



# A Study on the Attention of Yoga and Its Development Based on Complex Network Theory

Pengchao Li<sup>1</sup>, Qinghong Miao<sup>2\*</sup>, Yuchi Meng<sup>3</sup>, Jie Ning<sup>4</sup>, Jing Long<sup>5</sup> and Junya Huang<sup>1\*</sup>

<sup>1</sup>School of Art, Beijing Sport University, Beijing, China, <sup>2</sup>Beijing Jingkong Technology Co., Ltd., Beijing, China, <sup>3</sup>Chinese Skating Association, Beijing, China, <sup>4</sup>School of Physical Education, Zhoukou Normal University, Zhoukou, China, <sup>5</sup>Zhongshan Experimental Middle School, Zhongshan, China

Taking Baidu search index as the data source, this research collects yoga-related data in various provinces in China, analyzes the public's attention to yoga on the Internet from the perspective of the complex network theory, so as to dig out characteristics of those who are interested in yoga as well as the temporal and spatial change of yoga attention from 2011 to 2020. Then, by transforming the time series into a network through the VG model and HVG model, the paper analyzes the network characteristics and predicts the popularity of yoga. Furthermore, the publicity of yoga and the public's attention to it are analyzed, considering the policy, national education level, the influence of TV, mobile phone and other communication equipment, so as to help the market to provide corresponding products and services in a targeted manner and to promote the healthy development of the yoga industry.

**Keywords:** complex network, social network, yoga, attention, visualization graph

## INTRODUCTION

In recent years, the government has been vigorously developing national fitness. The “Healthy China 2030” Planning Outline and the “Opinions on Promoting National Fitness and Sports Consumption to Promote the High-quality Development of the Sports Industry” issued by the Party Central Committee and the State Council both recognize the necessity of carrying out national fitness campaign, activating the fitness training market and building a better platform for the sports industry. Yoga is a physical, mental, and spiritual exercise with a history of more than 5,000 years and it represents “harmony” and “consistency”. Its essence is to connect “self” and “superego,” to transform the soul and to improve physical and mental health. Since the 19th century, modern yoga has been attracting groups of all ages rapidly with its functions, such as improving posture and self-cultivation. It is estimated that there were 2.5 million yoga practitioners in the United Kingdom and 15 million in the US in 2008 [1], and the number has been increasing rapidly in recent years.

At present, the number of researches on yoga at home and abroad has been increasing significantly year by year. Though its research content covers the history of yoga, the feasibility of introducing yoga and the efficacy of yoga, the majority of them are purely theoretical description and analysis based on transplantation of related theories and adoption of conceptual introduction and explanatory methods. These researches focus on theoretical explanations and abstract categories, featuring low-level repeated studies and weakness of absorbing new research methods. The relationship between yoga and human health is one of the important directions of domestic research. Wang Min (2005) conducted a 15 weeks experiment on female college students, showing that yoga practice can effectively improve their respiratory system, circulatory system

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### \*Correspondence:

Qinghong Miao  
miaohq\_1101@163.com  
Junya Huang  
junyahuang@sina.com

### Specialty section:

This article was submitted to  
Social Physics,  
a section of the journal  
Frontiers in Physics

**Received:** 01 June 2021

**Accepted:** 26 July 2021

**Published:** 01 October 2021

### Citation:

Li P, Miao Q, Meng Y, Ning J, Long J  
and Huang J (2021) A Study on the  
Attention of Yoga and Its Development  
Based on Complex Network Theory.  
Front. Phys. 9:719012.  
doi: 10.3389/fphy.2021.719012

skills, physical flexibility, balance ability, and mental health [2]. Wu Minyue (2010) reviewed scientific research papers on yoga and health at home and abroad, showing that long-term insistent practice of yoga has a positive influence on preventing and treating chronic diseases such as cardiovascular diseases and diabetes [3]. Over time, the medical field has recognized the efficacy of yoga and has been adopting it into the treatment and management of diseases, including chronic disease [4], depression [5–7], cancer [8, 9], and rehabilitation. Later, the study of yoga is no longer restricted to its exercising and health function and covers the development of the entire industry, causing an in-depth impact on yoga research. Huang Min (2010), Chen Xiaoying (2010), and some other researchers analyzed the development status of yoga-related industries from the perspective of yoga industrialization and marketization and put forward suggestions for the sustainable development of yoga industry [10, 11]. Yu Jingjing (2011), Liu Min (2013), and Zhang Maomao (2014) discussed the social background and value orientation of yoga and the building of yoga teaching teams in universities [12–14]. VG model is also used in stock and venture capital [15, 16].

Compared with domestic research, foreign research presents the characteristics of overlap, penetration, and integration of multidiscipline. It pays special attention to the adoption of empirical research methods such as randomized controlled trials, double-blind trial intervention, meta-analysis, follow-up, prospective studies, and nationwide surveys. The research content is systematic and target-orientated. For instance, Cramer H (2013) analyzed 12 randomized controlled trials (619 participants) to study the relationship between yoga and its influence on relieving depression and anxiety and improving the quality of life. He argues that yoga can be considered as one of the adjunctive treatment methods for patients with depression or individuals with elevated levels of depression [17]. Stemlieb B (2011) conducted a randomized controlled experimental intervention on breast cancer patients, discovering that targeted yoga intervention can significantly improve the persistent fatigue symptoms [18]. Bussing A (2012) believes that although yoga has not been proven to be an independent treating method due to some research conditions, the beneficial effects of yoga intervention on physical and mental health related to pain do exist. As adjunctive therapy, yoga can improve body function and self-confidence [19]. With the widespread concept of practicing yoga, more research has been conducted on the relations between yoga and the treatment of diseases including obesity [20, 21], chronic blood disease [22], mental health [23, 24], cancer [25, 26], and even COVID - 19 prevention [27, 28]. The increasing popularity of yoga can be partly attributed to the Internet and social media. Social media bloggers have been attracting more and more yoga practitioners. Chen et al. (2014) designed a yoga pose recognition model to help yoga practitioners to practice with more appropriate postures. The Internet also provides researchers a better platform to conduct their studies. K Firestone (2014), Johnson (2014) conducted online surveys

to collect data [29, 30], which has some similarities to our study.

This paper breaks the boundaries of domestic literature, adopts search behavior data to measure public's attention on yoga, and attempts to investigate the time change trend of yoga attention in a specific time and space environment and the characteristics of the practitioner, so as to understand the public's need for yoga and its changing trend and analyze the evolution of yoga attention by establishing the time series prediction model of yoga attention degree, so as to propose suggestions on the future yoga development directions and strategies. The second part of the paper is a description of the methods used. The third part is a complex network-based analysis and visualization of the Baidu search index data of yoga from 2011 to 2020. The fourth part is the prediction of the popularity of yoga and relevant suggestions.

## MODEL DESCRIPTION

### Data Extraction and Processing

Attention, which refers to the degree to which a thing receives interests from social groups, is an important indicator of the strength of the internal relationship between things and group behavior, exerting an important influence on public opinion, culture, and policy. Attention can be reflected by different parameters, such as the number of searches, views, reposts, comments, and favorites of an event on the Internet. Based on Baidu's massive data, the Baidu index, on the one hand, analyzes the hotness of keywords and, on the other hand, explores in-depth the data characteristics of public opinion, market demand, and user characteristics. The Baidu index reflects the active search demands of internet users, and all activities that affect their search behavior may affect the Baidu index. Therefore, in order to show the public's attention to yoga and those who are interested in yoga, this study selects the visualization results of the Baidu index search as the data basis for analyzing domestic users' attention to yoga. The interpolation method is adopted to obtain equal interval data in case missing sampling or uneven sampling interval of the data occurs.

### Modeling of Complex Networks

A complex network describes a system composed of a large number of interacting individuals. The analysis of a complex network can help describe the structure of the network system and understand the law of information evolution on the network, so as to finally realize the intervention and optimization of information evolution process on the network. This paper uses the time series visualization method proposed by Lacasa et al. [31] to construct the network, which consists of the Baidu search index time series subsystem with the keyword "yoga" in 31 provinces in China. First, the discrete time series data of the subsystem  $X(t)$  corresponds to the nodes of the network, and the connection edges are constructed according to the visual criterion. The connection edge can be established by

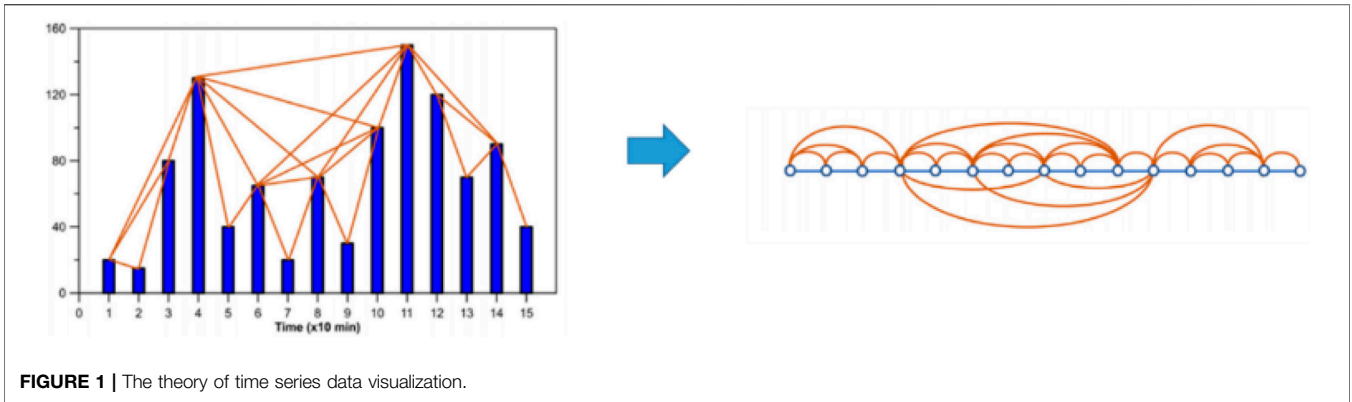


FIGURE 1 | The theory of time series data visualization.

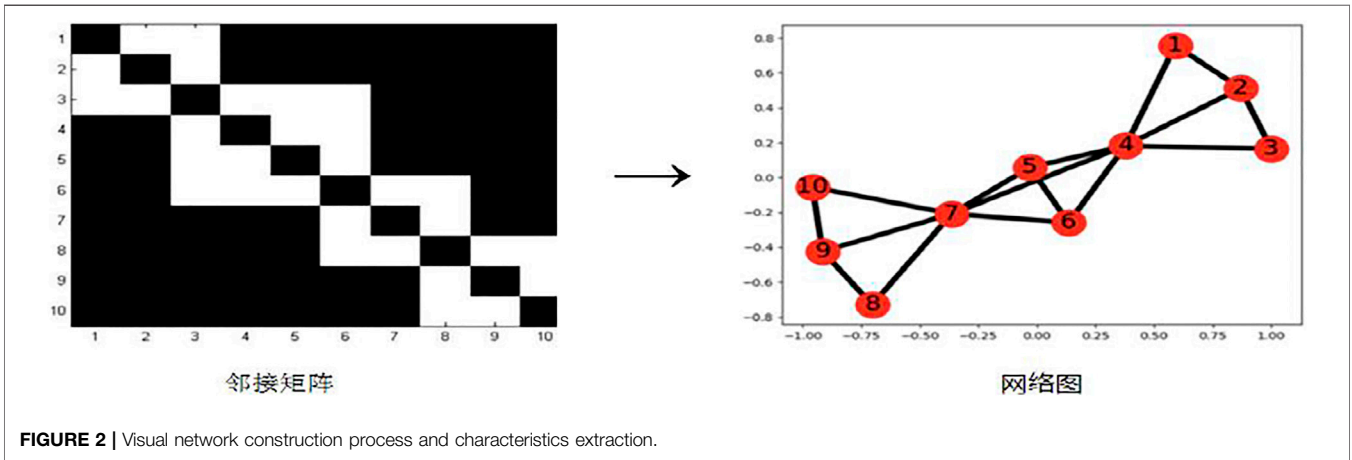


FIGURE 2 | Visual network construction process and characteristics extraction.

visualizing the data of any two points. In the time series  $(X(t))$  any point between  $(t^a, x^a)$  and  $(t^c, x^c)$  can be linked, and when  $t^a < t^b < t^c$  any point  $t^b, t^b$  between  $t^a, t^a$  and  $t^c, t^c$ , all satisfy:

As shown in **Figure 1**, the height of the bar represents the data value at each time point. If the tops of the 2 bars are visible to each other, the corresponding two points are connected by the network in the figure.

Secondly, to construct an adjacency matrix based on time series nodes and edges, and to form a network graph, as shown in **Figure 2**.

The important characteristics of the complex network are calculated as follows [32–34]:

(1) Degree and degree distribution.

The number of edges connected by a node is called the degree of the node, the node  $i$  is shown as  $k_i$ :

$$K_i = \sum_j a_{ij}$$

Among them,  $a_{ij}$  is the number of connecting edges between nodes  $i$  and  $j$ . In the network, the greater the degree, it means the more nodes are connected to it, then the greater influence of the node, and thus the stronger time correlation. The average degree is defined as follows:

$$K = \frac{1}{N} \sum_i k_i$$

Among them,  $N$  represents the number of nodes in the network.

(2) Average path length and diameter.

The path connecting two reachable nodes in the network with the least number of edges is called the distance between nodes, and the longest path between two nodes is called the diameter of the network  $d_{ij}$ . Both the average network path length and the network diameter can reflect the network transmission efficiency. The smaller the value, it means that the transmission effect can be achieved with fewer nodes in the network, thus the higher network efficiency. The calculation formula for the average network path length is as follows:

$$L = \frac{1}{\frac{1}{2}N(N-1)} \sum_{i \geq j} d_{ij}$$

(3) Clustering coefficient and clustering.

The clustering coefficient, which describes the degree of clustering of all nodes in the network, represents the tightness of the network. Its calculation formula is as follows:

$$C_i = \frac{2E_i}{K_i(K_i - 1)}$$

**TABLE 1 |** Descriptive statistics of Baidu Index of Yoga in 2020.

Province	Average			Maximum			Minimum			Standard error		
	Search index	PC	Mobile	Search index	PC	Mobile	Search index	PC	Mobile	Search index	PC	Mobile
Anhui	290.9559	49.1176	241.8382	441	74	367	136	0	136	85.3160	24.3436	70.2625
Macau	7.6176	0.0000	7.6176	60	0	60	0	0	0	19.6522	0.0000	19.6522
Beijing	437.1618	69.8676	367.2941	592	101	518	181	0	181	106.9644	18.3107	96.2235
Fujian	260.2794	52.3088	207.9706	350	78	287	144	0	123	57.8735	22.3395	46.2014
Gansu	175.6471	31.6029	144.0441	250	63	205	89	0	89	53.1994	29.1722	33.0266
Guangdong	704.0588	79.9412	624.1176	992	142	858	348	57	287	184.4647	16.2957	174.1870
Guangxi	238.5000	50.3971	188.1029	339	70	278	115	0	115	51.5927	22.4839	40.7710
Guizhou	163.8676	22.2941	141.5735	269	63	208	92	0	83	47.0779	28.5689	30.2188
Hainan	128.1618	26.5147	101.6471	191	63	139	67	0	67	37.8889	29.2026	18.7464
Hebei	501.1912	59.4706	441.7206	710	85	683	208	0	206	167.9120	19.9046	158.7823
Henan	491.6029	58.9559	432.6471	726	89	656	201	0	201	166.1601	19.4778	158.3369
Heilongjiang	274.8971	49.2647	225.6324	403	70	337	138	0	119	77.7641	24.3743	66.9417
Hubei	335.6912	56.5000	279.1912	527	76	453	128	0	128	104.3891	21.1861	93.0765
Hunan	281.3529	46.5000	234.8529	398	80	324	148	0	148	74.3916	27.3777	59.5925
Jilin	225.8235	43.5147	182.3088	333	74	267	92	0	92	62.9944	27.4783	44.9006
Jiangsu	468.7059	65.9118	402.7941	667	104	591	232	0	201	125.1420	21.4293	111.7364
Jiangxi	247.9412	47.8235	200.1176	387	78	326	109	0	109	68.6181	24.7844	54.2321
Liaoning	345.2206	59.3088	285.9118	479	80	419	157	0	157	87.5737	15.8060	80.3566
Inner mongolia	216.2794	41.1618	175.1176	337	66	278	95	0	95	67.1258	27.8233	49.5706
Ningxia	97.8235	11.0147	86.8088	176	61	121	63	0	63	30.6876	22.8307	15.5604
Qinghai	85.3529	9.4559	75.8971	153	61	100	57	0	57	26.4551	21.6963	10.4869
Shandong	636.7206	69.0000	567.7206	910	110	825	312	0	255	196.8528	15.6205	188.8028
Shanxi	286.9412	50.5000	236.4412	395	83	338	125	0	125	82.4659	23.9574	69.7311
Shaanxi	295.4706	58.4559	237.0147	401	70	337	125	0	119	72.0341	13.1324	65.0191
Shanghai	288.7794	63.2794	225.5000	374	104	313	122	0	122	51.5004	15.9382	42.4276
Sichuan	410.0882	59.6029	350.4853	587	80	521	186	0	186	120.6645	17.8494	110.3189
Taiwan	16.0147	3.3529	12.6618	115	57	58	0	0	0	29.4454	13.5115	23.9786
Tianjin	197.6324	40.4118	157.2206	282	70	219	86	0	86	52.4248	28.2691	33.5936
Tibet	63.1324	2.5735	60.5588	126	61	78	0	0	0	17.3609	12.0748	15.9658
Hongkong	53.5441	5.0882	48.4559	120	59	69	0	0	0	30.9542	16.4804	23.8924
Xinjiang	189.0441	36.1912	152.8529	269	64	212	99	0	99	51.2443	28.7341	35.3428
Yunnan	199.7059	31.1765	168.5294	291	66	227	109	0	109	53.6976	29.6668	34.0910
Zhejiang	403.8824	64.1176	339.7647	537	87	469	200	0	179	97.2186	19.8709	86.1114
Chongqing	223.0882	44.2353	178.8529	307	78	249	102	0	102	60.4621	26.9400	42.2273

Among them,  $C_i$  represents the clustering coefficient of node  $i$ ,  $K_i$  represents the number of nodes connected to node  $i$ , and  $E_i$  represents the actual number of edges between nodes in the network. It can be deduced that the average clustering coefficient  $C$  of the network is as follows:

$$C = \frac{1}{N} \sum_{i=1}^N C_i$$

The value of the clustering coefficient is generally between 0 and 1. The larger the coefficient, the better the connectivity of the network and the greater the degree of network aggregation. In general, some real-world network clustering coefficients are larger than random network clustering coefficients of the same size, which means that real networks have better clustering tendency, which features the nature of clustering.

(4) Density.

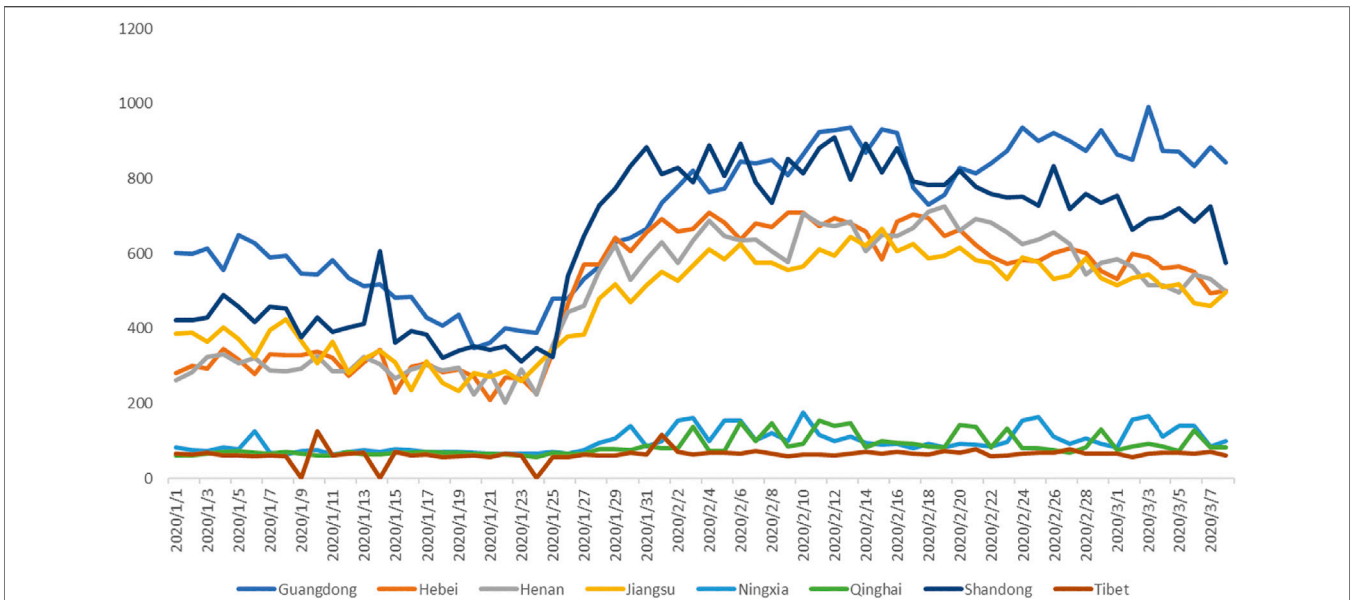
The density of the network is equal to the ratio of the actual number of edges in the network to the maximum possible number of edges in the network. The greater the density, the more the number of edges in the network and the denser the network.

## EMPIRICAL ANALYSIS

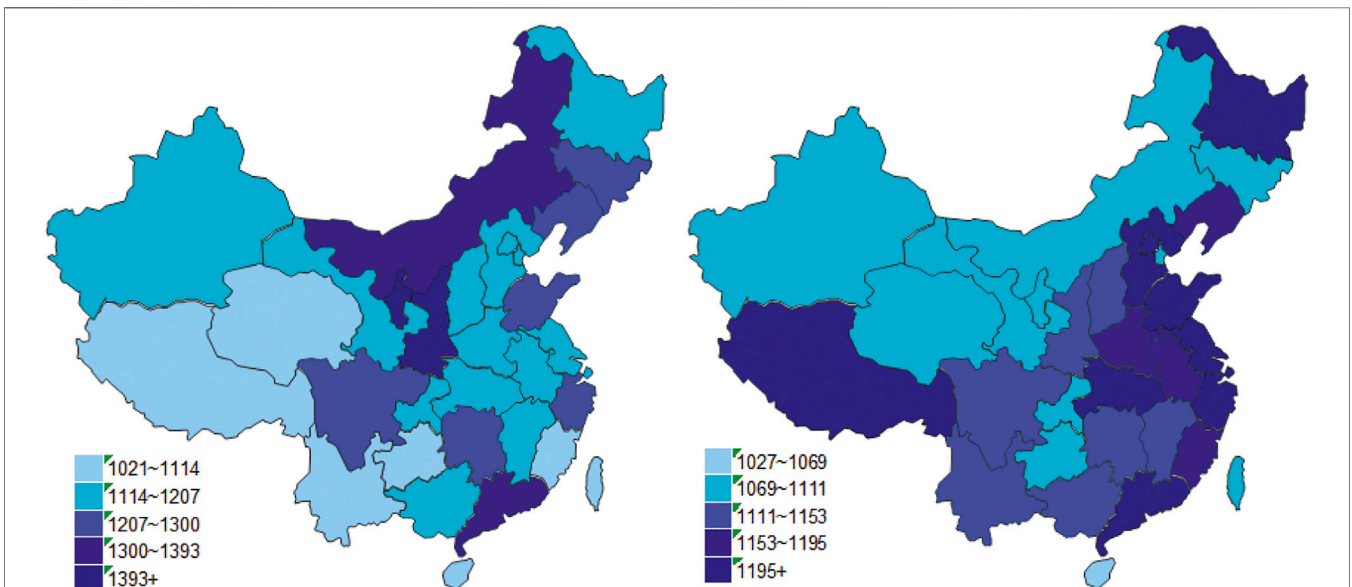
We analyze the time series data of the Baidu index for 31 provinces and cities from 2011 to 2020. The descriptive statistics, visualization of time series data, and complex network method are also applied to the analysis to find out the characteristics of the visualized networks.

### Descriptive Statistics

As showed in **Table 1**, based on the search result of “yoga” in the Baidu index, Guangdong, Shandong, Hebei, Henan, and Jiangsu are the top 5 provinces that pay the most attention to yoga. These five are all provinces with large population and economy. But we noticed that the standard error of the index in these provinces is in the top position too. It is found that the data of these provinces are more prone to fluctuations due to Internet searches. **Figure 3** shows the variation tendency of the Baidu index of the top 5 and the bottom 3 provinces in 2020. The increase of the Baidu index in 2021 is, on the one hand, due to the COVID-19 pandemic, which brings exercises and health issues to the public’s attention



**FIGURE 3 |** Top 5 and last 3 provinces by the Baidu index of yoga in 2020.



**FIGURE 4 |** The comparison of the total number of edges between 2011 and 2019.

and, on the other hand, benefited from the improvement of network infrastructure construction.

In addition, with the rapid development of the mobile phone and information technology, the mobile phone starts to become the main channel for information because it is more convenient and easy operating especially when doing exercise following the video on the Internet.

### Characteristic Evolution

Calculating the characteristic of visualized networks, the information is found out including the total number of edges, average degree, average path, diameter, clustering coefficient, and the annual results of density. Given space limitation, it only shows the comparison chart of 2011 and 2019 in **Figures 4–9**.

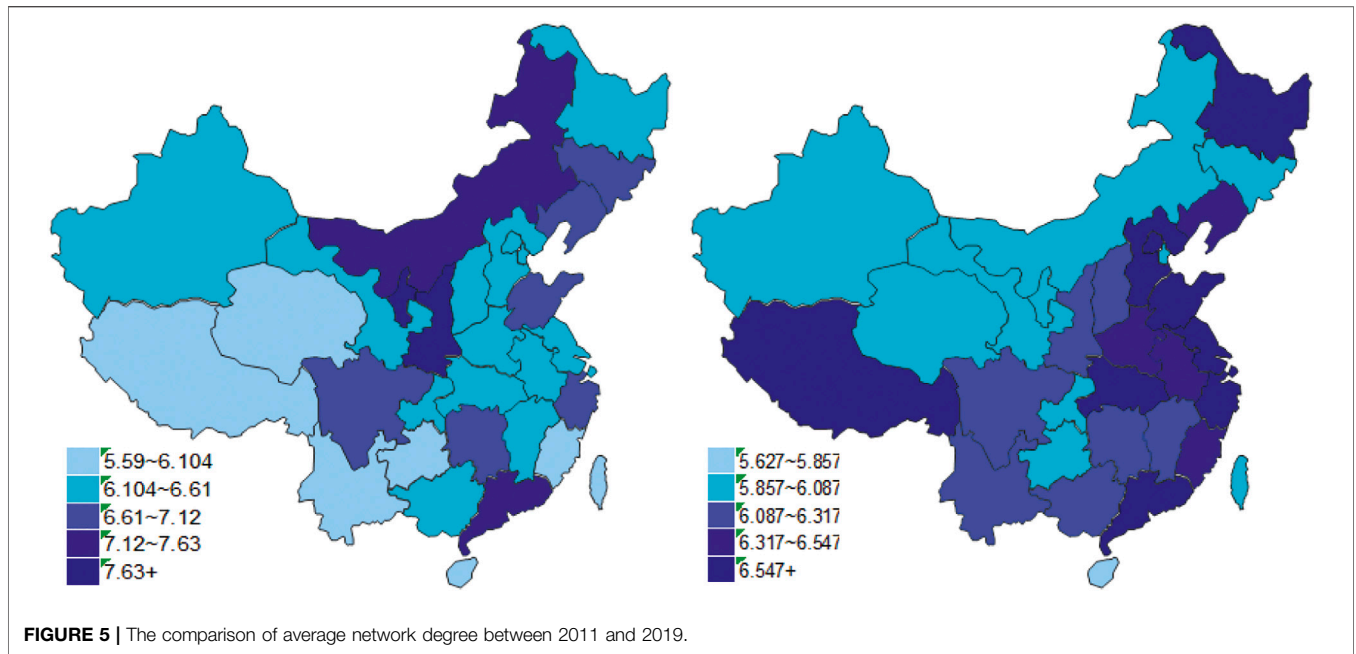


FIGURE 5 | The comparison of average network degree between 2011 and 2019.

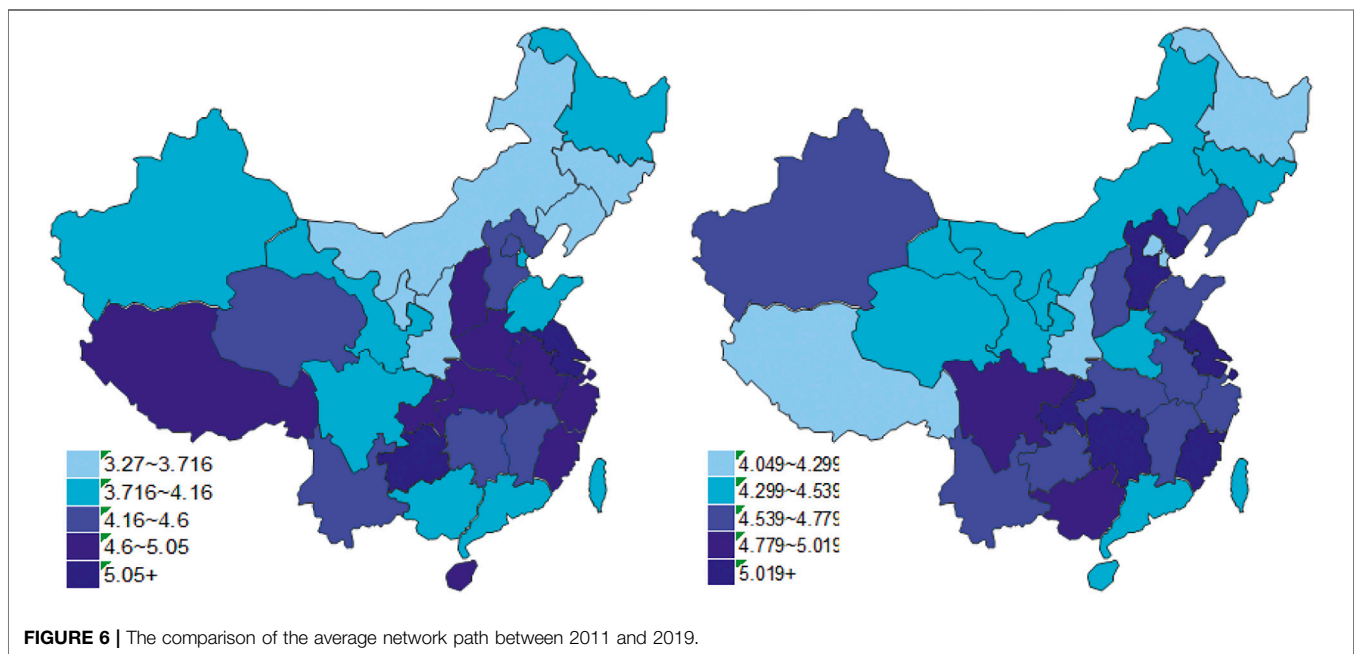


FIGURE 6 | The comparison of the average network path between 2011 and 2019.

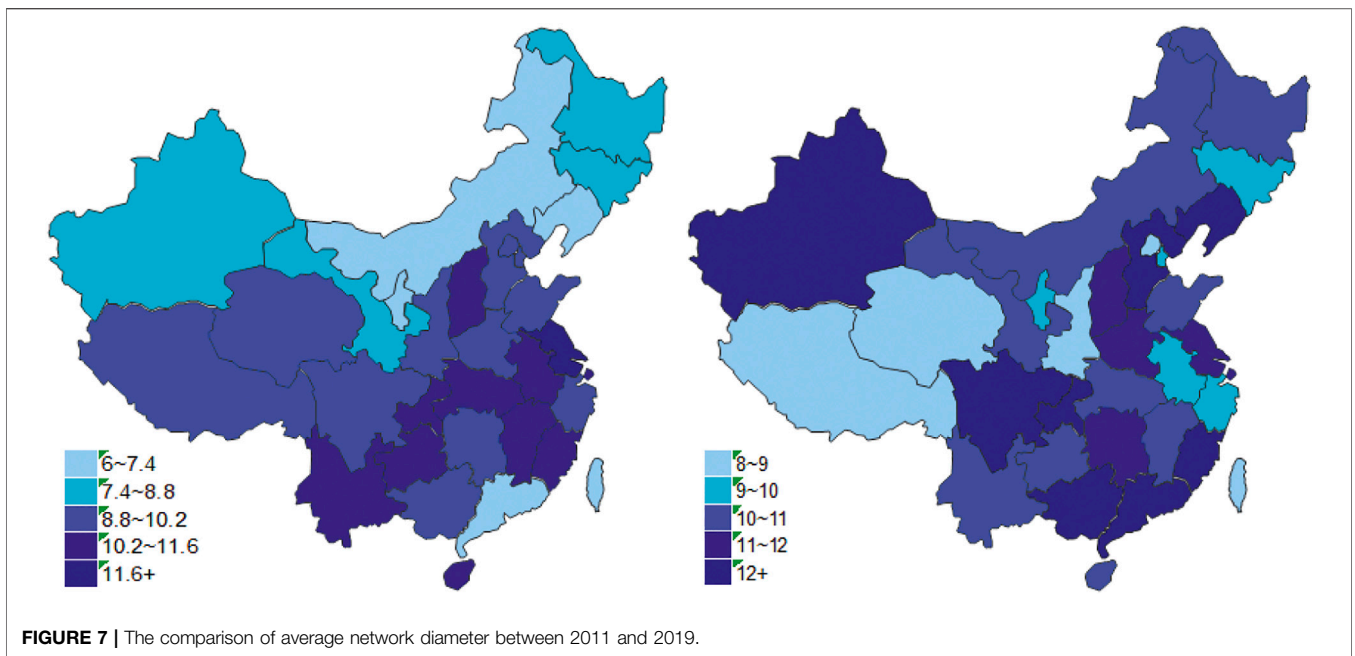
## Annual Change Characteristics of Yoga Attention

### 1) Geographical distribution characteristics of yoga attention

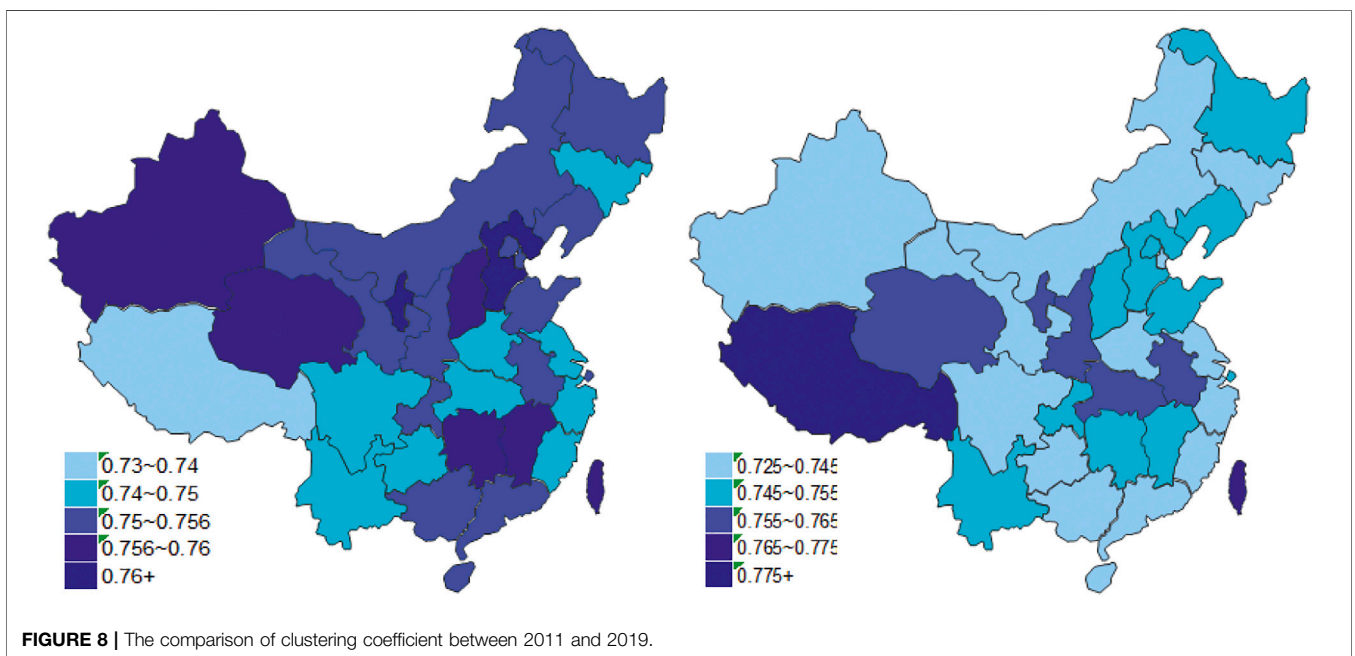
According to the analysis of relevant charts in 2011, we can find that most of the provinces and cities which pay great attention to yoga fall into the area of ethnic minority settlements or its neighboring provinces and cities, while the central and southwestern regions paid relatively little attention to yoga.

Since 2012, the peaks of attention appeared in Anhui, Hubei, Tibet, Yunnan, Guangxi, Shanxi, Hunan, and other places. Among them, Tibetans pay the greatest attention to yoga in China. In recent years, the attention to yoga in coastal areas has been rising.

We found that the degree of attention to yoga changes over time segments. The local people may search “yoga” a lot at a certain point in time, causing the increase of the index, while after the peak arrives, a sharp decline may occur because the exercise habit of the local people has not been cultivated due to exercises conditions or time limits. At the same time, first-tier cities and



**FIGURE 7 |** The comparison of average network diameter between 2011 and 2019.



**FIGURE 8 |** The comparison of clustering coefficient between 2011 and 2019.

provinces pay less attention to yoga and among them, Shanghai pays comparatively great attention.

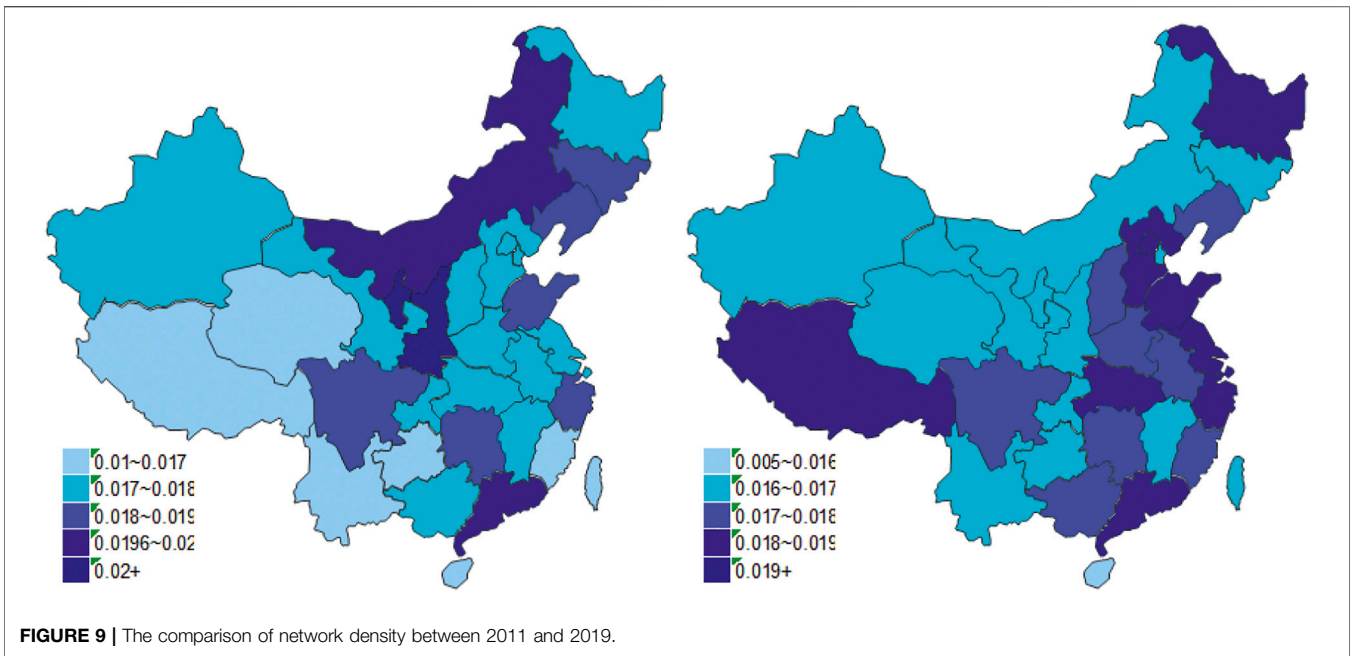
### 2) Temporal characteristics of yoga attention

Compared with 2011, it is found that the attention to yoga in most provinces has increased in recent years due to the development of yoga industry. In particular, with the development of the Internet, the retention time of information is longer, and the influence of each point of time on the others and

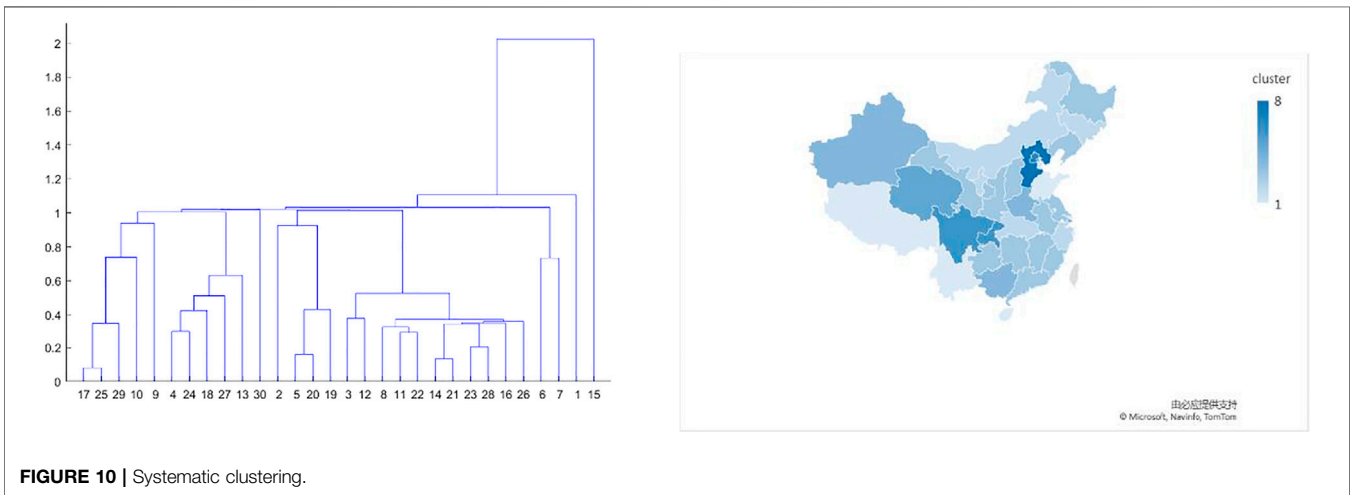
the correlation among them are more prominent. Collectively, it is mainly reflected in the following aspects:

① The network average degree has improved. That is, as time changes, the average influence of each node increases, and its time correlation is stronger.

② The total number of edges is relatively reduced. The reduction in the number of edges indicates that the visible amount of data at the top of the data bar is reduced, which indicates that the peak and bottom of the region's attention that year frequently occurred, meaning greater fluctuations.



**FIGURE 9 |** The comparison of network density between 2011 and 2019.



**FIGURE 10 |** Systematic clustering.

③ The average path and diameter of the network are longer and have been relatively stable in recent years. This shows that network efficiency declines with the passage of time and the rise of emerging technologies.

Relevant information can also be found from the existing literature. With the development of yoga, people start to analyze yoga from various aspects such as theoretical training, method learning, and practical skills. Before 2011, yoga literature focused on theoretical studies, including the fitness effects of yoga and physical education research, the comparison of traditional sports and culture between China and India, the study of religious Buddhism and the interpretation of philosophical thoughts, which did not arouse the public's interest, hence attracted little attention

from the public. Nowadays, the promotion of yoga focuses on people's daily life, such as soothing emotions, improving posture, which is the pursuit of people of all ages. News from all aspects attracts more public attention and the development of communication technology speeds up the spread of news in a short period of time, which has led to an increase in the frequency of related searches.

The diversified development of yoga presents different fashion trends at different times. The gimmick marketing could bring huge attention to yoga in a short period of time, but the attention will decrease quickly because the content of related articles is either exaggerated or unprofessional, resulting in a relative decrease in the total number of edges, which directly affects the average path and diameter of the network.



In this paper, we analyze the cluster data of 31 provinces in China, as shown in **Figure 10**.

It is found that Hebei, Beijing, and Qinghai are the same cluster; Sichuan and Chongqing are the same cluster; Shanghai, Henan, Xinjiang, and Guangxi are the same cluster; Guangdong, Jiangsu, Fujian, Heilongjiang, Shaanxi, Liaoning, Shanxi, Hunan, Jiangxi, Anhui, Gansu, and Guizhou are the same cluster; Hubei, Zhejiang, Jilin, Neimenggu, and Ningxia are the same cluster; Tianjin, Shandong, Yunnan, Hainan, and Xizang are the same cluster.

## CONCLUSION

Using the complex network to visualize the Baidu search index, we can clearly see the distribution of yoga attention in various provinces and cities and the changes that have occurred in recent years. The development of the network environment has provided a good carrier for the spread of yoga. The development of various public accounts and APPs has made the barriers for yoga practitioners continue to shrink, while the targeted group continues to expand, and the attention of yoga continues to rise. But at the same time, it has also led to the spread of distorted information and the decrease of public's interest in yoga. More importance shall be attached to the implementation of basic and popular tutorials so as to boost the development of yoga in China. The public should also choose wisely and get information from relatively authoritative content. All social organizations such as schools, yoga education institutions, and the local government should formulate the corresponding standards and system for the healthy development of yoga. Firstly, different standards shall be formulated based on the characteristic of different age groups and provide different tutorials and guidance methods for teenagers, middle-aged, and the elderly so as to help them practice yoga reasonably. The second is to promote yoga among the targeted group with practical content and tell them about the physical and mental health effects of yoga. Though the theoretical interpretation of yoga culture is of no interest to the public, its positive effect on various diseases and physical and mental health is obvious for them to understand. The positive function of yoga shall be

publicized to attract more targeted groups. Thirdly, the government should strengthen guidance and supervise relevant online content to avoid distorted and false information. At the same time, the government should encourage the adoption of new social media forms such as short video platforms to facilitate the production of online information in a healthy and upward way. It is also seen from the study of the geographical characteristic of yoga attention that the yoga attention has not been raised to a higher level because all provinces are promoting yoga in their own local areas with little cooperation, causing development barriers due to region limitations, which does not contribute to the development of yoga in China as a whole. All kinds of activities such as offline exercise can be organized to help expand the influence of yoga, giving full play to the advantages of different provinces to raise the attention of yoga.

Visualizing time series data is more intuitive and convenient to analyze the changing trend of data and explore the deep laws and characteristics of the development of the industry. This paper applies the time series visualization method to the study of yoga attention, which helps to grasp the current situation of yoga sports development and propose the policy to guide the future development direction. This study provides a paradigm and sample for the application of time series visualization methods in the field of social science research for further advancement of other analogous studies.

## DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available. Requests to access the datasets should be directed to <https://index.baidu.com/v2/index.html#/> and the corresponding authors.

## AUTHOR CONTRIBUTIONS

PL: conceptualization, methodology, software, validation, drawing, and writing; QM: visualization, software; YM: computation, drawing, and writing; JN: visualization, software; JL: investigation; JH: writing—reviewing and editing.

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**Conflict of Interest:** QM was employed by Beijing Jingkong Technology Co., Ltd.

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