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View From Above: Bibliometric and Citation Analysis of Global High Altitude Medicine Research

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Abstract

Introduction: High altitude destinations are popular among international travelers. Travel medicine practitioners should be familiar with altitude physiology and high altitude illness recognition, prophylaxis, and management. We performed the first bibliometric analysis of high altitude medicine research.

Methods: All articles published in a specialist high altitude medicine journal through April 2020 were mapped against the 34 domains in a theoretical body of knowledge. Citation counts of articles, as well as authors publishing the most articles, were obtained from Scopus. Collaboration analysis was performed using established methods.

Results: Mapping of 1150 articles published from 2000 to 2020 identified the leading domains represented by high altitude medicine articles. The top five domains were altitude acclimatization and deterioration (19.4%, n=510); cardiovascular physiology (6.8%, n=180); work at altitude (6.6%, n = 174); acute mountain sickness (6.4%, n=169); respiratory and acid-base physiology (5.9%, n=155). Published articles attracted a total of 13,324 citations, with a mean of 11.6 citations per article. The average number of citations per author was 22.3. The USA was the most productive country with 432 publications (37.6%), followed by the UK (9.5%, n=109) and Switzerland (5.6%, n=64). The collaboration index for multi-authored publications increased from 3.8 in 2002 to 5.4 in 2019.

Conclusion: We have performed the first comprehensive bibliometric analysis in high altitude medicine. Efforts to increase the research activity in neglected topics and to promote greater collaboration between high altitude medicine and related fields of study such as travel medicine may be worthwhile.

Keywords: Bibliometric Analysis, High Altitude Medicine, Research, Citation Analysis, Curriculum Map

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Introduction

Adequate pre-travel preparation is required for certain travel destinations due in part to challenging physical environments. These include high altitude destinations, access to which is facilitated in the modern era by improved transport infrastructure such as high altitude airports[1] and railway systems.[2] Traveling to high altitude destinations presents inherent challenges, including a toll on both physical[3] and mental health.[4] Much of the published literature focuses on preventive[5] and treatment strategies[6] for high altitude-related medical issues. The expectations and challenges encountered by workers at high altitude have also received attention from researchers in this field.[7]

High altitude medicine is a well-established discipline with an evolving scholarship and evidence base. It has close ties with travel medicine and is listed under the special itineraries sub-domain of the Body of Knowledge of the International Society of Travel Medicine (www.istm.org). The continued development of high altitude medicine requires that research priorities reflect its expanding knowledge base. This may be achieved by developing a body of knowledge or syllabus which reflects the current scope of high altitude research and practice. This framework may be beneficial for the professional development of high altitude physicians and researchers and for shaping the content of educational programs[8] in high altitude medicine. This has proved to be a successful and worthwhile initiative in other disciplines such as travel medicine.[9]

Bibliometric analysis is an established research methodology which involves a quantitative analysis of the academic literature in order to achieve a specific aim. These include evaluating the contribution and collaboration of authors, institutions, and countries, calculating the number of times a published article has been cited, and identifying gaps in the field that are amenable to further research.[10] Specialty and journal-level bibliometric analyses have also been published in the fields of travel medicine,[11-13] tropical medicine,[14] cardiovascular medicine,[15] respiratory medicine,[16] infectious diseases,[17] emergency medicine,[18] surgery,[19] and obstetrics and gynecology.[20]

High altitude medicine and biology (HAMB), which has been in existence since the turn of the new millennium, is the only journal devoted exclusively to high altitude medicine research. It is affiliated with the International Society for Mountain Medicine (ISMM), which was founded in 1985 by the medical commission of the International Climbing and Mountaineering Federation (UIAA) in Switzerland. To our knowledge, there has been no bibliometric analysis conducted to date for publications in HAMB. This study is the first journal-level bibliometric analysis of high altitude research articles. It has the additional aim of identifying research trends and gaps in a theoretical body of knowledge through the mapping of articles to specific domains. This may inform the setting of research priorities in this evolving area of clinical activity. By analyzing the characteristics of these publications, the qualities which make a high altitude medicine paper important to the specialty may be elucidated.

Methods

Curriculum Mapping Exercise

All indexed articles, including original research articles, reviews, editorials, letters, and case reports, appearing in the 81 issues of HAMB through April 2020, were retrieved from the journal website between February and April 2020. These articles were screened from their titles and abstracts. A theoretical framework was constructed, which yielded a body of knowledge in high altitude medicine. This collective effort involved consultation with experts and leading textbooks in the field, as well as the UIAA Diploma in Mountain Medicine.[21] The framework was divided into a series of domains, against which articles were mapped.

The full text versions of articles were interrogated further when their domain identity was not apparent from their title. Where an individual article reflected more than one domain, it was categorized into each domain. Additional information recorded included title, year of publication, article type, country of origin (corresponding author), institutional affiliations, number of countries and authors involved in individual articles, and the gender of authors.

Abstracts of proceedings or conferences, book reviews, and several miscellaneous article categories such as 'high altitude web', 'poems', and 'corrections' were not included in the analysis. Both authors followed the same search protocol independently and agreed upon the final list of articles for analysis. Data were entered and stored in a Microsoft Excel 2019 database. A consensus on final designations of domain allocations for each article was reached by the two authors. Publications were analyzed in Microsoft Excel by article type, annual number of publications, geographical location, authorship, international collaboration, and citation analysis. A temporal analysis of publication trends was also performed to track research productivity over time.

Citation Analysis

Citation counts of articles, as well as authors publishing the most articles in HAMB, were obtained from Scopus, the largest citation database of peer-reviewed literature.[22] To enrich the analysis of citation metrics, data on citations made to HAMB by other citing journals, as well as data on the cited half-life of HAMB, were obtained from Web of Science, Journal Citation Reports (JCR). Cited half-life refers to the median age of the citations received by a journal in a given JCR year.

Collaboration Analysis

Collaboration analysis was performed by examining the degree of collaboration (C), which was derived from the formula $C = N_m/(N_m+N_s)$, where N_m is the number of publications by multiple authors and N_s is the number of publications by a single author.[23] Collaboration index (CI) was obtained from the formula CI = number of multiple authors/number of publications by multiple authors.[23] VOSviewer version 1.6.15 (Leiden University, Leiden, The Netherlands), a visualizing software tool, was used to generate bibliometric network maps based on co-authorship and citations of retrieved publications. Under visualization mode, network maps represent different parameters using circles of different size, font size, colors, and connecting line thickness. The thickness of connecting lines indicates the strength of collaboration either between countries or between authors, which is summarized numerically as the total link strength. A stronger collaboration reflects a higher total link strength.[24,25] Descriptive analysis for categorical variables was presented as frequencies and percentages. Continuous data were presented as mean, median and interquartile range (Q1–Q3), and range values.

Results

Categorical Analysis and Bibliometric Mapping

A total of 1150 articles were retrieved. All of the articles were published in the English language. The majority of the published articles were full original research articles (47%, n = 541), review articles (16.1%, n = 185), or letters (10.4%, n = 119). Eleven (5.9%) of the review articles were systematic reviews. The remaining group of articles comprised editorials (5.9%, n = 68), case reports (4.4%, n = 51), and other article types (16.2%, n = 186). Categorical mapping of 1150 articles published from 2000 to 2020 (Table 1) yielded the following number of articles for the domain against which 100 articles or more were mapped: altitude acclimatization and deterioration (19.4%, n = 510); cardiovascular physiology (6.8%, n = 180); work at altitude (6.6%, n = 174); acute mountain sickness (6.4%, n = 169); respiratory and acid-base physiology (5.9%, n = 155); sports and exercise physiology at altitude (5.3%, n = 139); high altitude populations (4.8%, n = 127); pre-

Table 1. Bibliometric Analysis of High Altitude Medicine Articles

Body of Knowledge Domain	Number of Articles*
Altitude acclimatization and deterioration	510
Cardiovascular physiology	180
Work at altitude	174
Acute mountain sickness	169
Respiratory and acid-base physiology	155
Sports and exercise physiology at altitude	139
High altitude populations	127
Pre-existing medical conditions at altitude	108
Extreme attitude	102
Neuropsychiatric issues at altitude	88
Special population groups	82
History	75
Journal, society or congress	67
High altitude pulmonary edema	66
Genetics and high altitude	64
Rescue and survival	60
Ethicolegal aspects	54
Sleep	50
Other attitude-related conditions	46
Endocrine physiology	44
Chronic mountain sickness and high altitude pulmonary hypertension	41
Thermal extremes	40
Medical emergencies at high altitude	40
Mortality at altitude	30
High altitude cerebral edema	26
Geography and the human response to altitude	24
Travel medicine	20
Gastrointestinal physiology	18
Education and training	13
Renal physiology	11
The atmosphere	5
Aerospace medicine	5
High altitude environmental issues	4
Lightning injuries	2

*Where the total number of articles listed by article type does not equate to the total number of articles in the body of knowledge, it may be assumed that some articles are assigned to >1 domain.

existing medical conditions at altitude (4.1%, n = 108); and extreme altitude (3.9%, n = 102).

Publication Trends

The mean number of annual publications in HAMB for the study period was 55 publications. There was an increase in published research productivity over time, from 32 in 2000 to 76 in 2014, with recognizable peaks occurring mainly in the last decade. The maximum productivity per year was observed in 2013 and 2014 with 76 (6.6%) publications each, while the minimum productivity per year was recorded in 2000 (2.8%, n = 32). As of April 1, 2020, published articles had attracted a total of 13 324 citations, with a mean of 11.6 citations per article, a median (Q1–Q3) of 4 (0–15) and a range of 237 (0–237). Table 2 shows the total citation count of all articles published in any given year, from 2000 to 2020. The median number of citations per publication reached a peak in 2010 with 14 and was at its lowest level in 2019 with a median of zero and mean of 0.41 citations.

Geographical Distribution of Publications

The geographical distribution of publications in HAMB spanned 48 countries. The United States had 56 of the most cited papers (i.e., 25 or more citations), followed by Switzerland with 12 and the United Kingdom with 10 (Table 3). Eleven countries produced at least 5 of the most cited publications. Table 4 displays the leading countries in terms of productivity with a minimum of 25 publications each. The USA was the most productive country with 432 publications (37.6%), followed by the UK (9.5%, n = 109) and Switzerland (5.6%, n = 64). A total of 1031 different academic research institutions were represented in the analysis. Table 5 presents the most prolific institutions that have published articles in HAMB. The most prolific institution was the University of California, San Diego (99 publications), followed by the University of Colorado (68 publications) and the University of California, San Francisco (64 publications). Overall, eleven leading institutions, 5 of which were of European origin, published at least 25 articles each, accounting for 45.7% of the total publications.

Authorship Analysis

A total of 4712 authors contributed to the 1150 publications, with each publication having a mean of 4.1 authors. There were more male (76.7%, n = 3612) than female (23.3%, n = 1100) authors on papers published in HAMB to date (Figure 1). The leading eight authors published at least 20 papers each, accounting for 25.8% of the total number of papers (Table 6). John B. West was the most prolific author in HAMB (6.7%, n = 71), followed by Buddha Basnyat, Hermann Brugger, and John W. Severinghaus with 33 (3.1%) publications each. A total of 2868 individual authors were involved in articles published in HAMB. The number of authors with a single publication in HAMB was 2231 (77.8%). Table 7 summarizes the productivity of authors by year of publication. The average number of authors per article reflected the increasing collaboration pattern observed during the study period, from 3.3 in 2000 to 6.1 in 2019. Co-authorship analysis indicates a measure of the similarity relationship of publications using the number of authors on a given publication. Two authors, Buddha Basnyat and Hermann Brugger, had the strongest collaboration with other authors, represented by a total link strength of 151 each.

Collaboration Indices

Of the 1150 articles analyzed, 312 (27.1%) were single-authored publications and the remaining articles were multi-authored publications (72.9%, n = 838). This yielded a degree of collaboration of 72.9% among authors in HAMB, supported by the decrease in the number of single-authored publications, as well as the increase in the number of multi-

Table 2. Annual Number of Publications and Citation Metrics

Year	Frequency	Percentage (n=1150)	Total Number of Citations	Median Citations Per Paper	Q1–Q3*
2000	32	2.8	634	13.5	2.00–37.00
2001	58	5.0	1056	7.0	0.25–21.75
2002	48	4.2	961	7.0	1.75–25.25
2003	55	4.8	1161	11.0	2.00–30.00
2004	52	4.5	1141	7.5	1.00–27.00
2005	41	3.6	775	10.0	1.00–21.00
2006	39	3.4	739	13.0	3.00–26.50
2007	47	4.1	751	13.0	1.50–24.50
2008	56	4.9	972	10.0	3.00–25.50
2009	56	4.9	865	9.0	1.75–23.25
2010	45	3.9	735	14.0	4.00–22.00
2011	72	6.3	868	7.5	2.00–16.25
2012	53	4.6	531	8.0	2.00–14.00
2013	76	6.6	581	5.0	1.00–10.25
2014	76	6.6	639	6.0	1.00–10.25
2015	59	5.1	323	4.0	0.00–8.50
2016	50	4.4	230	3.0	0.25–6.00
2017	66	5.7	168	2.0	0.00–3.75
2018	60	5.2	159	2.0	0.75–3.00
2019	66	5.7	27	0.0	0.00–1.00
2020	43	3.7	8	2.0	1.75–2.25

*Q1-Q3, interquartile range.

Table 3. Country of Origin of the Most Cited Articles in High Altitude Medicine

Rank	Country	Number of Publications (N = 1064)
1	USA	56
2	Switzerland	12
3	UK	10
4	India	9
5	Peru	8
6	Canada	6
7	Austria	6
8	China	6
9	Germany	5
10	Nepal	5
11	Japan	5

*There are 164 articles in High Altitude Medicine and Biology that have received at least 25 citations based on data analysis in April 2020.

Table 4. Countries Publishing the Most High Altitude Medicine Articles

Rank	Country	Number of Publications (N = 1150)
1	USA	432
2	UK	109
3	Switzerland	64
4	China	55
5	Germany	49
6	Italy	44
7	India	40
8	Canada	39
9	Austria	39
10	Nepal	28
11	France	27

authored publications, over the period of the analysis. The collaboration index for multi-authored publications increased from 3.8 in 2002 to 5.4 in 2019 (Table 8). Multi-authored publications had an average of 4.4 authors per publication, which was derived from a calculation of the average annual number of authors per multi-author publication during the study period. The total number of articles with international collaboration, defined as articles that involved at least two countries on a given paper, was 329 (28.6%). The average number of international institutions involved in an individual paper was 1.4. International collaboration was further analyzed based on country of origin using VOSviewer. The

Table 5. Most Prolific Institutions of High Altitude Medicine Research

Institution	Number of Publications (N=1150)
University of California, San Diego	99
University of Colorado	68
University of California, San Francisco	64
University of Washington, Seattle	55
University of Zurich	43
Cayetano Heredia University	42
Heidelberg University	42
Nepal International Clinic	30
Medical University of Innsbruck	30
EURAC Research	27
University College London	25

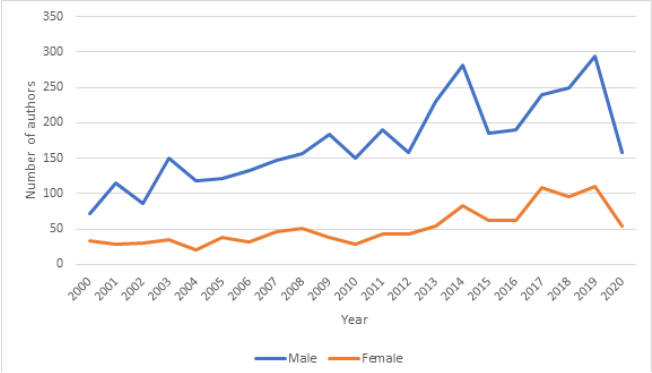

Figure 1. Temporal Trends in the Total Number of Authors by Gender.

USA had the strongest collaboration network, indicated by a total link strength of 158, followed by the UK (total link strength 143) and Switzerland (total link strength 132). Figure 2 and Figure 3 depict the strength of collaboration networks in the published high altitude medicine literature.

Citation Analysis

The total citations per year revealed two temporal peaks: 2001-2004 and 2008. The highest number of citations (1161) was recorded for articles published in 2003, while the lowest was in 2020 (8). In the JCR year 2018, the cited half-life of HAMB was 8.2. In the same JCR year, HAMB received 1193 citations for all of its articles that had been published up to that date (including the year 2018). Table 9 illustrates the top twenty journals that cited HAMB to the greatest extent in the JCR year 2018. The journal, *Frontiers in Physiology*, contributed the highest number of citations (149) to HAMB, followed by HAMB itself (115) and *PLoS One* (34). Articles published in HAMB from all years were cited by the journals listed in Table 9.

Of the 1150 articles, the most cited publication was entitled 'Consensus statement on chronic and subacute high altitude diseases' with a cumulative citation count of 237. This was an international consensus statement produced by a committee formed by the ISMM at the VI World Congress on Mountain Medicine and High Altitude Physiology in Xining, China (2004). It provided guidelines on the definition, diagnosis, treatment, and prevention of the most common chronic high altitude diseases. Table 10 summarizes the most cited publications in HAMB. Among the top ten cited publications, eight papers were review articles addressing topics such as high altitude illnesses and adaptation to high altitude hypoxia. The highest number of top cited papers (25 or more citations) was in 2003 (n = 17), followed by 2008 (n = 16).

A total of 2508 (87.5%) authors received at least one citation, 1372 authors accumulated at least ten citations (47.8%), and 93 authors had a citation count of at least 100 (3.2%). The most influential author was the Peruvian physiologist, Fabiola León-Velarde, from Cayetano Heredia University in Lima, with the highest cumulative citation count of 618 (1% of total citation counts for all authors). The average number of citations per author for papers published in HAMB was 22.3. Citation analysis revealed that the USA was the most prolific country (5650 citations), followed by the UK (1807) and Switzerland (1803).

Table 6. Most Prolific High Altitude Medicine Authors

Author	Number of Publications (N=1067)*
J.B. West	71
B. Basnyat	33
H. Brugger	33
J.W. Severinghaus	33
P. Bärtsch	29
E.R. Swenson	28
B. Kayser	25
F. León-Velarde	23

Source: Scopus. Accessed April 1, 2020.
*The total number of articles listed here does not equate to the total number of articles retrieved directly from the journal website.

Table 7. Number of Authors Per Published Article in High Altitude Medicine

Year	Number of Authors	Mean Number of Authors Per Article
2000	105	3.3
2001	144	2.5
2002	116	2.4
2003	185	3.4
2004	138	2.7
2005	159	3.9
2006	164	4.2
2007	194	4.1
2008	208	3.7
2009	222	4.0
2010	180	4.0
2011	233	3.2
2012	202	3.8
2013	285	3.8
2014	365	4.8
2015	248	4.2
2016	253	5.1
2017	348	5.3
2018	345	5.8
2019	405	6.1
2020	213	5.0

Discussion

We have completed the first bibliometric and citation analysis of papers published in a leading specialist high altitude medicine journal. This included a detailed analysis of publication trends and measures of research collaboration which chart the growth and trajectory of the journal over the past two decades. Bibliometric analysis allows for the identification of trends, patterns, areas of research neglect and imbalances in academic publishing, which may be variously addressed by editorial board strategies, active solicitation of articles and funded external research grant calls.[12]

Based on our experience with a similar tool in travel medicine,[9] we designed a body of knowledge comprising 34 domains, based on a triangulation of information from multiple reputable sources in order to map published articles against individual knowledge areas. This body of knowledge may have multiple applications for workers in

Table 8. Author Collaboration Indices for High Altitude Medicine Publications, 2000-2020

Year	Number (%) of Single-Authored Publications	Number (%) of Multi-Authored Publications	Number of Authors In Multi-Authored Publications	Collaboration Index	Number (%) of Publications With International Collaborations	Average Number of International Collaborations Per Publication
2000	12 (37.5)	20 (62.5)	93	4.7	8 (25.0)	1.3
2001	33 (56.9)	25 (43.1)	111	4.4	1 (1.7)	1.0
2002	27 (56.2)	21 (43.8)	79	3.8	8 (16.7)	1.2
2003	23 (41.8)	32 (58.2)	141	4.4	12 (21.8)	1.3
2004	23 (44.2)	29 (55.8)	105	3.6	10 (19.2)	1.3
2005	13 (31.7)	28 (68.3)	126	4.5	10 (24.4)	1.6
2006	12 (30.8)	27 (69.2)	142	5.3	9 (23.1)	1.3
2007	13 (27.7)	34 (72.3)	171	5.0	15 (31.9)	1.5
2008	15 (26.8)	41 (73.2)	183	4.5	9 (16.1)	1.2
2009	18 (32.1)	38 (67.9)	161	4.2	12 (21.4)	1.4
2010	16 (35.6)	29 (64.4)	132	4.6	11 (24.4)	1.3
2011	22 (30.6)	50 (69.4)	191	3.8	17 (23.6)	1.4
2012	10 (18.9)	43 (81.1)	181	4.2	16 (30.2)	1.5
2013	26 (34.2)	50 (65.8)	228	4.6	19 (25.0)	1.3
2014	13 (17.1)	63 (82.9)	279	4.4	31 (40.8)	1.6
2015	16 (27.1)	43 (72.9)	179	4.2	20 (33.9)	1.4
2016	3 (6.0)	47 (94.0)	186	4.0	24 (48.0)	1.7
2017	9 (13.6)	57 (86.4)	278	4.9	24 (36.4)	1.6
2018	2 (3.3)	58 (96.7)	231	4.0	26 (43.3)	1.7
2019	3 (4.5)	63 (95.5)	341	5.4	29 (43.9)	1.7
2020	3 (7.0)	40 (93.0)	179	4.5	18 (41.9)	1.8

the field, including the design of educational courses and webinars and the development of journal editorial strategy. The body of knowledge should be a live document that responds to changing priorities in the field and we believe that it should be updated at regular intervals with a more granular sub-categorization of topics in order to maximize its educational value. Our analysis revealed that the leading topics (domains) in high altitude medicine were altitude acclimatization, cardiovascular physiology, high altitude working environments, acute mountain sickness, and high altitude respiratory physiology. The least represented areas related to renal physiology at altitude, aerospace medicine, environmental issues, and lightning injuries.

The most cited papers tended to be review articles or randomized controlled trials. Systematic reviews constituted a very low proportion of the total number of reviews published and, given that they represent the highest level of research evidence,[26] there may be scope for increasing the proportion of systematic reviews published in the journal. The most cited paper to date has been a consensus statement on the theme

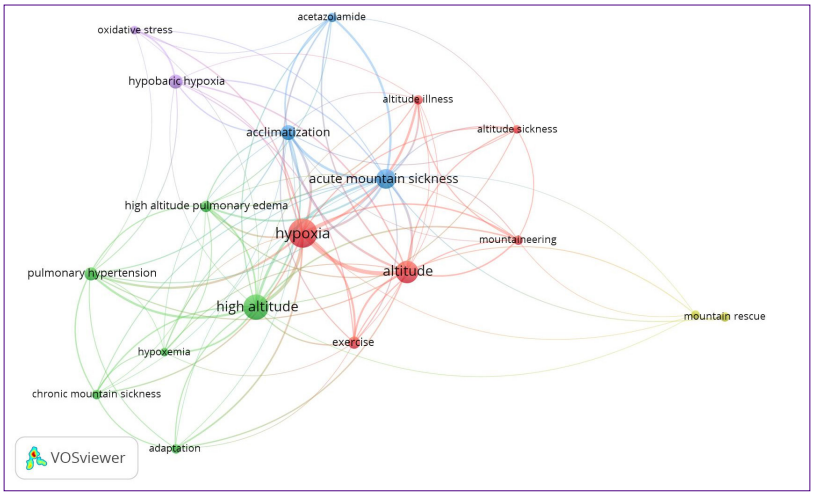

Figure 2. Network Visualization Map of Co-occurrence of Authors' Keywords. Keywords with minimum occurrence of 15 times are shown in the map. Keywords shown with the same color are closely related and listed together.

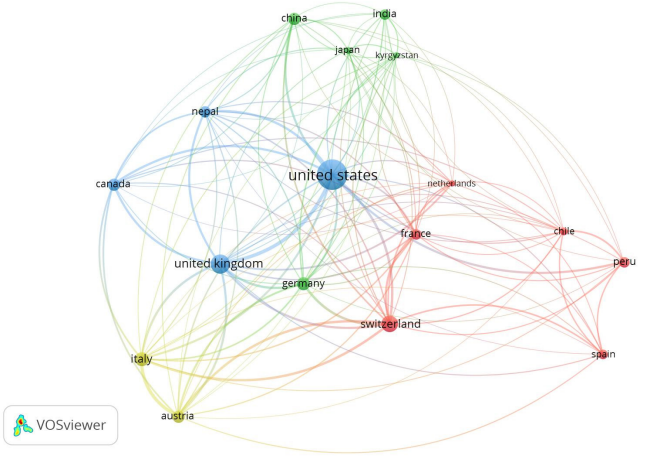

Figure 3. Network Visualization Map of International Collaboration Among Countries With a Minimum of 15 Publications. The size of the circle represents productivity and the thickness of the connecting lines represents collaboration strength. The same colors represent countries from one cluster.

of chronic and subacute mountain sickness. Older papers understandably tended to accumulate a larger number of citations and citations to HAMB papers were received from a diverse array of other academic journals, with the top citing journal in 2018 being a prominent physiology journal. There were relatively few citations to HAMB articles from travel medicine journals, which is surprising given the close interaction between these disciplines. It may be beneficial to develop closer links between high altitude medicine and travel medicine, for example in the joint hosting of scientific conferences. This is particularly pertinent given the educational needs of travel medicine clinicians, who are often consulted by international travelers for pre-travel health advice and recommendations for altitude illness chemoprophylaxis.[27]

There was a clear geographic dominance in both volume of research output and citations generated, with epicenters identified in Europe and Asia. A quarter of the most productive institutions were based in the USA. Despite the global reach of the ISMM, most countries do not appear to be research active in this field or at least have not yet published in the society journal. While there was a strong gender imbalance towards male authorship, with a 3:1 male-female ratio, the proportion of female authors has increased steadily over time and this should be actively encouraged. Collaboration between authors and international institutions on high altitude medicine articles has also increased over time, reflecting perhaps the work of the ISMM in promoting activity in high altitude medicine globally. We have recently observed a similar collaboration trend in the emerging discipline of preventive cardiology.[15]

The most prolific author in HAMB was the renowned respiratory physiologist, John B. West, who served as editor-in-chief of the journal for a large part of its existence (2000-2015). The total number of articles attributed to this leading academic high altitude scientist may have been inflated by

Table 9. Journals Citing High Altitude Medicine and Biology Most in 2018

Rank	Citing Journal	Impact Factor	Total Citation Count[a]	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008 to 2000
1	Front Physiol	3.201	149	5	10	11	7	14	11	2	5	7	8	69
2	High Alt Med Biol	1.490	115	5	10	7	4	7	7	4	6	3	8	54
3	PLoS One	2.776	34	1	1	4	3	3	3	4	5	1	0	9
4	J Appl Physiol	3.140	32	0	2	1	1	6	3	2	2	0	1	14
5	Wild Environ Med	1.450	31	0	2	3	1	8	0	2	1	1	2	11
6	Cochrane Db Syst Rev	7.755	23	0	0	1	1	3	0	2	1	2	1	12
7	Front Endocrinol	3.634	22	1	2	2	2	2	1	1	1	1	0	9
8	Sci Rep-UK	4.011	19	0	1	1	2	2	1	0	2	1	0	9
9	Expert Opin Pharmaco	3.038	18	3	2	1	1	2	0	1	0	2	0	6
10	Medicine	1.870	14	2	0	1	0	0	0	1	1	1	1	7
11	Scand J Med Sci Spor	3.631	14	0	1	1	1	3	1	1	0	2	0	4
12	Can Respir J	1.803	12	0	0	1	2	0	0	0	0	1	0	8
13	Am J Physiol-Reg I	3.176	11	0	0	1	0	2	1	0	0	0	0	7
14	Eur J Appl Physiol	3.055	11	1	1	1	0	1	0	1	0	0	3	3
15	J Physiol-London	4.984	11	0	0	1	1	0	1	0	1	0	2	5
16	Life Sci	3.448	11	0	1	0	1	1	1	0	0	3	0	4
17	J Travel Med	4.155	10	1	0	0	2	2	1	0	1	0	1	2
18	Int J Disast Risk Sc	2.162	8	0	2	0	0	1	0	0	0	1	0	4
19	Int J Mol Sci	4.183	8	0	0	0	1	0	1	1	0	2	0	3
20	Resp Med	3.237	8	0	0	1	1	1	1	0	0	0	1	3

Source: Web of Science, Journal Citation Reports (JCR). Accessed March 18, 2020.
No data available for 2019 when accessed.
[a] Citations made to articles published in High Altitude Medicine and Biology.

Table 10. Top Cited Articles in High Altitude Medicine

Rank	Authors	Year	Institution	Title	Type of Article	Citation Count
1	León-Velarde et al	2005	Cayetano Heredia University	Consensus statement on chronic and subacute high altitude diseases	Review	237
2	Moore	2001	University of Colorado	Human genetic adaptation to high altitude	Review	192
3	Hackett and Roach	2004	University of Colorado	High altitude cerebral edema	Review	166
4	Levine	2002	University of Texas Southwestern Medical Center	Intermittent hypoxic training: Fact and fancy	Review	134
5	Bärtsch et al	2004	Heidelberg University	Acute mountain sickness: Controversies and advances	Review	120
6	Wu and Kayser	2006	High Altitude Medical Research Institute, Xining	High altitude adaptation in Tibetans	Review	117
7	Basnyat et al	2003	Nepal International Clinic	Efficacy of low-dose acetazolamide (125 mg BID) for the prophylaxis of acute mountain sickness: A prospective, double-blind, randomized, placebo-controlled trial	Original Research	107
8	Bailey and Davies	2001	University of Glamorgan	Acute mountain sickness; prophylactic benefits of antioxidant vitamin supplementation at high altitude	Original Research	106
9	Serebrovskaya	2002	Bogomoletz Institute of Physiology of National Academy of Sciences of Ukraine	Intermittent hypoxia research in the former Soviet Union and the Commonwealth of Independent States: History and review of the concept and selected applications	Review	105
10	Storz and Moriyama	2008	University of Nebraska	Mechanisms of hemoglobin adaptation to high altitude hypoxia	Review	98

Source: Scopus. Accessed March 10, 2020.

the large number of editorials published in his role as journal editor. The most influential author as measured by cumulative citation counts was also a physiologist, Fabiola Léon-Velarde from Peru. This highlights the close connections between the disciplines of high altitude medicine and physiology. It is possible that other influential leaders in the field published their work in non-specialist journals and may thus not be recognized among the top authors in our citation analysis.

While the current bibliometric analysis reflects activity in this journal since it was founded in 2000, we recommend that a similar bibliometric analysis be performed at ten-yearly intervals, to allow for the effect of any editorial interventions in the interim to be discerned. Our analysis, though comprehensive, is limited in its capacity to truly quantify the full influence of individual authors and papers, given the inherent flaws in the process of citation metrics, including bias that results from excessive self-citation.[28] Our analysis cannot identify with any authority the changing editorial board strategies that may have influenced the article profile of the journal since its inception. The body of knowledge, while derived from multiple reputable sources, cannot be considered to be exhaustive and must also be subject to critical review and revision. Despite its modest impact factor which has declined in recent years, HAMB is regarded as a specialist journal in high altitude medicine with a strong affiliation to the ISMM. It would be of interest, however, to extend the bibliometric analysis to the level of the discipline as a whole, to incorporate articles published in other journals.[11] Travel medicine academic journals, including *International Journal of Travel Medicine and Global Health*, should issue calls for submission of manuscripts under the high altitude medicine theme, with particular emphasis on exploring the relevance of high altitude physiology and illness to recreational travelers.

Conclusion

We have performed the first comprehensive bibliometric analysis in high altitude medicine and mapped articles against a proposed body of knowledge. Our analysis has identified a broad range of topics published by almost 3000 authors from over 1000 institutions, with a particular focus on acclimatization, cardiovascular physiology, and acute mountain sickness. The USA has a dominant position in terms of institutional output, but most of the leading countries in terms of research volume and impact as measured by citations are based in Europe and Asia. There was a discernible longitudinal trend towards enhanced collaboration between authors from different institutions and countries, reflecting the academic maturation of high altitude medicine as a scholarly discipline. Efforts to increase the research activity in neglected topics and to promote greater collaboration between high altitude medicine and neighboring fields of study such as travel medicine may yield reciprocal benefits. Travel medicine journals should proactively solicit manuscripts from high altitude medicine researchers. Academic journals should not feel threatened by bibliometric analysis, but rather recognize it as a legitimate tool which serves the best interests of their contributors and readers and helps to raise the profile of their discipline.

Authors' Contributions

Both authors contributed equally to the conception, design, data acquisition, data analysis, drafting, and review of this manuscript. Each author has reviewed and approved the final draft before submission.

Research Highlights

What Is Already Known?

High altitude travel is a popular activity but one that carries attendant health risks, including high altitude illness and traumatic injuries. High altitude medicine is a relatively new scientific discipline but its evidence base is growing.

What This Study Adds?

We have developed the first theoretical body of knowledge in high altitude medicine and performed the first bibliometric analysis in the field. Interesting publication trends have emerged. Efforts to promote greater collaboration between high altitude medicine and related fields of study such as travel medicine should be encouraged. Travel medicine journals should actively solicit manuscripts which relate to high altitude travel risks and their mitigation.

Conflict of Interest Disclosures

The authors declare that they have no conflicts of interest.

Ethical Approval

Not applicable.

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References

1. Cabada MM, Maldonado F, Mozo K, Seas C, Gotuzzo E. Self-reported health problems among travelers visiting Cuzco: A Peruvian Airport Survey. Travel Med Infect Dis. 2009;7(1):25-29. doi:10.1016/j.tmaid.2008.09.005.
2. Wu TY, Ding SQ, Zhang SL, et al. Altitude illness in Qinghai–Tibet railroad passengers. High Alt Med Biol. 2010;11(3):189-198. doi:10.1089/ham.2009.1047.
3. Mieske K, Flaherty G, O'Brien T. Journeys to high altitude–risks and recommendations for travelers with preexisting medical conditions. J Travel Med. 2010;17(1):48-62. doi:10.1111/j.1708-8305.2009.00369.x.
4. Flaherty GT, Chua CW. High altitude travel and mental health. J Travel Med. 2018;25(1). doi:10.1093/jtm/tay025.
5. Nieto Estrada VH, Molano Franco D, Medina RD, Gonzalez Garay AG, Martí-Carvajal AJ, Arevalo-Rodriguez I. Interventions for preventing high altitude illness: part 1. Commonly-used classes of drugs. Cochrane Database Syst Rev. 2017;6(6):CD009761. doi:10.1002/14651858.CD009761.pub2.
6. Simancas-Racines D, Arevalo-Rodriguez I, Osorio D, Franco JV, Xu Y, Hidalgo R. Interventions for treating acute high altitude illness. Cochrane Database Syst Rev. 2018;6(6):CD009567. doi:10.1002/14651858.CD009567.pub2.
7. Brants A, Metcalfe T. Practical tips for working as an expedition doctor on high-altitude expeditions. High Alt Med Biol. 2017;18(3):193-198. doi:10.1089/ham.2016.0158.
8. Hillebrandt D. UIAA/ICAR/ISMM Diploma of Mountain Medicine. High Alt Med Biol. 2011;12(3):291. doi:10.1089/ham.2011.1034.
9. Kozarsky P. The Body of Knowledge for the practice of travel medicine–2006. J Travel Med. 2006;13(5):251-254. doi:10.1111/j.1708-8305.2006.00054.x.
10. Cronin B. Bibliometrics and beyond: Some thoughts on web-based citation analysis. Journal of Information Science. 2001;27(1):1-7. doi:10.1177/016555150102700101.
11. Flaherty GT, Browne DP. Citation analysis of the most influential publications in travel medicine. Int J Travel Med Glob Health. 2016;4(4):122-131. doi:10.21859/IJTMGH-040407.
12. Flaherty GT, Yap KL. Bibliometric analysis and curriculum mapping of travel medicine research. J Travel Med. 2017;24(5). doi:10.1093/jtm/tax024.
13. Oh KE, Flaherty GT. Travel medicine research in the new millennium: A bibliometric analysis of articles published in Travel Medicine and Infectious Disease, 2003-2019. Travel Med Infect Dis. 2020;33:101549. doi:10.1016/j.tmaid.2019.101549.
14. Glover SW, Bowen SL. Bibliometric analysis of research published in Tropical Medicine and International Health 1996-2003. Trop Med Int Health. 2004;9(12):1327-1330. doi:10.1111/j.1365-3156.2004.01331.x.
15. Manyangu G, Dineen B, Geoghegan R, Flaherty G. Descriptive bibliometric analysis of global publications in lifestyle-based preventive cardiology. Eur J Prev Cardiol. 2019;2047487319854827. doi:10.1177/2047487319854827.
16. Michalopoulos A, Falagas ME. A bibliometric analysis of global research production in respiratory medicine. Chest. 2005; 128(6):3993-3998. doi:10.1378/chest.128.6.3993.
17. Bonilla-Aldana DK, Quintero-Rada K, Montoya-Posada JP, et al. SARS-CoV, MERS-CoV and now the 2019-novel CoV: Have we investigated enough about coronaviruses? – A bibliometric analysis. Travel Med Infect Dis. 2020;33:101566. doi:10.1016/j.tmaid.2020.101566.
18. Li Q, Jiang Y, Zhang M. National representation in the emergency medicine literature: A bibliometric analysis of highly cited journals. Am J Emerg Med. 2012;30(8):1530-1534. doi:10.1016/j.ajem.2011.12.023.
19. Rymer BC, Choa RM. A worldwide bibliometric analysis of published literature in Plastic and Reconstructive Surgery. J Plast Reconstr Aesthet Surg. 2015;68(9):1304-1308. doi:10.1016/j.bjps.2015.05.024.
20. Brandt JS, Hadaya O, Schuster M, Rosen T, Sauer MV, Ananth CV. A bibliometric analysis of top-cited journal articles in obstetrics and gynecology. JAMA Netw Open. 2019;2(12):e1918007. doi:10.1001/jamanetworkopen.2019.18007.
21. International Climbing and Mountaineering Federation. Diploma in Mountain Medicine. 2019. https://www.theuiaa.org/mountain-medicine/diploma-in-mountain-medicine. Accessed January 20, 2020.
22. Schotten M, el Aisati M, Meester WJN, Steiginga S, Ross CA. A brief history of Scopus: The world's largest abstract and citation database of scientific literature. In: Cantu-Ortiz FJ, ed. Research Analytics: Boosting University Productivity and Competitiveness through Scientometrics. New York: Taylor and Francis; 2017:31–58.
23. Sweileh WM, Al-Jabi SW, AbuTaha AS, Zyoud SH, Anayah FMA, Sawalha AF. Bibliometric analysis of worldwide scientific literature in mobile-health: 2006-2016. BMC Med Inform Decis Mak. 2017;17(1):72. doi:10.1186/s12911-017-0476-7.
24. Waltman L, van Eck NJ, and Noyons ECM. (2010). A unified approach to mapping and clustering of bibliometric networks. Journal of Informetrics. 2010;4(4):629-635. doi:10.1016/j.joi.2010.07.002.
25. Perianes-Rodriguez A, Waltman L, van Eck NJ. Constructing bibliometric networks: A comparison between full and fractional counting. Journal of Informetrics. 2016;10(4):1178-1195. doi:10.1016/j.joi.2016.10.006.
26. Oxford Centre for Evidence-Based Medicine Levels of Evidence Working Group. The Oxford 2011 Levels of Evidence. 2011. https://www.cebm.net/2016/05/ocebm-levels-of-evidence/. Accessed June 13, 2020.
27. Flaherty GT, Kennedy KM. Preparing patients for travel to high altitude: advice on travel health and chemoprophylaxis. Br J Gen Pract. 2016;66(642):e62-e64. doi:10.3399/bjgp16X683377.
28. Moustafa K. Aberration of the citation. Account Res. 2016;23(4):230–244. doi:10.1080/08989621.2015.1127763.