





# Bibliometric analysis of main diseases due to exposure to altitude in the world

Análise bibliométrica das principais doenças decorrentes da exposição à altitude no mundo

Christian Renzo Aquino-Canchari , Nicole Stephanie Baquerizo-Quispe , Diana Maricielo Florez-Soto ,  
Adriana Isabel Lorenzo-Roque 

## ABSTRACT

**Introduction:** Around 140 million people in the world live in high-altitude regions; however, there are few bibliometric studies. **Objective:** Describe the scientific production of the main diseases due to exposure to altitude in the world. **Methods:** Observational study, bibliometric type. After a systematic search in Scopus, original articles were included, whose main variable was mountain sickness, high-altitude cerebral edema and high-altitude pulmonary edema. Characteristics of each study were manually extracted and analyzed using descriptive statistics. **Results:** 2305 articles were found on mountain sickness (n=1531), high-altitude pulmonary edema (n=549) and high-altitude cerebral edema (n=225), respectively, in Scopus. Regarding the most influential journal was *High Altitude Medicine and Biology* in all three diseases, the country with the highest number of articles was the United States (458, 168 and 75), the most used language was English (91.31%, 85.33% and 84.19%), the author with the highest number of publications was Bartsh P. (2.94%, 18.60% and 3.42%) and most of the articles were open access (41.08%, 42.06% and 76.53%), respectively. **Conclusion:** The scientific production of original articles on mountain sickness, high-altitude pulmonary edema and high-altitude cerebral edema in Scopus has increased in recent years; however, it is still scarce compared to other diseases.

**Keywords:** Bibliometrics, Altitude sickness, Citation databases, Journal article (Source: Terms-MeSH).

**Contribution to literature:** It is a priority to investigate in altitude since there is currently more than a third of the world's population living in these geographical areas. Additionally, there are no bibliometric studies in the world that characterize the scientific production on the most frequent diseases due to exposure to altitude.

## RESUMO

**Introdução:** Cerca de 140 milhões de pessoas no mundo vivem em regiões de grande altitude, porém, existem poucos estudos bibliométricos. **Objetivo:** Descrever a produção científica sobre as principais doenças decorrentes da exposição à altitude no mundo. **Métodos:** Estudo observacional, do tipo bibliométrico. Após busca sistemática no Scopus, foram incluídos artigos originais, cuja variável principal foi mal da montanha, edema cerebral de altitude e edema pulmonar de altitude. As características de cada estudo foram extraídas manualmente e analisadas por meio de estatística descritiva. **Resultados:** Foram encontrados 2.305 artigos sobre mal da montanha (n=1.531), edema pulmonar de altitude (n=549) e edema cerebral de altitude (n=225), respectivamente no Scopus. Em relação ao periódico mais influente foi *High Altitude Medicine and Biology* nas três doenças, o país com maior número de artigos foi os Estados Unidos (458, 168 e 75), o idioma mais utilizado foi o inglês (91,31%, 85,33% e 84,19%), o autor com maior número de publicações foi Bartsh P. (2,94%, 18,60% e 3,42%) e a maioria dos artigos foi de acesso aberto (41,08%, 42,06% e 76,53%), respectivamente. **Conclusão:** A produção científica de artigos originais sobre mal da montanha, edema pulmonar de altitude e edema cerebral de altitude em Scopus tem aumentado nos últimos anos, porém ainda é escassa em comparação com outras doenças.

**Palavras-chave:** Bibliometria, Mal de altitude, Bancos de dados de citação, Artigo de jornal (Fonte: Terms-MeSH)

Universidad Peruana los Andes Sociedad Científica de Estudiantes de Medicina Los Andes. Facultad de Medicina Humana, Perú



## INTRODUCTION

It is estimated that more than 140 million human beings live above 2,500 meters of altitude in the world and up to 10% of them suffer from diseases due to exposure to altitude<sup>1</sup>. In addition, more than 100 million people climb to high mountainous regions around the world each year, also at non-extreme altitudes (less than 5,500 m), between 10 and 85% are affected by altitude<sup>2</sup>.

An inadequate adaptation to altitude triggers certain pathologies, which depend on the altitude reached, speed of ascent, time of exposure to altitude and the physiological response of the individual<sup>2</sup>. Among the most common pathologies, mountain sickness or altitude sickness (MS) stands out. Of these, the acute presentation is the most frequent; it is the most common disease induced by hypobaric hypoxia, its chronic manifestation being Monge's disease. There are two serious forms of acute mountain sickness that require urgent treatment: high-altitude pulmonary edema (HAPE) and high-altitude cerebral edema (HACE), the first attributable to a failure in the blood-brain barrier due to mechanical or cytotoxic aggression or difficulty in draining the cerebral venous flow<sup>2</sup> and the second due to generalized pulmonary arterial vasoconstriction caused by hypoxia and an increase in capillary permeability<sup>3</sup>.

The increase in research in recent years has led the scientific community to propose its measurement, giving rise to bibliometric studies, so bibliometrics can not only help researchers to quickly understand critical research points and trends development of a specific field of research, but also assess the distribution of countries/regions, authors and journals in the field of research, laying the foundations for the direction and development of future research<sup>4</sup>.

Currently, there are few bibliometric studies in the world that characterize the scientific information on the MS, HACE and HAPE, despite the considerable number of countries that have cities in their geography that exceed 2500 meters above sea level.

Due to the above, the objective of the work is to describe the scientific production on main diseases due to exposure to altitude in the world in the Scopus database.

## METHODS

### Study design

Observational study, bibliometric type.

### Source of information

The Scopus database (<https://www.scopus.com/home.uri>) was used to collect the articles published on MS, HACE and HAPE in the world. The use of Scopus as a source of information is justified because it is a bibliographic database of abstracts and citations of articles from scientific journals with more than 22,000 titles from 5,000 international publishers, which allows a multidisciplinary view of science, and especially of medicine<sup>5</sup>.

### Inclusion and exclusion criteria

Original articles on MM, RCT and EPA indexed in the Scopus database were included and articles whose study population was not human beings were excluded.

### Search Strategy

The search was performed on March 04, 2022. The search strategy used for the present study was:

#### a) Mountain Sickness

**TITLE-ABS-KEY** ("Mal de montaña" OR "altitude Sickness\*" OR "acute mountain sickness" OR "Mountain sickness" OR "chronic mountain sickness" OR "Enfermedad de Monge" OR "Monge's disease") AND (PUBYEAR > 1988) AND (LIMIT TO (SRCTYPE, "j")) AND (LIMIT TO (DOCTYPE, "ar")) AND (EXCLUDE (PUBYEAR, 2022))

#### b) High Altitude Cerebral Edema

**TITLE-ABS-KEY** ("high-altitude cerebral edema" OR "high-altitude cerebral edema") AND (PUBYEAR > 1988) AND (LIMIT TO (SRCTYPE, "j")) AND (LIMIT TO (DOCTYPE, "ar")) AND (EXCLUDE (PUBYEAR, 2022))

#### c) High Altitude Pulmonary Edema

**TITLE-ABS-KEY** ("high-altitude pulmonary edema" OR "high-altitude pulmonary edema AND (PUBYEAR > 1988) AND (LIMIT TO (SRCTYPE, "j")) AND (LIMIT TO (DOCTYPE, "ar")) AND (EXCLUDE (PUBYEAR, 2022))

### Analysis variables

The bibliometric analysis of the scientific production on MS, HACE and HAPE in the world, was evaluated according to the following variables:

- 1) Scientific production: quantifies the number of publications in each thematic area per year.
- 2) Editorial characteristics: scientific journals with greater production.
- 3) Characteristics of the authors: institutional affiliation of the corresponding author.
- 4) Characteristics of the published articles: financing entity, country, language and type of access, most cited articles.
- 5) Network of keywords: main descriptors in the set of documents analyzed.

### Ethical considerations

This research complies with the bioethical principles of the Declaration of Helsinki, and the research project was approved by the Institutional Ethics Committee of the Faculty of Medicine of the Universidad Peruana Los Andes through resolution No. 017-2022-CE-FMH -UPLA.

## RESULTS

### Data Collection

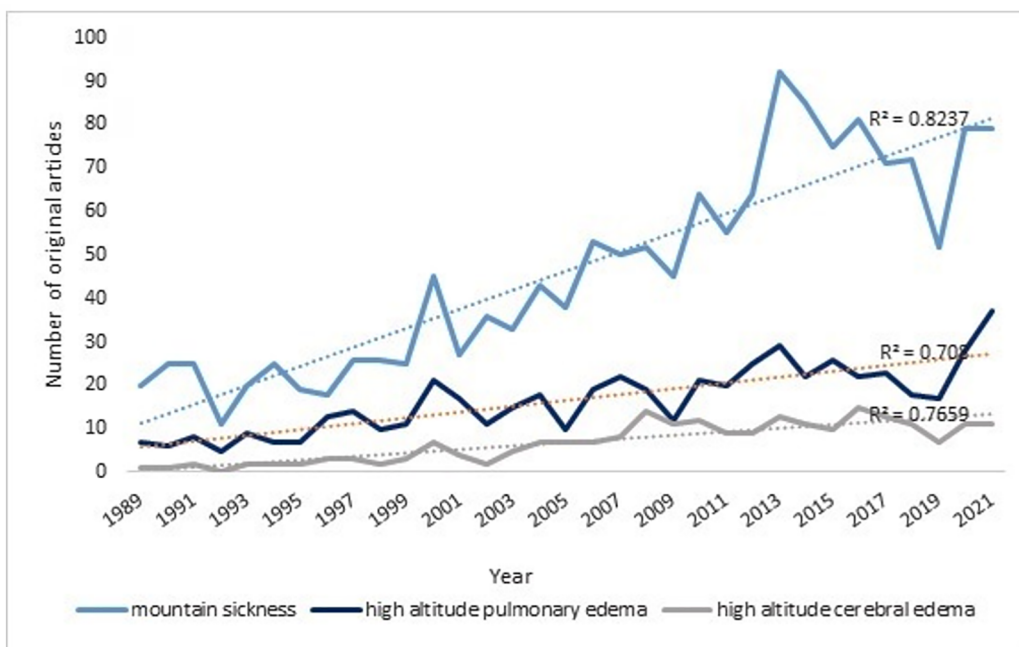
The data was collected from the search strategies mentioned above, which were downloaded from the Scopus portal in CSV format, performing quality control by two authors, eliminating inconsistencies.

### Analysis of data

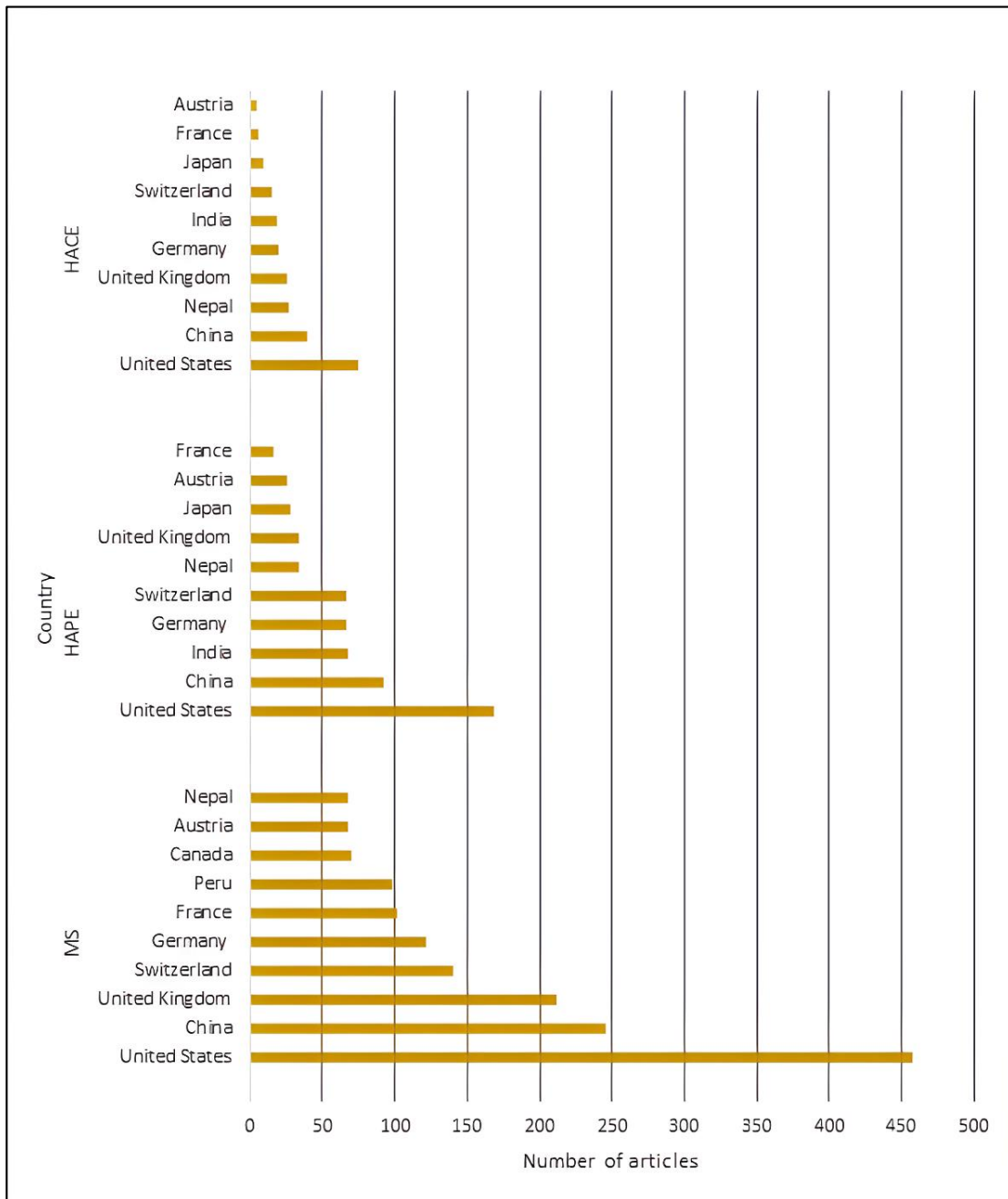
The data obtained were collected in files of the Microsoft Excel 2016 program, the was processed using the statistical program SPSS v 21.0, through frequency distribution tables. To complement the study, the keyword co-occurrence networks generated with VOSviewer v1.6.18<sup>6</sup> were analyzed.

Two thousand three hundred and five original articles were analyzed (MS= 1531 articles, HAPE=549 articles and HACE=225 articles). It can be seen that the number of publications has experienced a notable increase in the last decade. Only 51.93% of the total documents were published from 1989 to 2011. However, from 2011 the number of publications increased with maximum production peaks in 2013 for the MS (n=92), in 2021 for HAPE (n=37) and for HACE in 2016 (n=15). **Figure 1**

Regarding the geographical distribution of the articles, we can see in **Figure 2** that the country with the highest scientific production on MS, HAPE and HACE was the United States, with 458, 168 and 75 documents, respectively and the People’s Republic of China with 246, 92 and 40 documents, respectively. In



**Figure 1.** Distribution by year of the Scientific production on the MS, HAPE and HACE.



**Figure 2.** Top 10 contributing countries of original articles on the MS, HAPE and HACE, in the Scopus database from 1989 to 2021.

addition, note a greater presence of European countries in the top ten of countries with the highest production.

Regarding the journals with the highest production, leadership of the journal High Altitude Medicine and Biology is observed with respect to MS 211 (13.78%), HAPE 68 (12.39%) and HACE 38 (16.24%), followed by Wilderness And Environmental Medicine, MS 95 (6.20%), HAPE 41 (7.47%) and

HACE 22 (9.40%), and in third place the Journal of Applied Physiology, MS 75 (4.09%), HAPE 29 (5.28%) and HACE 9(3, 85%). **Table 1**

The most influential funding entities were the National Heart, Lung, and Blood Institute for the HAPE 39 (5.79%), HACE 8 (2.61%) and the National Natural Science Foundation of China for the MS 57 (3.95%). **Table 2**

Regarding the affiliation of the corresponding author, a predominance of the Universidad Peruana Cayetano is observed for MS 94 (6.14%), University of Washington for HAPE 27 (4.92%) and Third Military Medical University 15 (4.24%). **Table 3**

Regarding the authors who contributed the most, it was observed that Bartsh P. had a greater number of publications compared to MS and HAPE with 45 (2.94%) and 40 (18.60%), respectively, and compared to the HACE, it was Basnyat B 15 (6, 41%). **Table 4**

Concerning the ten most cited articles in the Scopus database, the title with the highest number of citations on the MS was Natural Selection on HAPES1

(HIF2 $\alpha$ ) associated with low hemoglobin concentration in Tibetan highlanders (555 citations), concerning EPA was Hypoxic pulmonary vasoconstriction (425 citations) and HACE was Acute high-altitude illnesses (266 citations). **Suppl. 1**

Regarding the type of access, the majority was open access MS 576 (41.08%), HAPE 196 (42.06%) and HACE 75 (76.53). Most of the articles were written in English, MS 1398 (91.31%), HAPE 471 (85.33%) and HACE 197 (84.19%). **Suppl. 2**

It is observed that the descriptor with the highest frequency of appearances for MS, HAPE and HACE was (1255), lung edema (368), altitude desired (179), respectively. **Suppl. 3**

**Table 1**

The 10 main scientific journals contributing original articles on the MS, HAPE and HACE, in the Scopus database from 1989 to 2021.

	Journal	MS		Journal	HAPE		Journal	HACE	
		n	%		n	%		n	%
1	High Altitude Medicine and Biology	211	13.78%	High Altitude Medicine and Biology	68	12.39%	High Altitude Medicine and Biology	38	16.24
2	Wilderness and Environmental Medicine	95	6.20%	Wilderness And Environmental Medicine	41	7.47%	Wilderness And Environmental Medicine	22	9.40
3	Journal of Applied Physiology	75	4.09%	Journal Of Applied Physiology	29	5.28%	Journal Of Applied Physiology	9	3.85
4	Aviation Space and Environmental Medicine	52	3.39%	Chest	22	4.01%	Chinese Critical Care Medicine	4	1.71
5	Frontiers in Physiology	28	1.82%	Respiratory Physiology And Neurobiology	14	2.55%	PLoS One	4	1.71
6	Chest	25	1.63%	American Journal of Respiratory and Critical Care Medicine	12	2.19%	Aerospace Medicine and Human Performance	3	1.28
7	PLoS One	23	1.50%	Zhongguo Yingyong Shenglixue Zazhi Chinese Journal of Applied Physiology	8	1.46%	Journal of Travel Medicine	3	1.28
8	Journal of Travel Medicine	20	1.31%	Circulation	7	1.28%	Neurology	3	1.28
9	Journal of Wilderness Medicine	20	1.31%	Medical Journal Armed Forces India	7	1.28%	Stroke	3	1.28
10	Experimental Physiology	18	1.17%	Aviation Space and Environmental Medicine	6	1.09%	American Journal of the Medical Sciences	2	0.85

-MS: mountain sickness; HAPE: high altitude pulmonary edema; HACE: High altitude cerebral edema.

**Table 2**

The 10 main financing entities of original articles on the MS, HAPE and HACE, in the Scopus database from 1989 to 2021.

	Institution financier	MS		Institution financier	HAPE		Institution financier	HACE	
		n	%		n	%		n	%
1	National Natural Science Foundation of China	57	3.95	National Heart, Lung, and Blood Institute	39	5.79	National Heart, Lung, and Blood Institute	8	2.61
2	National Institutes of Health	53	3.68	National Institutes of Health	27	4.01	National Natural Science Foundation of China	8	2.61
3	National Heart, Lung and Blood Institute	44	3.05	National Natural Science Foundation of China	22	3.27	National Institutes of Health	5	1.63
4	U.S Department of Health and Human Services	28	1.94	U.S. Department of Health and Human Services	16	2.38	National Institute of Neurological Disorders and Stroke, EEUU	4	1.31
5	Natural Sciences and Engineering Research Council of Canada	17	1.18	Defence Research and Development Organisation	11	1.63	U.S. Department of Health and Human Services	4	1.31
6	Japan Society for the Promotion of Science	15	1.04	Ministry of Defence Delhi, India	9	1.34	Defence Research and Development Organisation, Delhi, India	3	0.98
7	National Key Research and Development Program of China	15	1.04	National Center for Research Resources	9	1.34	National Key Research and Development Program of China	3	0.98
8	Ministry of Health of the People's Republic of China	14	0.97	Council of Scientific and Industrial Research, India	7	1.04	Natural Science Foundation of Gansu Province	3	0.98
9	Wilderness Medical Society	14	0.97	Ministry of Science and Technology of the People's Republic of China	6	0.89	Ministry of Science and Technology of the People's Republic of China	2	0.65
10	National Institute of Neurological Disorders and Stroke	13	0.90	Schweizerischer Nationalfonds zur Förderung der Wissenschaftlichen Forschung	5	0.74	National Center for Research Resources	2	0.65

- MS: mountain sickness; HAPE: high altitude pulmonary edema; HACE: High altitude cerebral edema

**Table 3**

Affiliation of the corresponding author of original articles on the MS, HAPE and HACE, in the Scopus database from 1989 to 2021.

Affiliation	MS		Affiliation	HAPE		Affiliation	HACE	
	n	%		n	%		n	%
Universidad Peruana Cayetano Heredia	94	6.14	University of Washington	27	4.92	Third Military Medical University	15	4.24
Third Military Medical University	74	4.83	Zürich University Hospital	27	4.92	Nepal International Clinic	12	3.39
University of Colorado Anschutz Medical Campus	57	3.72	Heidelberg University Hospital	25	4.55	Heidelberg University Hospital	10	2.82

Affiliation	MS		Affiliation	HAPE		Affiliation	HACE	
	n	%		n	%		n	%
Zürich University Hospital	51	3.33	Defence Institute of Physiology and Allied Sciences India	24	4.37	University of Washington	10	2.82
United States Army Research Institute of Environmental Medicine	45	2.94	Shinshu University Faculty of Medicine	23	4.19	University Hospital Bern	7	1.98
University of Washington	44	2.87	Heidelberg University Hospital	23	4.19	University of Colorado School of Medicine	7	1.98
Heidelberg University Hospital	39	2.55	Institute of Genomics and Integrative Biology India	20	3.64	Himalayan Rescue Association	6	1.69
University Hospital Bern	34	2.22	University of Colorado Anschutz Medical Campus	19	3.46	Defence Institute of Physiology and Allied Sciences India	6	1.69
University of California, San Diego	34	2.22	University Hospital Bern	17	3.10	Massachusetts General Hospital	6	1.69
University of Colorado School of Medicine	32	2.09	Centre Hospitalier Universitaire Vaudois	17	3.10	Friends of Patan Hospital Nepal	6	1.69

- MS: mountain sickness; HAPE: high altitude pulmonary edema; HACE: High altitude cerebral edema

**Table 4**

The 10 main contributing authors of original articles on the MS, HAPE and HACE, in the Scopus database from 1989 to 2021.

	Autor	MS		Autor	HAPE		Autor	HACE	
		n	%		n	%		n	%
1	Bartsh P.	45	2.94	Bartsh P	40	18.60	Basnyat B.	15	6.41
2	Basnyat B.	43	2.81	Maggiorini M.	27	12.56	Bartsch P.	8	3.42
3	Maggiorini M.	39	2.55	Swenson ER	25	11.63	Swenson ER	7	2.99
4	Huang L.	34	2.22	Kobayashi T.	22	10.23	Hackett PH	6	2.56
5	León-Velarde F.	32	2.09	Mairbaurl H.	20	9.30	Zafrén K.	6	2.56
6	Muza SR.	32	2.09	Scherrer U.	20	9.30	Gao YQ	5	2.14
7	Swenson ER.	32	2.09	Kubo K.	18	8.37	Bansal A.	4	1.71
8	Richalet JP.	31	2.02	Sartori C.	15	6.98	Gao Y.	4	1.71
9	Cymerman A.	28	1.83	Basnyat B.	14	6.51	Imray CHE	4	1.71
10	Kayser B.	28	1.83	Dehnert C.	14	6.51	Küpper T.	4	1.71

- MS: mountain sickness; HAPE: high altitude pulmonary edema; HACE: High altitude cerebral edema.

**Suppl. 1**

The 10 most cited original articles on the MS, HAPE and HACE, in the Scopus database from 1989 to 2021.

	First author	Title	Citations	Journal	Year	Q
<b>MS</b>						
1	Beall CM., et al.	Natural selection on EPAS1 (HIF2α) associated with low hemoglobin concentration in Tibetan highlanders	555	Proceedings of the National Academy of Sciences of the United States of America	2010	Q1



	<b>First author</b>	<b>Title</b>	<b>Citations</b>	<b>Journal</b>	<b>Year</b>	<b>Q</b>
2	Honigman B, et al.	Acute mountain sickness in a general tourist population at moderate altitudes	359	Annals of Internal Medicine	1993	Q1
3	Haase VH.	Regulation of erythropoiesis by hypoxia-inducible factors	358	Blood Reviews	2013	Q1
4	Moore LG, et al	Human Adaptation to High Altitude: Regional and Life-Cycle Perspectives	275	Yearbook of Physical Anthropology	1998	Q1
5	Hill DR.	Health problems in a large cohort of Americans traveling to developing countries	267	Journal of Travel Medicine	2000	Q1
6	Maggiorini M, et al.	Prevalence of acute mountain sickness in the Swiss Alps	264	British Medical Journal	1990	Q3
7	Schneider M, et al.	Acute mountain sickness: Influence of susceptibility, preexposure, and ascent rate	232	Medicine and Science in Sports and Exercise	2002	Q1
8	Moore LG.	Human genetic adaptation to high altitude	225	High Altitude Medicine and Biology	2001	Q1
9	Roach RC, et al	Exercise exacerbates acute mountain sickness at simulated high altitude	182	Journal of Applied Physiology	2000	Q2
10	Roach RC, et al.	The 2018 lake louise acute mountain sickness score	176	High Altitude Medicine and Biology	2018	Q1
<b>HAPE</b>						
1	Sylvester JT, et al.	Hypoxic pulmonary vasoconstriction	425	Physiological Reviews	2012	Q1
2	West JB, et al	Stress failure in pulmonary capillaries	422	Journal of Applied Physiology	1991	Q2
3	Sartori C, et al.	Salmeterol for the prevention of high-altitude pulmonary edema	342	New England Journal of Medicine	2002	Q1
4	Maggiorini M, et al	High-altitude pulmonary edema is initially caused by an increase in capillary pressure	342	Circulation	2001	Q1
5	Bartsch P, et al.	Prevention of High-Altitude Pulmonary Edema by Nifedipine	320	New England Journal of Medicine	1991	Q1
6	Grocott MPW, et al.	Arterial blood gases and oxygen content in climbers on Mount Everest	300	New England Journal of Medicine	2009	Q1
7	Swenson ER, et al	Pathogenesis of high-altitude pulmonary edema: Inflammation is not an etiologic factor	268	Journal of the American Medical Association	2002	Q1
8	Scherrer U, et al.	Inhaled nitric oxide for high-altitude pulmonary edema	268	New England Journal of Medicine	1996	Q1
9	Bärtsch P, et al.	Acute high-altitude illnesses	266	New England Journal of Medicine	2013	Q1
10	Maggiorini M., et al.	Both tadalafil and dexamethasone may reduce the incidence of high-altitude pulmonary edema: A randomized trial	212	Annals of Internal Medicine	2006	Q1
<b>HACE</b>						
1	Bärtsch P, et al.	Acute high-altitude illnesses	266	New England Journal of Medicine	2013	Q1



	First author	Title	Citations	Journal	Year	Q
2	Hackett PH, et al.	High-altitude cerebral edema evaluated with magnetic resonance imaging. Clinical correlation and pathophysiology	239	Journal of the American Medical Association	1998	Q1
3	Askew EW.	Work at high altitude and oxidative stress: Antioxidant nutrients	177	Toxicology	2002	Q2
4	Krasney JA.	A neurogenic basis for acute altitude illness	95	Medicine and Science in Sports and Exercise	1994	Q1
5	Basnyat B, et al.	Disoriented and ataxic pilgrims: An epidemiological study of acute mountain sickness and high-altitude cerebral edema at a sacred lake at 4300 m in the Nepal Himalayas	90	Wilderness and Environmental Medicine	2000	Q3
6	Imray CHE, et al.	Effect of exercise on cerebral perfusion in humans at high altitude	88	Journal of Applied Physiology	2005	Q1
7	Schoene RB.	Illnesses at high altitude	87	Chest	2008	Q1
8	Fengping XU, et al.	Rat brain VEGF expression in alveolar hypoxia: Possible role in high- altitude cerebral edema	84	Journal of Applied Physiology	1998	Q1
9	Luks AM, et al.	Medication and dosage considerations in the prophylaxis and treatment of high-altitude illness	80	Chest	2008	Q1
10	Van-Osta A, et al.	Effects of high-altitude exposure on cerebral hemodynamics in normal subjects	77	Stroke	2005	Q1

- MS: mountain sickness; HAPE: high altitude pulmonary edema; HACE: High altitude cerebral edema  
- Q=quartile.

## Suppl. 2.

Type of access and language of articles on the MS, HAPE and HACE, in the Scopus database from 1989 to 2021.

	MS		HAPE		HACE	
	n	%	n	%	n	%
<b>Access type</b>						
All Open Access	576	41.08	196	42.06	75	76.53
Gold	183	13.05	56	12.02	21	21.43
Hybrid Gold	32	2.28	11	2.36	5	5.10
Bronze	253	18.05	89	19.10	34	34.69
Green	358	25.53	114	24.46	38	38.78
<b>Language</b>						
English	1398	91.31	471	85.33	197	84.19
Chinese	51	3.33	35	6.34	15	6.41
German	20	1.30	19	3.44	6	2.56
Spanish	22	1.43	7	1.27	5	2.14
French	18	1.17	4	0.72	2	0.85

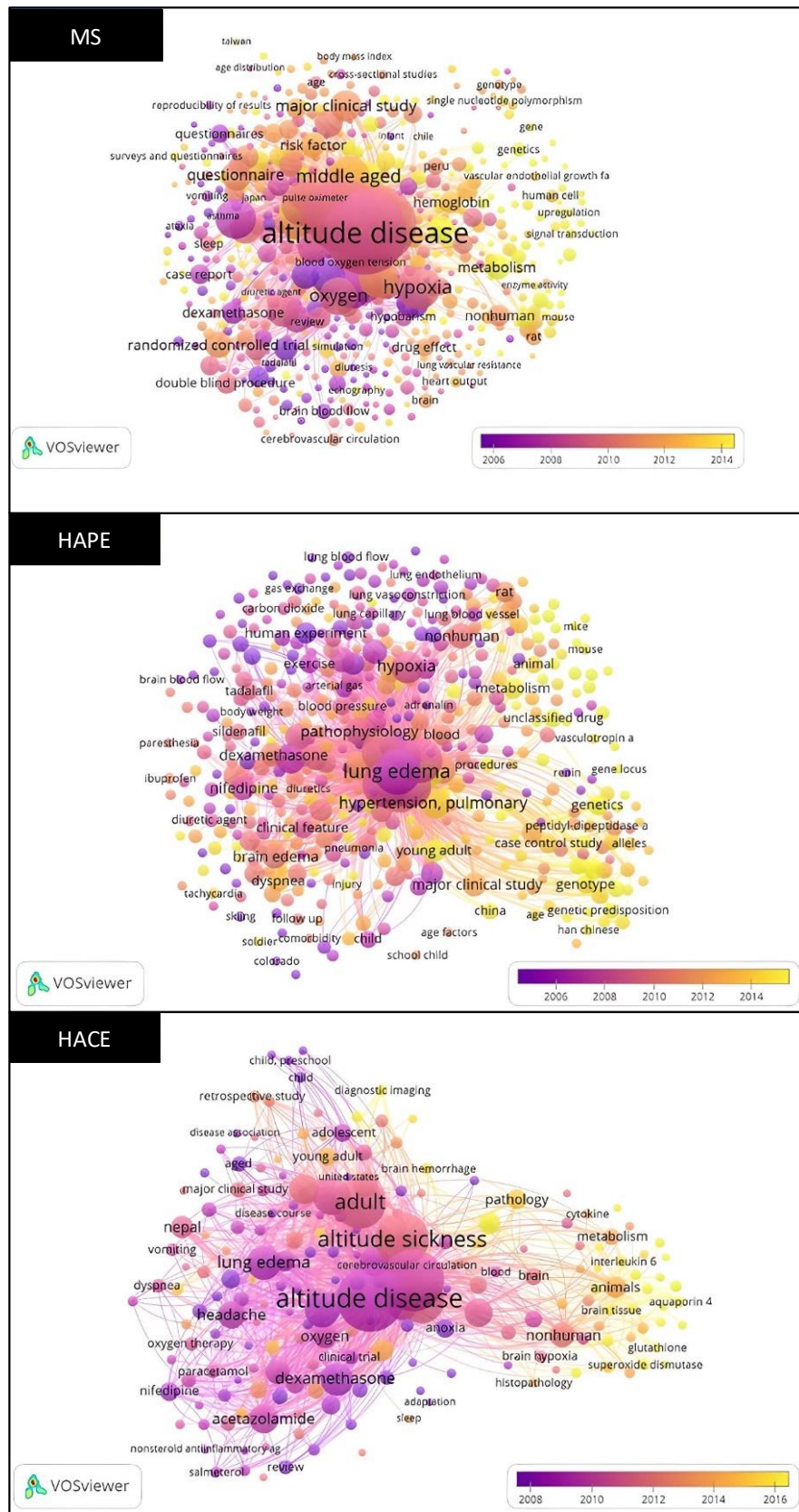
MS: mountain sickness; HAPE: high altitude pulmonary edema; HACE: High altitude cerebral edema

## DISCUSSION

The altitude, as a natural laboratory, serves to develop research that helps to solve the health problems of its inhabitants since it generates evidence to understand the mechanisms that allow life to be maintained in hypoxic conditions<sup>7</sup>.

Our study found an increase in the number of publications on MS, HAPE and HACE, especially in the last decade, similar to that reported by Chee L et al., who found that the scientific production of the journal Global High Altitude Medicine Research had increased by 8% in the last ten years, a possible response to this behavior is due to the fact that scientific research in the world has increased considerably thanks to economic, technological and socio-cultural advances<sup>8</sup>.

However, it should be noted that, despite the increase in publications on MS, HAPE and HACE, this is considerably less than the number of scientific publications on arterial hypertension (100,789 articles in 19 years)<sup>9</sup>, obesity (5,359 in 15 years)<sup>10</sup>, dengue (19,581 in 144 years)<sup>11</sup>.



Suppl 3. Visualization of a network of concomitant appearance of keywords on MS, HAPE and HACE.

It was found that the countries with the greatest collaboration on diseases due to exposure to altitude were the USA, China and the United Kingdom, which agrees with Hwui et al., who found that the United States (n= 432), the United Kingdom (n=109) and China (n=55) were among the four countries with the highest scientific production in the journal *Global High Altitude Medicine Research* during 2000 to 2020. This supports the supremacy of the United States and China on research in different thematic areas, which also rank first in terms of the number of publications and local citations in the area of oncology<sup>12</sup> and malaria<sup>13</sup>.

It was found that most of the investigations on diseases due to exposure to altitude were published in the *High Altitude Medicine and Biology* journal with 317 articles, being similar to those reported by Chee L et al.<sup>14</sup> where *High Altitude Medicine and Biology* is among the two journals that cite high altitude medicine more; this could be because it is one of the few journals dedicated exclusively to covering medical and biological issues that affect human life at altitude.

Our study found that the University Peruana Cayetano Heredia was the most frequent institutional affiliation of the corresponding author on the MS, denoting that this institution continues to contribute significantly to the field of research on research at altitude, as endorsed by Arévalo J et al., mentioning that for more than 60 years, the university has contributed to world-class knowledge in high-altitude medicine and physiology<sup>14</sup>.

Another aspect to highlight is the presence of researchers with affiliation from a university, being more than 50% in MS, HAPE and HACE. This demonstrates the importance of the university as a generator of knowledge, as well as its social responsibility, which ranges from the identification of health needs until the verification of the effects achieved on them<sup>15</sup>.

As for the funding entities, the National Heart, Lung, and Blood Institute was one of the influential ones to subsidize studies on medicine at altitude. This may be due to the fact that within its lines of research are diseases of the heart, blood vessels, the lungs and blood<sup>16</sup>; aspects that are connected with high altitude medicine. In addition, the US government allocates a budget to this entity<sup>17</sup> to improve health research and reduce disease and disability.

Likewise, the most influential funding entity for research on Mountain Sickness was the National

Natural Science Foundation of China. This could be due to the fact that part of the territory of the People's Republic of China is located more than 2,500 meters above sea level, an example being the inhabitants of the Qinghai-Tibet plateau since it is located at 4500 meters above sea level.

The 10 most cited articles were published in journals specialized in physiology due to their variation, according to the change in altitude, and showing the interest in the relationship between living at altitude and its impact on human beings, which should be highlighted, always existed<sup>18</sup>. Likewise, the objective of the studies was based on searching for genomic influence associated with high altitudes, determining the incidence of altitude sickness diseases, and explaining the physiological responses<sup>19,20,21</sup>, mainly. In addition, it should be noted that the majority of articles that are more than 5 years old probably continue to be cited due to the "reproducibility crisis", that is, the impossibility of replicating the scientific results<sup>22</sup>.

On the other hand, the authors with the largest number of publications are the most cited due to the great variety of topics they cover, adding that the first author with the most articles was Bartsch P, who has almost all of his articles focused on medicine at altitude<sup>23</sup>.

Our study showed that the majority of articles were open access (OA), being superior to journal articles on electrophysiology (OA=35.00%)<sup>24</sup>, oncology (OA=34.40%)<sup>25</sup>, and dentistry (OA=40.90%)<sup>26</sup>.

It is known that open access allows anyone with an Internet connection, regardless of where they are in the world, to access, read and take advantage of the most up-to-date scientific literature, which helps researchers to better develop. Making deeper discoveries possible, sharing more information, and improving the educational quality in the research area<sup>27</sup>.

It was found that the majority of scientific articles were written in English since it is currently considered the lingua franca of research due to the fact that articles in English are accessible to a wider audience<sup>28</sup>. As Garfield mentioned: "The cultural value of linguistic training is in fact, vital for good science, since it will increase the type of personal contacts that will lead to a better identification of important information"<sup>28</sup>. However, there are movements of researchers that encourage publishing their results in their native language English<sup>29</sup>.

## LIMITATIONS

Within the limitations of the study, we found the inclusion of only scientific articles in IMRD format indexed in the Scopus database. Another limitation would be the inclusion of only information consigned in the articles, which could be incorrect or imprecise.

## CONCLUSIONS

The scientific production on MS, HAPE and HACE in Scopus has increased in recent years. The journal High Altitude Medicine And Biology was the most influential, in addition, the country with the greatest collaboration was the United States, the most contributing funding entity was National Heart, Lung, and Blood Institute, and the most influential author was Bartsh P, the predominant language being English, most of the information was freely available. Efforts are required to increase scientific production on MS, HAPE and HACE.

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**CRAC:** contributed to the conceptualization, methodology, formal analysis, investigation, data curation, supervision and writing. **NSBQ:** contributed to the methodology, investigation, data curation, and writing. **DMFS:** contributed to the methodology, investigation, supervision and writing. **AILR:** contributed to the methodology, investigation, supervision, and writing. All authors have read and agreed to the published version of the manuscript.

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Corresponding Author:

Christian Renzo Aquino Canchari  
christian.aquino.canchari@gmail.com

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