output and research-producing output by country income. Income classification comes from the World Bank [12].

production and human capital in plastic surgery in low-income (LI) countries is negligible. Authors in HI countries produce 20% (i.e., 1.8 compared with 1.5) and 41.7% (i.e., 1.8 compared with 1.2) more publications than authors in MI and LI countries, respectively.

Discussion and Conclusion

Our findings show that the USA is the global leader in research production, confirming previous studies [7, 14, 15]. Other top research-producing countries include China, South Korea, Turkey and the UK. Our ranking differs from those in previous studies [7, 14, 15]. Notably, our study of 110 countries captures the research contribution of countries excluded from previous investigations (e.g., Russia) [8, 14, 15, 17]. These differences can be attributed to the outlets included in each study. Our study is the most inclusive and thorough to this day. We included the 10 most highly cited journals in the field of plastic and reconstructive surgery. The net we cast represents a broad spectrum of plastic surgery research. Our outlet spectrum ranges from ASJ, which focuses on aesthetic surgery, PRS, which represents more areas of plastic surgery research (e.g., hand surgery, reconstruction, cosmetic, pediatrics, basic science research), to JCS, which covers craniofacial surgery [14]. Thus, our results can be seen as more inclusive of the breadth of research interests in plastic surgery and more accurate in the representation of each country's contribution to the field, mitigating any selection bias present in previous studies.

We find a substantial increase in plastic surgery research output globally over time. The increase is not equally distributed across nations. A limited number of countries drive the expansion in research production and emerge as leaders. Research output in China, for example, more than doubled between 2015 and 2021.

Our study confirms that North America and Asia are the two prevailing regions in plastic surgery research. Previous studies debated whether Europe or Asia were more productive in terms of publications [7, 8, 14, 15, 17]. Our analysis provides a verdict. We have concluded that Asia outperforms Europe in research output by 59.6% (i.e., 9687 compared with 6069). Asia has 57.0% more first authors than Europe (i.e., 5973 compared with 3805). Our findings corroborate previous research documenting Asia's aspiration to be included in the international plastic surgery research elite [7, 18]. The flourishing plastic surgery research in Asia may be partially attributed to the change in people's attitude toward aesthetic and reconstructive surgery [19, 20].

Our study is the first one to conduct a US state-specific analysis using multiple highly cited journals in the field of plastic surgery. The breadth of our investigation allows us to depict more accurately the current state of research production and draw safer conclusions. In contrast to Liechty et al, we find that California is the greatest contributor in plastic surgery research with 1813 articles in total, while Texas holds the third place with 1336 articles [8]. We corroborate the finding of Liechty et al. that New York and Texas belong in the top three of the most research-productive states. It is important to note that the top 5 research-producing States are homes to the preponderance of academic plastic surgery programs in the nation. Our study includes 9 States not previously represented in Liechty et al. [8]. The small number of publications from these States may reflect the absence of scientific support from major academic plastic surgery programs. When comparing the concentration of publications across countries and the concentration of US publications across states we find that no specific State stands out in the nation as much as the USA does in the global ranking of plastic surgery research production. This suggest the existence of nationwide system of research support or appetite for publications among plastic surgeons in the USA.

Our study brings forth two contextual benchmarks of research production, the population and the total number of first authors from each country. First, the number of publications per 100K of population allows us to adjust our measure of research productivity to differences in country size [7]. Our results are consistent with those of Zhang et al., who find that the USA is the leader of global research with 3.86 publications per 100K people. However, China which is the second most productive country in absolute

number of publications produces only 0.21 publications per 100K people. Our extended number of outlets in our analysis allows us to adjust for differences between countries in plastic surgery outlets they publish and provide an updated and more accurate metric of research productivity per unit of population.

Second, we propose a new index, the ratio of publications of each country and the number of first authors affiliated with that country. This ratio represents average author research productivity. The magnitude of the ratio may be determined by the research training of the authors, the resources and funding available to researchers, the incentives provided to published researchers, and access to research-generating networks of plastic surgeons.

Countries with a high average author productivity (e.g., the USA with a ratio of 2.1) may have greater amounts of the aforementioned determining factors. At the same time, countries with low average author productivity and substantial number of authors (e.g., China and South Korea with ratios of 1.5 and 1.8, respectively) have not unveiled the magnitude of their research potential yet. However, they may increase their research output exponentially in the future if more system-wide support and incentives are provided to researchers.

This study has certain limitations. First, our bibliometric analysis does not distinguish be- tween the different types of publications (i.e., clinical trials, systematic reviews, perspectives, etc.) produced in each country. Different types of publications in plastic surgery may represent different levels of evidence with varying levels of contribution to scientific knowledge and the evidence base for health care [21–23]. Second, changes in author names or author migration over time may contribute to some double counting of authors. Third, to the extent that manual investigation was required to infer author affiliation, there is the possibility of limited human error.

Future research could explore different types of publications (i.e., double-blind randomized control trials, multicenter analysis, retrospective cohort studies, survey research, meta-analysis, etc.) by country as well as a more exhausting list of research outlets, some of which potentially accepting manuscripts in languages other than English. Further investigation of human capital and productivity by research center or institution could provide insights into the institutional drivers of geographical variations in research productivity. Future research could also investigate the contribution of plastic surgeons–scientists in journals that have a more diverse scientific scope, appeal to a broader audience, and fall out of the strict categorization of the field of plastic surgery journals. Further research can also cast a wider net of articles by including regional outlets. Future endeavors could investigate whether regional journals capture the contributions of smaller countries in knowledge production. Future research can also provide an in-depth investigation of regional variation in the human capital and research productivity in plastic surgery in countries beyond the USA.

Our study contributes to a broader understanding of the level of concentration of research activity and personnel in plastic surgery across the world. The human capital component in particular, investigated here for the very first time, provides insights into future nuclei of plastic surgery innovation. Our artificial intelligence technology (i.e., web scraping) can be applied in more contexts of research in medicine to obtain rich and accurate large-scale information from established repositories.

Declarations

Conflict of interest The authors declare that they have no conflicts of interest to disclose.

Human and Animal Rights This article does not contain any studies with human participants or animals performed by any of the authors.

Informed Consent For this type of study, informed consent is not required.

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