Trans R Soc Trop Med Hyg 2023; **117**: 645–654
https://doi.org/10.1093/trstmh/trad021 Advance Access publication 24 April 2023

ORIGINAL ARTICLE

Highly cited tropical medicine articles in the Web of Science from 1991 to 2020: A bibliometric analysis

Julián Monge-Nájera [a] and Yuh-Shan Ho [b,*]

[a]*Laboratorio de Ecología Urbana, Vicerrectoría de Investigación, Universidad Estatal a Distancia, San José 11502, Costa Rica;* [b]*Trend Research Centre, Asia University, No. 500 Lioufeng Road, Wufeng, Taichung 41354, Taiwan*

*Corresponding author: Tel: +886-4-23323456; E-mail: ysho@asia.edu.tw

Received 28 November 2022; revised 14 March 2023; editorial decision 28 March 2023; accepted 29 March 2023

Background: An adequate response to health needs to include the identification of research patterns about the large number of people living in the tropics and subjected to tropical diseases. Studies have shown that research does not always match the real needs of those populations, and that citation reflects mostly the amount of money behind particular publications. Here we test the hypothesis that research from richer institutions is published in better-indexed journals, and thus has greater citation rates.

Methods: The data in this study were extracted from the Science Citation Index Expanded database; the 2020 journal Impact Factor (IF_{2020}) was updated to 30 June 2021. We considered places, subjects, institutions and journals.

Results: We identified 1041 highly cited articles with ≥100 citations in the category of tropical medicine. About a decade is needed for an article to reach peak citation. Only two COVID-19–related articles were highly cited in the last 3 y. The most cited articles were published by the journals *Memorias Do Instituto Oswaldo Cruz* (Brazil), *Acta Tropica* (Switzerland) and *PLoS Neglected Tropical Diseases* (USA). The USA dominated five of the six publication indicators. International collaboration articles had more citations than single-country articles. The UK, South Africa and Switzerland had high citation rates, as did the London School of Hygiene and Tropical Medicine in the UK, the Centers for Disease Control and Prevention in the USA and the WHO in Switzerland.

Conclusions: About 10 y of accumulated citations is needed to achieve ≥100 citations as highly cited articles in the Web of Science category of tropical medicine. Six publication and citation indicators, including authors' publication potential and characteristics evaluated by *Y*-index, indicate that the currently available indexing system places tropical researchers at a disadvantage against their colleagues in temperate countries, and suggest that, to progress towards better control of tropical diseases, international collaboration should increase, and other tropical countries should follow the example of Brazil, which provides significant financing to its scientific community.

Keywords: bibliometric, citation analysis, tropical medicine, Web of Science Core Collection, *Y*-index

Introduction

The bibliometric study of tropical medicine covers two main approaches: diseases and geographic areas; and often considers subjects, historical trends and citation rates.

Studies about the scientific output of particular diseases currently include malaria, leishmaniasis, giardiasis, dengue, Zika, scrub typhus, mycetoma and orofacial necrosis. These studies have reported a strong increase in the number of documents published each year since the mid-twentieth century. For example, the output on malaria during pregnancy increased nearly 40 times between the 1960s and 2009 and has been dominated by articles, theses and books.[1] Research on leishmaniasis has grown rapidly, led by the USA, Brazil and India;[2] a similar growth has been reported for giardiasis.[3] In all these subjects, the most cited articles are those from well-financed projects published in large American and European journals.[1–3]

The USA or Europe often has the most publications about tropical diseases in this database, but dengue is an exception: countries most affected by dengue are also the leaders in its study, particularly Thailand and India.[4] For the Zika virus, which increased the number of publications by a factor of 50 from 2015 to 2017, most papers are from the USA.[5] Scrub typhus also had an important increase in article output and citations over time, with a mean 11 citations per paper and led by Korea, India, China and Thailand.[6] For mycetoma, the top productive countries include Sudan, India and Mexico; while orofacial necrosis has been neglected and most of the relatively few studies about it originate mainly in the USA, Nigeria and the UK.[7] Again, citation rates recorded by this database are greater for researchers from industrialized countries publishing in their own journals.[5–7]

The bibliometrics of geographic trends include global and continental approaches, but most are limited to specific countries. A general count of tropical medicine publications for the period 1995–2003 found that most articles originated in Western Europe, Africa and Latin America.[8] At the regional level, African public health, in general, had a strong growth in productivity, closely related to increasing collaboration with Europe and the USA.[9] For Latin America and Caribbean diseases, research has focused on dengue and leishmaniasis, and has been led by the USA and Brazil.[10] Citations for articles published in journals from tropical countries are generally less recorded by the Web of Science.[8–10]

Bibliometric studies about the diseases of tropical countries found the same general patterns: low citation rates for articles from the tropical countries themselves; high citation rates for megaprojects financed and published by industrialized countries; and a strong local dependence on research financed and led by temperate countries.[11–14]

Here we test two hypotheses: the first one, that to reach their full citation potential, articles need more than the 2 y currently used to measure impact; and the second one, that authors from powerful institutions and countries, with better access to the fraction of journals covered by the Journal Citation Report, are the ones with more citations in it, rather than researchers from the tropical countries themselves.

Methods

The data in this study were extracted from the Science Citation Index Expanded database of the Web of Science Core Collection, Clarivate Analytics (referred to as the index in the rest of this article). The 2020 journal Impact Factor (IF_{2020}) is from the Journal Citation Report (JCR) on 30 June 2021. According to the definition of journal impact factor, it is best to search documents published in 2020 after IF_{2020} was available. The index only covers 9649 journals, a fraction of the currently published journals. There were 23 journals listed in the Web of Science category of tropical medicine in 2020. A total of 69 480 articles were in the category of tropical medicine from 1991 to 2020 (data updated on 19 January 2022). The citation indicator of TC_{year} was used to characterize the highly cited articles.[15] TC_{year} is the total citation number from the Web of Science Core Collection from the publication year to the end of the most recent year.[16] $TC_{year}\geq 100$ was used to retrieve the highly cited articles.[15] The citation indicators of C_{year} and CPP_{year} were also applied to compare the impact of the highly cited articles. C_{year} is the number of citations in the most recent year.[17] CPP_{year}: average number of citations per publication ($CPP_{year}=TC_{year}/TP$); TP is the total number of publications.[18] Finally, 1041 articles (1.5% of 69 480 articles) were defined as highly cited articles in the category of tropical medicine from 1991 to 2020. The full record of the index and the number of citations in each year for each article were checked and downloaded into Microsoft Excel 365 (Microsoft Corporation, Redmond, Washington), and additional coding was manually performed. The functions in Microsoft Excel 365, for example, Counta, Concatenate, Match, Vlookup, Proper, Rank, Replace, Freeze Panes, Sort, Sum and Len, were applied. The journal impact factors (IF_{2020}) were taken from the JCR published in 2020.

To reduce misrecordings in this index, some data pretreatments are needed. In the database, the corresponding author is designated as the 'reprint' author, and the 'corresponding author' will remain as the primary terminology instead of reprint author.[17] In a single-author article where authorship is unspecified, the single author is considered both the first author and the corresponding author.[15] Similarly, in an individually institutional article, the institution is classified as the first-author institution and the corresponding-author institution.[15] In multi-corresponding author articles, all authors and institutions were counted.

Affiliations in England, Scotland, North Ireland (Northern Ireland) and Wales were reclassified as in the UK.[19] Affiliations in French Guiana and New Caledonia were reclassified as being from France. Affiliations in Senegambia were checked and reclassified as being from Gambia and Senegal, respectively. Similarly, Univ London London Sch Hyg & Trop Med in the UK was reclassified as London Sch Hyg & Trop Med (London School of Hygiene and Tropical Medicine).

The Y-index was used to evaluate the publication performance of authors. The Y-index[15,17] is defined as:

$$Y\text{−index}\,(j, h)\,,$$

where j is a constant related to the publication potential, the sum of the first-author articles and the corresponding-author articles; and h is a constant related to the publication characteristics, polar angle about the proportion of RP to FP. The greater the value of j, the more the first and corresponding author contribute to the articles.

$h=\pi/2$ indicates an author has only published corresponding-author articles ($FP=0$ and $RP=j$);

$\pi/2>h>\pi/4$ indicates that an author has more corresponding-author articles than first-author articles ($FP>0$);

$h=\pi/4$ indicates that an author has the same number of first- and corresponding-author articles;

$\pi/4<h<0$ indicates an author has more first-author articles than corresponding-author articles ($RP>0$);

$h=0$ indicates that an author has only published first-author articles ($RP=0$ and $FP=j$).

To test the hypothesis, based on previous findings,[20] that to reach their full citation potential, articles need more than the 2 y currently used by the Web of Science to measure impact, we extracted citation numbers for a 27-y period, from 1993 to 2020, for the most cited articles.

Six publication indicators were applied to evaluate the publication performances of countries and institutions[21]:

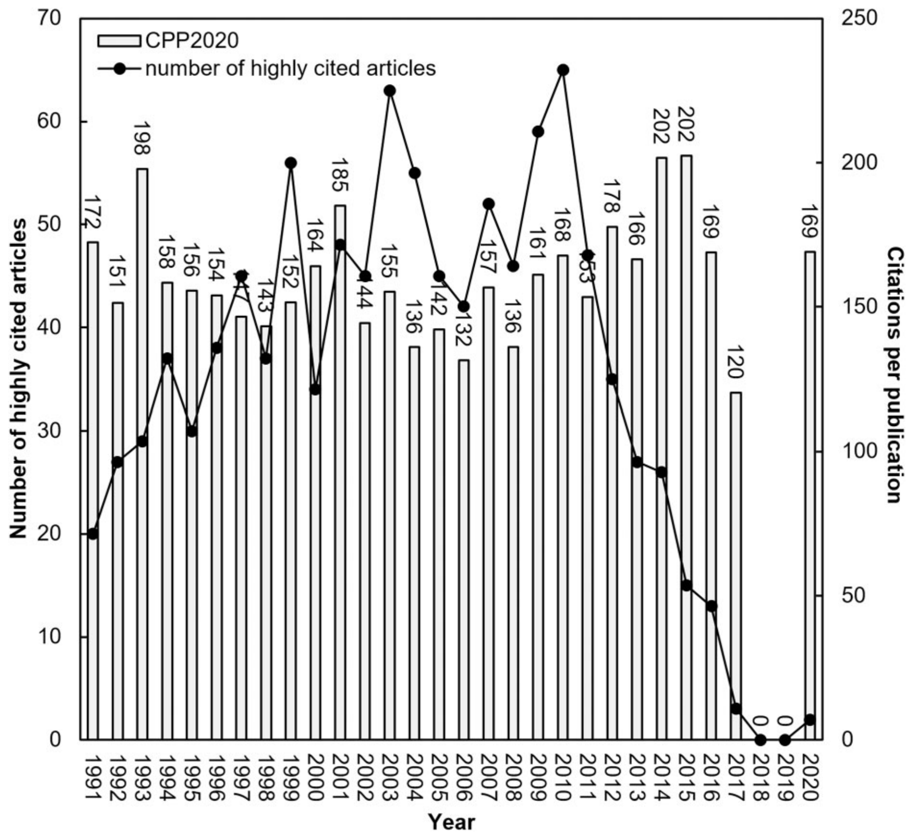

Figure 1. Number of highly cited articles and average number of citations per publication by year.

Table 1. The 16 journals in Web of Science category of tropical medicine with highly cited articles

Journal	*TP* (%)	IF_{2020} (*R*)	APP	CPP_{2020}
American Journal of Tropical Medicine and Hygiene	421 (40)	11 (2.345)	7.3	161
PLoS Neglected Tropical Diseases	152 (15)	2 (4.411)	10	169
Tropical Medicine & International Health	109 (10)	9 (2.622)	6.4	140
Transactions of the Royal Society of Tropical Medicine and Hygiene	105 (10)	12 (2.184)	6.2	130
Acta Tropica	82 (7.9)	4 (3.112)	5.2	183
Malaria Journal	63 (6.1)	5 (2.979)	8.5	142
Memorias Do Instituto Oswaldo Cruz	45 (4.3)	8 (2.743)	4.7	184
Parasites & Vectors	25 (2.4)	3 (3.876)	8.5	165
Pathogens and Global Health	14 (1.3)	6 (2.894)	6.8	144
Revista Da Sociedade Brasileira De Medicina Tropical	4 (0.38)	15 (1.581)	8.8	159
Journal of Tropical Pediatrics	4 (0.38)	18 (1.165)	4.5	111
Infectious Diseases of Poverty	2 (0.19)	1 (4.520)	5.0	169
Journal of Venomous Animals and Toxins Including Tropical Diseases	2 (0.19)	7 (2.831)	4.5	114
Asian Pacific Journal of Tropical Medicine	2 (0.19)	17 (1.226)	6.0	139
Leprosy Review	1 (0.10)	22 (0.537)	10	106
Tropical Doctor	1 (0.10)	20 (0.731)	4.0	106

Abbreviations: *TP*, total number of highly cited articles; IF_{2020}, journal impact factor for 2020; *R*, rank in Web of Science category of tropical medicine; *APP*, average number of authors per publication; CPP_{2020}, average number of citations per publication (TC_{2020}/TP).

TP: total number of highly cited articles

IP: number of single-country highly cited articles (IP_C) or single-institution highly cited articles (IP_I)

CP: number of internationally highly cited articles (CP_C) or inter-institutionally collaborative highly cited articles (CP_I)

FP: number of first-author highly cited articles

RP: number of corresponding-author highly cited articles

SP: number of single-author highly cited articles

Six related citation indicators proposed by Ho and Mukul[22] were applied to evaluate the publication performances of countries and institutions. We also calculated the *Y*-index[15,17] to compare the authors' research performances.

Results

A total of 1041 highly cited articles (1.5% of 69 480 articles in the category of tropical medicine in SCI-EXPANDED) with TC_{2020} of ≥100 were found from 1991 to 2020. The article entitled 'Guideliness in paracoccidioidomycosis'[23] published in Portuguese by authors from Brazil was the only non-English highly cited article in the tropical medicine field with a TC_{2020} of 287.

We analyzed 1041 tropical medicine articles that were highly cited in the Web of Science records. The maximum TC_{2020} was 997 and the average was 158. Only two COVID-19 highly cited articles appeared in the last 3 y: 'Expression of the SARS-CoV-2 cell receptor gene *ACE2* in a wide variety of human tissues'[24] with a TC_{2020} of 209 and 'A mathematical model for simulating the phase-based transmissibility of a novel coronavirus'[25] with a TC_{2020} of 129 (Figure 1). No highly cited article was identified in 2018 and 2019. CPP_{2020} fluctuated from 120 in 2017 to 202 in 2014 and 2015. *TP*s take 11 y to reach a peak, depending on the subject, for example, emergency medicine (10 y); anesthesiology (13 y); dentistry and oral surgery and medicine (14 y) (Figure 1).

Journals

We identified 21 journals with highly cited papers from 1991 to 2020; among them, 20 articles were published in five journals without IF_{2020} no longer listed in tropical medicine in 2020; for example, the *Annals of Tropical Medicine and Parasitology*, with 14 highly cited articles, which was renamed *Pathogens and Global Health* in 2012. The *Annals of Tropical Paediatrics* was changed to *Paediatrics and International Child Health* and moved to pediatrics in 2012. The *Annals of Tropical Medicine and Parasitology* changed its name to *Pathogens and Global Health*.

Seven of the 23 tropical medicine journals (Table 1) had no highly cited articles: *Journal of Tropical Medicine* (IF_{2020}=2.488; rank 10th), *Revista do Instituto de Medicina Tropical de Sao Paulo* (1.846; 13th), *Journal of Vector Borne Diseases* (1.688; 14th), *Asian Pacific Journal of Tropical Biomedicine* (1.545; 16th), *Biomedica* (0.935; 19th), *Tropical Biomedicine* (0.623; 21st) and *Southeast Asian Journal of Tropical Medicine and Public Health* (0.267; 23rd). Table 1 shows the 16 journals in the Web of Science category of tropical medicine in 2020. Articles published in the *Memorias Do Instituto Oswaldo Cruz* (IF_{2020}=2.743; rank eighth) had the highest CPP_{2020}:184. *Acta Tropica* had 82 highly cited articles with a CPP_{2020} of 183. One highly cited article was published in *PLoS Neglected Tropical Diseases*; the *Leprosy Review* had the greatest *APP* (10), while one article published in *Tropical Doctor* had the lowest CPP_{2020} (4).

Countries

The articles in our sample covered 116 countries. The average CPP_{2020} was 158. Internationally collaborative articles had a CPP_{2020} of 154 (higher than single-country articles, with 144 CPP_{2020}). The USA dominated in five of the six publication indicators with a *TP* of 454 articles (44% of 1038 highly cited articles), an *IPC* of 115 articles (34% of 342 single-country highly cited articles), a CP_C of 339 articles (49% of 696 internationally collaborative highly cited articles), an *FP* of 298 articles (29% of 1038 first-author highly cited articles) and an *RP* of 274 articles (29% of 954 corresponding-author highly cited articles); the UK ranked top with an *SP* of 12 articles (29% of 42 single-author highly cited articles) (Table 2). Comparing the top 15 countries, South Africa had the highest CPP_{2020} for their total articles (*TP*) and internationally collaborative articles (*CPC*) with a CPP_{2020} of 175 and 177, respectively. Switzerland had the highest CPP_{2020} for their single-country articles (IP_C) with a CPP_{2020} of 247. India published one single-author highly cited article (*SP*) with the highest CPP_{2020} of 416. Senegal had the highest CPP_{2020} for their 11 first-author highly cited articles (*FP*) and 10 corresponding-author highly cited articles (*RP*) with a CPP_{2020} of 214 and 225, respectively (Table 2).

Institutions

In total, 877 were inter-institutionally collaborative articles, and 161 were single-institution articles. Single-institution articles had a CPP_{2020} of 158, which was slightly higher than inter-institutionally collaborative articles (155). Four of the top institutions were from the UK, two from Switzerland and one each from the USA, Kenya, France and Thailand. The London School of Hygiene and Tropical Medicine led the three publication indicators with a *TP* of 101 highly cited articles (10% of highly cited articles), with a CP_I of 91 highly cited articles and an *SP* of six articles. The Centers for Disease Control and Prevention in the USA ranked top in the other three publication indicators with an IP_I of 15 articles, an *FP* of 51 articles and an *RP* of 46 articles (Table 3). Comparing the top 10 productive institutions, the WHO in Switzerland had the highest CPP_{2020} for their total 49 highly cited articles (*TP*), four single-institution highly cited articles (IP_I), 17 first-author highly cited articles (*FP*) and 15 corresponding-author highly cited articles (*RP*) with a CPP_{2020} of 173, 354, 223 and 238, respectively. The University of Oxford in the UK had the highest CPP_{2020} for their 67 inter-institutionally collaborative articles (CP_I) with a CPP_{2020} of 169. The London School of Hygiene and Tropical Medicine in the UK had the highest CPP_{2020} for their six single-author highly cited articles (*SP*) with a CPP_{2020} of 170 (Table 3).

Authors

For 957 highly cited articles used to calculate the *Y*-index for highly cited authors (5293 authors including 838 first authors and 809 corresponding authors), 4318 authors had no first or corresponding authorship (*Y*-index=0); 166 had only first author articles with h=0 and $j\neq0$; 15 authors had more first author articles with $0<h<\pi/4$; 629 authors had the same numbers

Table 2. Top 15 most productive countries with $TP \geq 30$

Country	TP	TP		IP_C		CP_C		FP		RP		SP	
		TPR (%)	CPP_{2020}	IP_CR (%)	CPP_{2020}	CP_CR (%)	CPP_{2020}	*FPR* (%)	CPP_{2020}	*RPR* (%)	CPP_{2020}	*SPR* (%)	CPP_{2020}
USA	454	1 (44)	166	1 (34)	173	1 (49)	164	1 (29)	166	1 (29)	165	2 (21)	190
UK	293	2 (28)	162	3 (8.8)	153	2 (38)	163	2 (12)	164	2 (12)	165	1 (29)	159
Switzerland	121	3 (12)	170	7 (3.8)	247	3 (16)	161	4 (5.1)	187	4 (5.0)	184	4 (7.1)	151
Brazil	119	4 (11)	165	2 (16)	161	7 (9.2)	169	3 (8.1)	161	3 (8.1)	160	3 (12)	145
France	99	5 (10)	168	5 (4.4)	150	5 (12)	171	6 (4.1)	140	6 (3.9)	148	8 (2.4)	131
Kenya	96	6 (9.2)	159	20 (0.58)	157	4 (14)	159	8 (3.1)	139	8 (2.9)	130	N/A	N/A
Thailand	87	7 (8.4)	158	9 (1.5)	133	6 (12)	159	5 (4.4)	150	5 (4.2)	150	4 (7.1)	123
Australia	71	8 (6.8)	160	4 (5.6)	156	10 (7.5)	162	7 (3.7)	159	7 (3.6)	158	6 (4.8)	120
Netherlands	68	9 (6.6)	154	9 (1.5)	116	8 (9.1)	157	9 (2.8)	147	8 (2.9)	149	8 (2.4)	104
Tanzania	55	10 (5.3)	156	N/A	N/A	9 (7.9)	156	15 (1.0)	145	14 (1.0)	145	8 (2.4)	204
Belgium	47	11 (4.5)	150	20 (0.58)	126	11 (6.5)	151	10 (2.3)	129	10 (2.4)	129	N/A	N/A
Senegal	37	12 (3.6)	152	15 (0.88)	190	12 (4.9)	149	14 (1.1)	214	14 (1)	225	8 (2.4)	334
Germany	34	13 (3.3)	146	8 (2.3)	124	15 (3.7)	153	11 (1.8)	123	11 (2.1)	126	8 (2.4)	102
India	33	14 (3.2)	160	6 (4.1)	170	19 (2.7)	151	11 (1.8)	161	12 (2.0)	161	8 (2.4)	416
South Africa	30	15 (2.9)	175	28 (0.29)	108	13 (4.2)	177	17 (0.87)	154	16 (0.94)	154	N/A	N/A

Abbreviations: *TP*, total number of articles; *TPR* (%), rank of total number of articles and percentage; IP_CR (%), rank of single-country articles and percentage in all single-country articles; CP_CR (%), rank of internationally collaborative articles and percentage in all internationally collaborative articles; *FPR* (%), rank of first-author articles and percentage in all first-author articles; *RPR* (%), rank of corresponding-author articles and percentage in all corresponding-author articles; *SPR* (%), rank of single-author articles and percentage in all single-author articles; CPP_{2020}, average number of citations per publication (TC_{2020}/TP); N/A, not available.

Table 3. Top 10 productive institutions in the Web of Science category of tropical medicine

Institution	TP	TP		IP_C		CP_C		FP		RP		SP	
		TPR (%)	CPP_{2020}	IP_IR (%)	CPP_{2020}	CP_IR (%)	CPP_{2020}	*FPR* (%)	CPP_{2020}	*RPR* (%)	CPP_{2020}	*SPR* (%)	CPP_{2020}
London School of Hygiene & Tropical Medicine, UK	101	1 (10)	156	2 (6.2)	169	1 (10)	155	2 (4.0)	149	2 (3.9)	147	1 (14)	170
Centers for Disease Control and Prevention, USA	91	2 (8.8)	163	1 (9.3)	142	2 (8.7)	167	1 (4.9)	158	1 (4.8)	155	N/A	N/A
Oxford University, UK	68	3 (6.6)	168	23 (0.62)	113	3 (7.6)	169	3 (2.1)	212	3 (2.1)	220	2 (4.8)	114
Kenya Medical Research Institute, Kenya	54	4 (5.2)	153	N/A	N/A	4 (6.2)	153	5 (1.7)	146	7 (1.4)	132	N/A	N/A
Mahidol University, Thailand	52	5 (5.0)	163	N/A	N/A	5 (5.9)	163	4 (1.9)	160	4 (1.9)	161	8 (2.4)	114
World Health Organization (WHO), Switzerland	49	6 (4.7)	173	3 (2.5)	354	6 (5.1)	157	6 (1.6)	223	5 (1.6)	238	2 (4.8)	164
University of Liverpool, UK	37	7 (3.6)	155	6 (1.9)	175	7 (3.9)	153	11 (0.87)	142	11 (0.94)	142	N/A	N/A
Swiss Tropical Institute, Switzerland	31	8 (3.0)	153	3 (2.5)	236	8 (3.1)	141	6 (1.6)	160	5 (1.6)	136	8 (2.4)	126
John Radcliffe Hospital, UK	27	9 (2.6)	146	N/A	N/A	8 (3.1)	146	24 (0.48)	166	29 (0.42)	179	N/A	N/A
Institut Pasteur, France	25	10 (2.4)	165	N/A	N/A	10 (2.9)	165	9 (1.3)	138	10 (1.2)	162	N/A	N/A

Abbreviations: *TP*, total number of articles; *TPR* (%), the rank and the percentage of total articles in the total number of articles; IP_IR (%), the rank and the percentage of single-institution articles in the total single-institution articles; CP_IR (%), the rank and the percentage of inter-institutionally collaborative articles in the total inter-institutionally collaborative articles; *FPR* (%), the rank and the percentage of first-author articles in the total first-author articles; *RPR* (%), the rank and the percentage of the corresponding-author articles in the total corresponding-author articles; *SPR* (%), the rank and the percentage of the single-author articles in the total single-author articles; CPP_{2020}, average number of citations per publication (TC_{2020}/TP); N/A, not available.

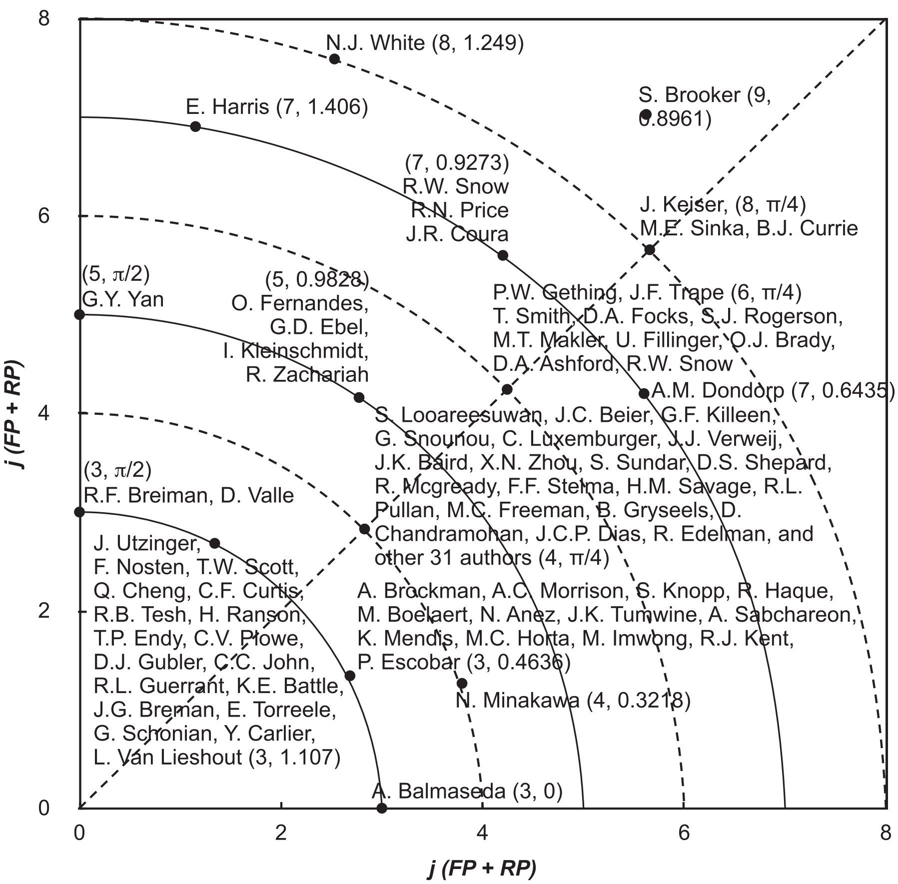

Figure 2. Distribution of the top 109 authors with their *Y*-index values ($j \geq 3$).

of first authorship and corresponding authorship articles with $h=\pi/4$; 28 authors had more corresponding author articles with $\pi/2>h>\pi/4$; and 137 authors had only corresponding author articles with $h=\pi/2$ and $j\neq 0$ (Figure 2).

In the distribution of the *Y*-index (j, h) of the top 109 authors with $j\geq 3$, each dot represents a value that could be one or several authors (Figure 2),[26] for example, J. F. Trape and another eight authors had the same *Y*-index of (6, $\pi/4$); S. Looareesuwan and another 49 authors had the same *Y*-index of (4, $\pi/4$); J. Utzinger and another 17 authors had the same *Y*-index of (3, 1.107); and A. Brockman and another 12 authors had the same *Y*-index of (3, 0.4636). S. Brooker with a *Y*-index (9, 0.8961) from the London School of Hygiene and Tropical Medicine in the UK had the highest publication potential with a j of 9.

Authors with the same j have the same publication potential, with different publication characteristics h; in Figure 2, N. J. White (8, 1.249) and J. Keiser (8, $\pi/4$) had the same value of j (8), but White, with an h of 1.249, has a higher ratio of corresponding-author to first-author articles than Keiser (but the same number of first-author and corresponding-author articles). The same applies to E. Harris (7, 1.406), R. W. Snow (7, 0.9273) and A. M. Dondorp (7, 0.6435) (Figure 2). Harris had the highest ratio of *RP* to *FP* with an h of 1.460, followed by Snow with an h of 0.9273 and Dondorp with an h of 0. 6435. Harris had a higher ratio of corresponding-author to first-author articles than Snow. However, Dondorp published more first-author articles than corresponding-author articles. Furthermore, R. F. Breiman (3, $\pi/2$), J. Utzinger (3, 1.107), A. Brockman (3, 0.4636) and A. Balmaseda (3, 0) had the same publication potential with a j of 3 for all. Breiman published only corresponding-author articles. Utzinger published more corresponding-author articles than first-author articles. Brockman published more first-author articles than corresponding-author articles. Balmaseda published only first-author articles. The h of J. Keiser (8, $\pi/4$), J. F. Trape (6, $\pi/4$) and S. Looareesuwan (4, $\pi/4$) were all the same ($\pi/4$) and located on the same straight line (diagonal). All these authors had the same publication characteristics with the same proportion of *RP* to *FP*. Keiser had the highest publication potential with a j of 8, followed by Trape with a j of 6 and Looareesuwan with a j of 4. Similarly, G. Y. Yan (5, $\pi/2$) and R. F. Breiman (3, $\pi/2$) were located on the same straight line (y-axis), indicating that Yan and Breiman had the same publication characteristics with an h of $\pi/2$. Yan had a higher publication potential than Breiman.

Citation history

The 10 most cited articles in the SCI-EXPANDED were: by Mendis et al.,[29] which ranked third in TC_{2020} with 706 but ranked 125th in

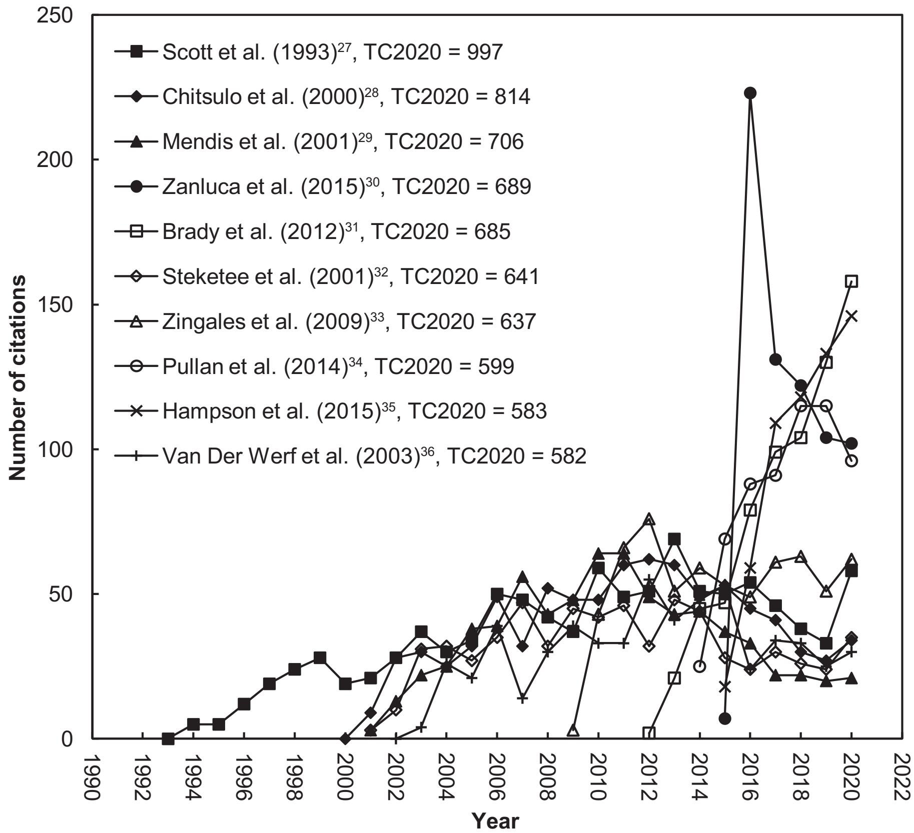

Figure 3. Citation history of the top 10 most frequently cited articles in the Web of Science Category of tropical medicine.

C_{2020} with 25. An article by Zanluca et al.[30] had a sharply increasing trend of citations in 2 y after its publication and then had a sharp decrease to reach a C_{2020} of 102 (rank sixth). An article by Brady et al.[31] and an article by Hampson et al.[35] had a similarly sharp early increase (Figure 3). Five of the top 10 articles were published in *PLoS Neglected Tropical Diseases* with an IF_{2020} of 4.411 (ranked second in tropical medicine), two in *Infectious Diseases of Poverty* (IF_{2020}=4.520; ranked first) and one each in *Tropical Medicine & International Health* (IF_{2020}=2.622; ranked ninth), *Memorias do Instituto Oswaldo Cruz* (IF_{2020}=2.743; ranked eighth) and *Parasites & Vectors* (IF_{2020}=3.876; ranked third). Recent articles like 'Expression of the SARS-CoV-2 cell receptor gene *ACE2* in a wide variety of human tissues' by Li et al.,[24] and 'A mathematical model for simulating the phase-based transmissibility of a novel coronavirus'[25] (Chen et al., 2020), appear to be future top articles, with a C_{2020} of 209 (ranked first) and C_{2020} of 129 (ranked fourth) (Table 4).

The majority of citations for nearly all publications in our sample of top cited papers were done after the first 2 y, as can be seen in Figure 3, which covers citations of the most cited articles for a period of 27 y. This result indicates that the method used by the *Web of Science*, which only counts citations in the first 2 y after publication, as described on the *Clarivate* website, does not represent the real impact of the publications because it takes longer for them to be read, used and cited.

Discussion

Slightly more than a 1000 tropical medicine articles accumulated >100 citations each, according to the Web of Science. This number can be considered small, if considered within the range of health-related articles published each year, or large if compared with smaller fields such as the specific study of cancrum oris, which is highly neglected.[7,41] In any case, it shows that tropical medicine is still a vigorous field of research, as it should be, considering that more people will live under tropical conditions in the future than ever before.[9] Only two highly cited articles deal with the COVID-19 pandemic of 2019–2022, but this and our general results simply reflect the fact that citations need more years to accumulate, a key element that the 'impact factor' fails to cover because it is limited to 2, or 5 y after publication, which does not give enough time for citation in science, where planning, data collecting and processing, and publication, take several years[42]; even the more recently implemented '5-year citation impact' is insufficient: our results suggest that at least 10 y are needed for an acceptable idea of how influential a publication becomes.

Although rare, short citation picks can also occur and consideration of the two cases we found can be informative. The two articles with citation picks were Zanluca et al.'s report of the first case of autochthonous transmission of the Zika virus in Brazil in 2015, and Brady et al.'s proposal of an evidence-based consensus for refining the global spatial limits of dengue virus

Table 4. The 10 most impact articles with $C_{2020} \geq 66$ in the category of tropical medicine

Rank (C_{2020})	Rank (TC_{2020})	Article title	Country
1 (209)	140 (209)	Expression of the SARS-CoV-2 cell receptor gene *ACE2* in a wide variety of human tissues[24]	China
2 (158)	5 (685)	Refining the global spatial limits of dengue virus transmission by evidence-based consensus[31]	UK, USA
3 (146)	9 (583)	Estimating the global burden of endemic canine rabies[35]	UK, France, Tanzania, USA, Germany, Brazil, Cambodia, South Africa, St Kitts & Nevi, Switzerland, Canada
4 (129)	535 (129)	A mathematical model for simulating the phase-based transmissibility of a novel coronavirus[25]	China
5 (108)	51 (316)	Updated global burden of cholera in endemic countries[37]	USA, Philippines
6 (102)	4 (689)	First report of autochthonous transmission of Zika virus in Brazil[30]	Brazil
7 (97)	17 (461)	The global burden of disease study 2010: Interpretation and implications for the neglected tropical diseases[38]	USA, UK, France, Netherlands, Kenya, Switzerland, India
8 (96)	8 (599)	Global numbers of infection and disease burden of soil transmitted helminth infections in 2010[34]	UK, USA
9 (81)	26 (415)	Burden of disease from inadequate water, sanitation and hygiene in low- and middle-income settings: A retrospective analysis of data from 145 countries[39]	Switzerland, USA, UK, South Africa
10 (66)	57 (299)	*Strongyloides stercoralis*: global distribution and risk factors[40]	Switzerland, Cambodia

Abbreviations: TC_{2020}, total number of citations from Web of Science Core Collection since publication year to the end of 2020; C_{2020}, citations in 2020 only.

transmission in 2012. In both cases, the rapid reaction of the scientific community can be explained by the serious effects of the Zika virus infection (microcephaly, miscarriage, neuropathy, myelitis) and severe dengue being a leading cause of serious illness and death in some Asian and Latin American countries, according to the WHO. Control measures were successful and, especially after the WHO declared the Zika emergency over, researchers' interest in those two diseases decreased, and both publications and citations fell rapidly.

While the limited number of journals appearing in our results (21 journals only) show both that the field is small and that this index fails to include the majority of tropical journals,[43] the presence of authors from 116 countries indicates that tropical medicine covers a large geographic area.[44]

The high citation rate for both local and internationally collaborative articles from South Africa probably reflects the fact that, according to official World Bank data, South Africa has a large and well-funded scientific apparatus that receives 0.62% of its gross domestic product. A similar explanation would fit the high single-country CPP_{2020} for Switzerland, which has both a well-funded health research system and the headquarters of the WHO.

India's top position for 'single-author highest CPP_{2020} citation' is an article on drug resistance in Indian visceral leishmaniasis. Although it was published in a relatively small and new journal (*Tropical Medicine & International Health*), the subject was of much interest for two reasons: according to Pan American Health Organization official data, 350 million people are at risk of infection with leishmaniasis, and this particular article alerted about the emergence of resistant strains of *Leishmania donovani* and proposed optional treatments to combat the problem.

The high citation of Senegal first-author and corresponding-author articles can also be explained by the access that Senegalese authors have to large American and European journals, thanks to their association with French coauthors in those articles.

The predominance of the USA, the UK and Switzerland was to be expected as these are the countries with the highest budgets for research, while the fact that The *American Journal of Tropical Medicine and Hygiene* had the most articles covered here is to be expected because the Science Citation Index is produced by an American company that mostly covers American and Western European journals.[9,43]

The London School of Hygiene and Tropical Medicine was the most frequent collaborative partner, and the Centers for Disease Control and Prevention in the USA had the highest independent research trend, reflecting in the case of the London schools its history of work in imperial colonies, and in the case of the American centers, the large resources that they have.[43]

The high citation rate of the WHO in Switzerland may result from their shifting focus on urgent fields as part of their United Nations mandate.[45] We could not reject our hypotheses about the advantage of working in powerful institutions outside the tropics: the *Y*-index, which placed together highly cited authors with similar characteristics, indicated that most work directly at well-founded institutions outside the tropics, or that they publish as coauthors of researchers in those institutions. In the same vein, we could not reject our hypothesis that 2, or even 5 y, is insufficient to assess the impact of articles in the field of tropical medicine: at least a decade of citations must accumulate for a reliable estimate, which is >100 citations for highly influential articles.

The currently available indexing system places tropical researchers at a serious disadvantage when compared with researchers in the USA and Europe, simply because they have limited access, or more often, no access at all, to journals covered by the Web of Science, which are the only ones in which citations are covered for the 'impact factor'. Nevertheless, tropical researchers still make a key contribution to understanding, treating and managing tropical diseases, as reflected here for the relatively few cases of articles from Brazil, India, South Africa and Senegal that are able to be published in those journals through coauthorship with European and American researchers.

For the study of tropical infections, the negative effects of the citation disadvantage are twofold: findings published in journals outside the Web of Science—which is the majority of tropical journals—do not get to be known, used and cited; and, from the point of view of patients, this means lost opportunities for the reduction and control of the infections.

What endeavors might help change this pattern?

One of our main findings is that research from the tropics can break the barrier, and become highly read and cited, if published in the large and influential European and American journals. There are two implications for this: that editors of large journals can help by increasing support for tropical authors; and that everyone will benefit from North–South cooperation, giving tropical authors access to the large journals in Europe and the USA.

Limitations of this study: The majority of tropical journals—in all fields, not just medicine—are not included in the Science Citation Index published by the Web of Science: most of the citations on tropical medicine done every year are missed by the index and the real impact factor is not known. Our study only considered articles published in that small sample of journals that are included in the Web of Science and our conclusions cannot be extrapolated beyond that sample. Hopefully, as technology advances and new indices are developed in the tropics themselves (e.g. SCIELO and Latindex), a more representative sample of journals will be available for researchers to test these two hypothesis in the future.

Authors' contributions: Both authors contributed in similar amounts to all aspects of the study, from choosing the hypotheses to be tested, to analyzing the data and writing and correcting the manuscript. However, based on their respective fields of expertise, YSH focused more on data collection and statistical analyses, and JMN on the biomedical interpretation of results.

Acknowledgements: We would like to acknowledge the reviewers for very constructive recommendations.

Funding: None.

Competing interests: None declared.

Ethical approval: Not required.

Data availability: The full dataset can be freely downloaded from the European Repository here: https://zenodo.org/record/7814224.

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