

## Publication Trends and Hot Spots in Altitude Training Research: A 10-year Bibliometric Analysis

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### Abstract

With the increase of excellent long-distance runners from countries located in highlands such as Kenya and Ethiopia, researches related to altitude training has been conducted worldwide. At present, there are still some problems to be solved in the development of altitude training. In this study, the scientific knowledge mapping and visualization of Chinese and English literatures in the field of altitude training research by Citespace was used to mine the hot content in the field of intermittent hypoxia training research in order to reveal the evolutionary path of the research related to intermittent ground oxygen training over the years. On this basis, we conclude that: (1) The publication volume of altitude training-related literatures in Chinese journals in the past ten years is in a period of fluctuating decline, and the publication volume of altitude training-related literatures in English literature in the past decade is in a rapid development area; (2) The main authors of the Chinese journal altitude training-related research are Binghong Gao and Shifeng Lian. Beijing Sport University has conducted in-depth research on altitude training, and the main authors of English literatures in altitude training-related researches are Millet GP and Gore CJ. Univ Lausanne published the highest number of articles related to altitude training in English literature journals; (3) The keywords in Chinese journals are mainly about specific methods of altitude training, altitude training environment, altitude training research objects and experimental objectives of altitude training. Altitude training related research in English journals mainly focused on sports human science. Altitude training related researches focus and direction of each stage are different, and the research related to altitude training has been greatly developed in both breadth and depth; (4) The keyword with the highest emergence value in Chinese journals is "lipid metabolism"; The keyword with the highest emergence rate in English journals is "prediction"; (5) The lack of closer relationships with other institutions and sports human science as English journals. is an issue for future research in Chinese journals to explore. Future studies in English journals could investigate the association between special projects in seek of the most reasonable and effective altitude training methods.

### Keywords

Altitude Training; Hypoxic Training; Citespace; Review.

### 1. Introduction

The 1968 Mexico City Olympics were held on a high plateau and African middle-distance runners won all gold medals in races from 1500 m to marathon[1], which drew the attention of sports scientists, coaches and athletes around the world for highland training and competition [2]. Due to the decrease in partial pressure of oxygen at high altitude, the pressure of oxygen diffusion from alveoli to blood is reduced, therefore, the oxygen consumption and maximum oxygen consumption are lowered, which leads to the decrease of blood oxygen content and

blood oxygen saturation, resulting in insufficient oxygen supply to tissues. Thus the body will respond to the low oxygen stress through a series of adaptive changes[3-4]. Altitude training is a training method that utilizes both hypoxia and exercise to mobilize the functional potential of the body to produce anti-hypoxic physiological responses and thus improve aerobic exercise capacity[5]. Most of scholars believe that altitude training and hypoxic training can play an important role in addressing the issue of improving the physiological function of athletes[6].

Scholars published about the effects of altitude training on physical performance as early as 1967. After the 1968 Mexico Olympic Games, the research on altitude training came to a climax. But Chinese core journals began to gradually include articles on plateau training until 1992[7], and the number of articles about altitude training by Chinese scholars gradually increased from 1992 to 2012[8]. Nowadays, altitude training is a major area of interest within the field of sports research around the world. More and more athletes from all over the world have been training at altitude on a large scale and in an organized manner in order to achieve better competition results[9]. At the same time, there are also some problems about altitude training, such as the optimal load intensity and the selection of suitable altitude, which need further in-depth research and discussion[10]. Based on this, this paper uses CiteSpace software to draw a knowledge map of 2972 research papers related to altitude training of CNKI and Web of Science from 2012 to 2022. The CiteSpace can summarize and organize the data to analyze their development, research hot spots and research frontiers, so as to provide a reference basis for the high-quality development of altitude training.

## 2. Data Collection and Methods

### 2.1. Data Collection

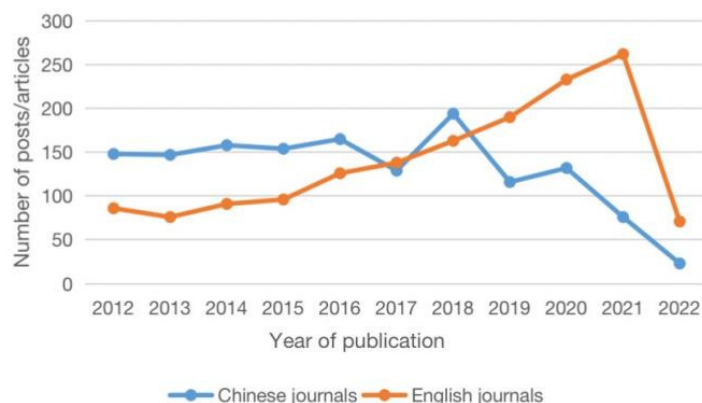
CNKI database and Web of Science database were used as the data sources of this paper. The Chinese literature was searched with "altitude training" and "hypoxic training" as the topics. 4 types of literature were selected: academic journals, master's theses, doctoral dissertations and conference papers, and the time span of the retrieved literature was from 2012 to 2022. The English literature was searched by "TS=(altitude training\* or hypoxic training)", and the library was selected from the Web of Science core collection. A total of 2972 valid search results, spanning the years 2012-2022, were obtained by eliminating book chapters, letters, revisions, news, and other worthless records, and excluding unrelated researches. The search was conducted on May 7, 2022.

### 2.2. Methods

CiteSpace is a Java-based literature visualization and analysis software that allows researchers to transform research content into a knowledge map that clearly shows the trends and movements of a discipline or knowledge domain over time[11]. In this study, we used CiteSpace bibliometric visualization software with the subject terms altitude training and hypoxic training, and imported the filtered literature into CiteSpace 5.8.R4 (64bit) software with the analysis time set to "2012-2022"; the value of "Time scaling" was set to "1", representing each year as a basic unit of the study. On the one hand, the bibliometric statistics were conducted, and on the other hand, suitable thresholds were selected to map the number of annual publications, core authors and institutions, keyword clustering and Co-occurrence, etc., in order to better present the core topics and trends of highland training in the last decade[12].

### 3. Results

#### 3.1. Annual Distribution of the Number of Articles



**Figure 1.** Annual distribution of the number of articles

the number of altitude training-related research literature published in Chinese literature journals (Figure 1) is in a period of fluctuation and decline in the past 10 years. The number of altitude training-related research published in English literature has increased significantly, and the number of altitude training-related publications exceeding the number of publications in Chinese literature in 2017, and has always maintained a steady growth [13]. By analyzing the literature, it is easy to see that the improvement of the overall level of athletic sports and the intensity of competition in the world can promote the further growth of the number of publications related to altitude training in English literature. Because the competitive level of sports reflects the development level of the sport in a country or region, and in today's world pattern, competitive sports are an important channel to show the comprehensive ability of countries and establish the national image [14]. The scientific training methods have led to a significant increase in the average level of competitive sports in the world, and the intensity of competition has also been generally improved. The improvement of athletes' abilities has led to a stronger demand for relevant sports training science and technology [15]. In contrast, the number of altitude training articles in Chinese literature decreases year by year after 2018 mainly, due to the fact that more research results have been accumulated in this field in the previous period and other reasons. Scholar who publishes in Chinese journals should conduct more relevant research.

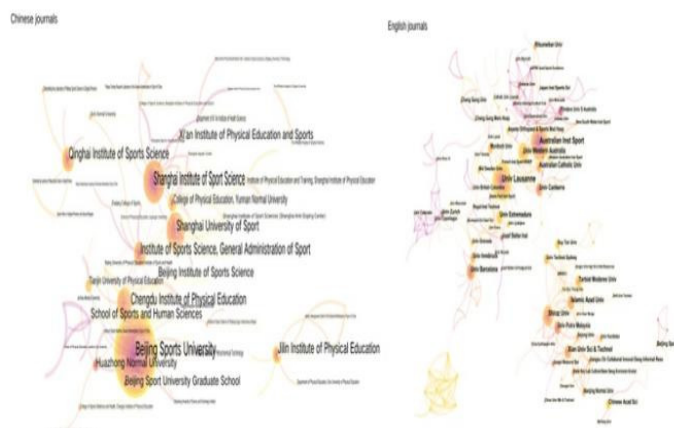
#### 3.2. Literature Agency Cooperation

As a platform for researchers, scientific research institutions are both oriented to national strategic needs and have the mission of cultivating talents, and their analysis is indispensable [16]. In the Chinese literature institutional Co-occurrence mapping (Figure 2), there are 313 nodes, 156 network links, and the density is 0.0032.

There are 5 units with more than 25 publications: Beijing University of Physical Education (66), Shanghai Institute of Physical Education (37), Chengdu Physical Education Institute (31), Shanghai Sports Science Institute (29), and China Physical Science Institute (25). The more major institutional groups in this field in Chinese journals are divided into two main groups: Beijing University of Physical Education, Chengdu Physical Education Institute, Tianjin Physical Education Institute, etc; Shanghai Physical Education Institute, Shanghai Sports Science Institute, Yunnan Sports Science Institute, etc. China Physical Science Institute actively participates in the scientific research work of the above two institutional groups.

**Table 1.** Top 10 issuing institution

No.	Institution in Chinese Literature	Number of articles	Institution in English Literature	Number of articles in
1	Beijing Sports Univ	66	Univ Lausanne	39
2	Shanghai Univ of Sport	37	Australian Inst Sport	31
3	Chengdu PE Institute	31	Univ Western Australia	29
4	Shanghai Sport Science Institute	29	Xian Univ Sci & Technol	24
5	China Physical Science Institute	25	Islamic Azad Univ	24
6	Yunnan Institute of Sports Science	21	Univ Extremadura	22
7	Jilin Institute of Physical Education	17	Australian Catholic Univ	18
8	Qinghai Sports Science Institute	16	Australian Catholic Univ	18
9	Guizhou Sports Science Institute	12	Univ Barcelona	14
10	Beijing Sports ScienceInstitute	12	Tarbiat Modares Univ	14



**Figure 2.** Literature Agency Cooperation Chart

While the number of articles issued by Beijing Physical Education University is significantly higher than others. The reason for this is that altitude training is different from other training methods in sports, and it is difficult to conduct research on it, especially experimental research. In the English literature institutional Co-occurrence map (Figure 2), there are 396 nodes and 540 network connections, with a density of 0.0069. There are three institutions with more than 25 publications: Univ Lausanne (39), Australian Inst Sport (31), and Shiraz Univ (29). The field is divided into two main groups of institutions in English literature journals: Univ Lausanne, Australian Inst Sport, Univ Western Australia, and Shiraz Univ, Islamic Azad Univ, Xian Univ Sci & Technol, and Tarbiat Modares Univ. Tarbiat Modares Univ is the main group of institutions. In the English journals, the publishers of altitude training-related research cooperate more closely and are mainly divided into two institutional clusters. In Chinese journals, altitude training related research is concentrated in several institutions such as Beijing University of Physical Education, Shanghai Institute of Physical Education. It can also reflect that the group of highly productive institutes in this field is indeed about to be formed, and there are certain

academic barriers among them. Basically, scholars of the same platform collaborate with each other, and the connection with the others is very weak.

### 3.3. Keyword Co-occurrence Relationship

The intermediary centrality of a keyword is a measure of the control of the node over the other two nodes connected to it in the knowledge graph network, and to a certain extent, it can characterize the importance and role of the keyword in the whole network. In the keyword Co-occurrence spectrum of Chinese literature (Figure 3), the number of network nodes is 444, the node connection is 881, and the density is 0.009. The words "altitude training" and "hypoxic training" belong to the research phrase of this paper itself, showing a binary star pattern. Basically, they are linked with the rest of the key words.



Figure 3. Keyword Co-occurrence relations

Table 2. Top 10 Keywords information Chinese and English keywords

No.	Keyword in Chinese Literature	Number	Keyword in English Literature	Number
1	Altitude training	424	exercise	222
2	Hypoxic training	171	performance	169
3	Hypoxia	48	altitude	128
4	Sub-plateau training	43	adaptation	92
5	Aerobic capacity	36	response	87
6	Yunnan Institute of Sports Science	29	normobaric hypoxia	79
7	Skeletal muscle	29	gi	78
8	Obesity	28	exercise performance	71
9	Altitude	28	model	67
10	Sub-plateau	28	logistic regression	66

In the keyword Co-occurrence spectrum of English literature (Figure 3), the total number of network nodes obtained is 394, the node connection is 1341, and the density is 0.0173. Without a particularly obvious central word, this paper divides the 20 words with the highest frequency into roughly 3 categories: experimental environment, research methods process and experimental.



In Chinese journals (Table 2) there are more overall key words related to altitude training, focusing on describing training methods, training environments, experimental subjects, and experimental purposes, but there are fewer key words for research methods. The in English journals (Table 2), the key words of altitude training related research are more closely connected, and there are more key words for research methods as well as describing objects' changes during researches.

### 3.4. Staged Keyword Emergence

The staged keyword emergence refers to the significant increase in the frequency of keyword use within a short period of time, and the analysis of keyword emergence can clarify the research focus and hotspot within a certain period of time, and determine the development trend and frontier research. The strength is the intensity of the keyword mutation, and the higher the strength means the greater the influence. The higher the strength, the greater the influence. In the keyword emergence (Figure 4), the light blue part represents the time span of this study, and the red part represents the start and end time of a keyword outbreak.

The focus of research and hotspots (Figure 4) were different at each stage when the time span was 1 or 2 years. Among them, the keyword with the highest emergence value in Chinese literature is "lipid metabolism", with the emergence year of 2017-2020 and the emergence degree of 4.17, indicating that "lipid metabolism" is the frontier of research of altitude training in this time period that obesity becomes a frequent problem. It is widely mentioned by scholars in Chinese literature; The keyword with the highest emergence degree in English literature about altitude training is "prediction". The keyword "prediction" has the highest emergence rate of 5.69, indicating that "prediction" is the frontier of research of altitude training in this time period. It is widely mentioned by scholars in English literature. It can be seen that, in just ten years, researches related to altitude training has gone from the concept of "intermittent hypoxic training" "simulated altitude", through high residence and low training, aerobic performance, red cell volume, to remote sensing data, neural network level research, each stage of research focus and direction are different, the research related to plateau training both breadth and depth, have been greatly developed.

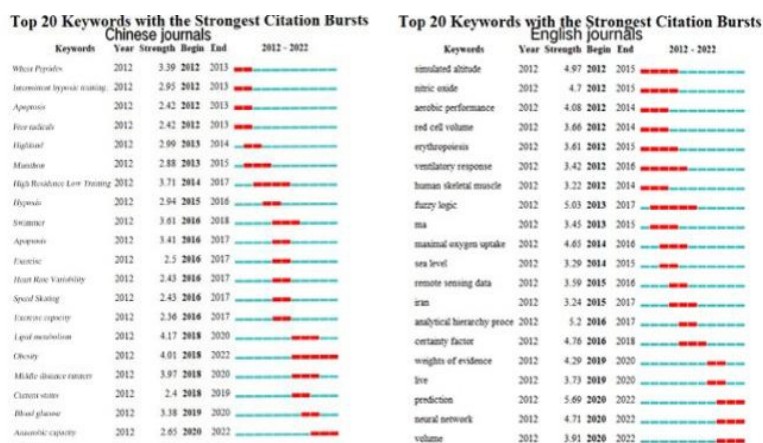


Figure 4. Altitude Training Research Pre-Hotspot Emergence

## 4. Conclusion

(1) From the volume of publications, the volume of altitude training-related literature published in Chinese journals in the last decade is in a period of fluctuation and decline, mainly due to the fact that the field has accumulated more research results in the previous period. In the English literature, the number of publications related to altitude training in the last ten years is in a rapid development zone, mainly because the scientific training methods have led

to a significant increase in the average level of competitive sports in the world and the improvement of athletes' ability has led to a stronger demand for related sports science and technology in various countries.

(2) The main Research institution of altitude training-related research in Chinese journals is Beijing Sport University, with a significantly higher number of publications than other institutions. The reason is that altitude training is different from other training methods in sports, and it is difficult to conduct research on it, especially experimental research; The highest Research institution of plateau training-related research in English literature is Univ Lausanne and the connection between institutions is closer than that of Chinese journals institutions, and the development about the research of plateau training-related research is more balanced.

(3) The keywords in Chinese journals are mainly about specific methods of plateau training, plateau training environment, altitude training research objects and experimental objectives of plateau training; The keywords in English journals are mainly about altitude training experimental environment, plateau training experimental process, plateau training experimental results and plateau training research methods. The English journals mainly focus on sports human science, while the Chinese journals mainly focus on altitude training methods and intervention effects.

(4) The keyword with the highest emergence value in Chinese journals is "lipid metabolism", with the emergence year of 2017-2020 and the emergence degree of 4.17, indicating that "lipid metabolism" is the frontier of research in this time period, which is widely mentioned by scholars in Chinese journals. The keyword with the highest emergence rate in English journals is "prediction", with a emergence rate of 5.69 for the period of 2020-2022, indicating that "prediction" is the frontier of research in this time period and is widely mentioned by scholars in English journals. Both Chinese and English journals have different research focus and direction at each stage, and the research related to plateau training has been greatly developed in terms of both breadth and depth.

(5) In conclusion, all our preliminary results throw light on the nature of altitude training-related researches. On the one hand, one primary problem with altitude training-related researches in Chinese journals is the lack of closer relationships with other institutions and sports human science as English journals. This is an issue for future research in Chinese journals to explore. On the other hand, future studies in English journals could investigate the association between special projects in seek of the most reasonable and effective altitude training methods.

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## Disclosure Statement

The author declares no conflict of interest.

## Authors' Contributions

Yihan ZHANG conceived the idea of this study. Geng LI analyzed the data and wrote the paper.

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