Global obesity research trends during 1999 to 2017
A bibliometric analysis

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Abstract
Background: The interest in obesity has considerably increased in the scientific community in the last 2 decades. We present a bibliometric analysis to find out the future research hotspot and trends of obesity.

Methods: Data were based on the Science Citation Index Expanded (SCI-E), from the Institute of Scientific Information Web of Science database and the 5-year impact factor of a journal were issued from the Journal Citation Reports (JCR) in 2017. Articles referring to obesity during 1999 to 2017 were concentrated on the analysis by scientific output characters and the frequency of author keywords used.

Results: Globally, 50,246 articles meet the inclusion criteria during 1999 to 2017. The cumulative number of publication about obesity followed exponential distribution (R²=0.9974) from 2008. USA was the most productive countries in both independent and international collaborative papers, the countries/regions with the highest average Times Cited scores for independent articles was France and The United Kingdom scored the highest in average Times Cited for international collaborative papers. Collaboration among countries, playing an ever-growing role in contemporary scientific research. The 2 most prolific journals are Obesity Surgery and International Journal of Obesity, responsible for 3.95% of the publication.

Conclusion: Obesity has been a field of intense research in the last 19 years. By reasonably analyzing the author keywords and the distribution of journals, “bariatric surgery” (especially “sleeve gastrectomy”) and “obese complications” (especially “diabetes mellitus,” “metabolic syndrome,” “depression,” and “polycystic ovary syndrome”) will undoubtedly maintain the hotspots of obesity research in the next few decades.

Abbreviations: % = the percentage of the author keyword, ↑ = percentage went up significantly over time, ↓ = percentage went down significantly over time, Av. NR = the average cited reference count per article, Av. PG = the average page count per article, Av. TC = average number of Times Cited per article, CP = the number of international collaborative articles, CP/TP = the percentage of international collaborative publications in total publications, IF = 5-year impact factor, IP = the number of independent articles, No. A = annual number of articles, No. Cr = the number of countries participated in obesity research, P = publications in the study period, Pal = participation index, QR = quartile rank, R = the rank of the author keyword, TC = Times Cited, TP = total articles.

Keywords: bariatric surgery, bibliometric analysis, obesity, research trends

1. Introduction
Obesity is a long-standing metabolic disorder caused by multiple factors, which can be traced back to 25,000 years ago, the earliest recorded in the Paleolithic statue.[1] Now obesity has become one of the key causes of public health, with the rapid development of the global economy, the improvement of people’s living standards, coupled with unreasonable dietary structure, bad lifestyle, etc. Data from the World Health Organization[2] show that about 200 million men and nearly 300 million women are obese in 2008. According to a report[3] in the JAMA Journal of Internal Medicine, more than two-thirds of people in the United States are overweight or obese. In 2013, the American Medical Association[4] made it clear that obesity should not only be considered a disease risk factor, but also a real disease state. With the epidemics of obesity and obesity-related diseases, research on obesity is more and more popular. In this paper, we focus on summarizing the global research trends of obesity studies.

Over the past decades, the interest of bibliometric information in quantitative analysis for a given topic, and acquiring statistics to evaluate the contribution of scientific publications to the advancement of knowledge increased, especially in the medical research fields.[5–7] Mela and Cimmino[8] evaluate the distribution and scope of papers published by the European Union (EU) in rheumatological journals and the impact of rheumatological research in the EU in comparison with that produced elsewhere. Scientific publications indeed represent current research trends and can be used to identify the focus of present, past, or future
research.[9] However, conventional bibliometric analysis in medical research has 2 inherent deficiencies: on the one hand, datasets used in analysis are incomplete. For instance, some studies only select several journals or categories to represent global research trends related to the topic,[8,10]; on the other hand, citations or publication counts of countries and organizations, which are widely used in conventional bibliometric analysis, cannot comprehensively reveal the trend in a research field.[11] More information, which is closer to the research itself, such as source title, author keyword, and abstracts should be introduced in the study of research trend.

This paper presents alternative statistical methods in bibliometric analysis. Both citation and author keywords analyses in the Scientific Citation Index database were used to describe the global trends of obesity research during the period of 1999 to 2017. We attempted to provide all-around insights into the current state of global obesity research, including annual outputs characters, international collaborations, and author keywords analyses. Results provide a better understanding of trends in global obesity research and point to the direction for future studies.

2. Materials and methods

This study protocol was approved by the ethics committee of our college. Documents considered in this study come from Web of Science, published by the Institute for Scientific Information (ISI) in Philadelphia, USA. The ISI database provides a readily available and comprehensive data source for bibliometric analysis. Rodrigues et al.[12] used a bibliometric indicator to map the Brazilian cancer, cardiovascular and malaria research areas from 1981 to 1995. They reported that the ISI databases can produce reliable performance indicators for the mapping of scientific capabilities and for monitoring scientific capabilities and activity in Brazil in the health-related areas. We do not use the Medline database, because it does not record all the address listed on a paper, but only that of the first author. Therefore, some authors are not always found and the articles retrieved are limited to those where country appears in at least one of the Medline search fields (address, title, abstract, etc.). Moreover, Medline does not provide information concerning citations of publications, while the performance of the articles can hardly be exhibited. One mesh term “obesity” already checked in PubMed mesh database was used to conduct searching titles, abstracts, and author keywords from 1999 to 2017. Our search formula was “TS=(“obese” or “obesity”), Databases=SCI-E, Time span=1999–2017.” Articles originating from England, Scotland, Northern Ireland, and Wales were categorized as being from the United Kingdom. The collaboration type was determined based on the address of each author, with the term “independent article” being assigned if the addresses of the researchers were only in 1 country. Articles were labeled as “international collaborative article,” if they are co-signed by researchers from multiple countries.

This searching strategy located 62,943 publications on obesity in the SCI database, including 20 documents types. Because journal articles and the language of English represented the majority of publications and were of high quality due to rigorous peer-review processes, we thus focused on articles and proceedings papers written in English (50,246 papers in total) in the following analysis.

3. Results and discussions

3.1. Scientific outputs

Several publication outputs characters of current obesity research during the time span of 1999 through 2017 was summarized in Table 1. The length of the article fluctuates slightly, with an average of 7.5 pages. The number of references cited has increased slightly through the 19 years, with an average of 28 references in 1999 and 37 in 2017. Times Cited (TC) for an article increased slightly through the 19 years, with an average of 28 years.

\[
Y = 1244.5X - 1100.6 (1999 - 2007)
\]

\[
Y = 2889.6e^{0.122X} (2008 - 2017)
\]

For further study, a significant correlation was found between the yearly cumulative number of publications and the year from 1999 to 2017 (Fig. 1). In this study period, the growth of cumulative publication number followed a linear trend before 2006, while this figure had increased exponentially in the last decade, which can be expressed as follows: where Y is the number of publication, X denotes the corresponding year, and e is the Napier’s constant. Due to the high coefficients of determination of both Eq. (1) \((R^2 = 0.9984)\) and Eq. (2) \((R^2 = 0.9974)\), the world publications related to obesity research could be estimated using this model. It can be predicted that the number of scientific articles on the topic of obesity is still growing at a high rate in the future. Moreover, it can be calculated that, by the time of 2022, the number of scientific articles on the topic of obesity will be twice of the number of publications in 2017.

3.2. Collaboration type

The mainstream of participation and collaboration on obesity research was obtained after analyzing all the countries producing

| Years | No. A | Av. NR | Av. TC | Av. PG | No. Cr |
|-------|-------|--------|--------|--------|--------|
| 1999  | 404   | 28.0   | 43.8   | 7.0    | 44     |
| 2000  | 1096  | 28.8   | 43.9   | 6.9    | 61     |
| 2001  | 1098  | 28.7   | 48.4   | 6.7    | 62     |
| 2002  | 1178  | 29.7   | 40.8   | 7.1    | 61     |
| 2003  | 1115  | 29.9   | 44.6   | 7.0    | 60     |
| 2004  | 1213  | 31.0   | 45.4   | 7.3    | 59     |
| 2005  | 1202  | 30.7   | 48.4   | 7.0    | 59     |
| 2006  | 1452  | 30.6   | 64.6   | 7.0    | 60     |
| 2007  | 1731  | 30.9   | 35.0   | 7.1    | 73     |
| 2008  | 2110  | 31.9   | 29.3   | 7.4    | 71     |
| 2009  | 2540  | 31.0   | 26.2   | 7.3    | 79     |
| 2010  | 2807  | 32.5   | 22.6   | 7.5    | 79     |
| 2011  | 3194  | 33.0   | 18.3   | 7.6    | 80     |
| 2012  | 3664  | 34.3   | 18.6   | 7.8    | 86     |
| 2013  | 3903  | 35.6   | 11.9   | 8.0    | 91     |
| 2014  | 4543  | 35.5   | 9.2    | 8.1    | 89     |
| 2015  | 4998  | 36.2   | 7.1    | 8.2    | 95     |
| 2016  | 5362  | 37.5   | 5.5    | 8.6    | 103    |
| 2017  | 6456  | 37.4   | 2.4    | 8.7    | 112    |
| Total | 50,246 |   -    |   -    |   -    | 153    |
obesity papers. Among the total 153 countries/territories over the investigation period, 47 countries/territories had no publication output during 1999 to 2017, and 10 countries/territories have just begun to publish papers in the year 2017. Top 15 most productive countries/territories participated in >78% of all world obesity articles from ISI database, while 26 countries published only 1 article. Domination and imbalance in publication from mainstream countries was not surprising since this pattern occurred in most scientific fields.

Collaboration among countries, playing an ever-growing role in contemporary scientific research, can usually manifest itself in internationally coauthored papers tracked by bibliometric tools. Among the 50,246 articles with address information, 86.1% were publications from single country, and others were international collaborative work. A joint interpretation of our current findings and other bibliometric analyses of medical fields suggest that the collaboration rates in medical fields are significantly less than other science fields. This is probably due to nature of medical research, as it is generally more difficult for medical institution to carry out international collaborations, because of constraints of national regulations, standards, communications, and time effects. In Fig. 2, international collaborative articles were more prevalent in recent years than earlier years, from a 14.9% percentage of world ISI articles in 1999 to 16.5% in 2017. In general, the ascending trend of collaborative article proportion to world publication was somewhat owing to the rising number of the institutes and countries that engaged in the research, and the increased ease of communication in a technologically connected world. Moreover, TC indicators of international collaborative articles are much higher than that of independent publications all through the study period, which indicates that international collaborative articles have higher visibility than others. Among all the 50,246 articles, 6964 papers are international collaborative publications. These articles had an average TC of 23.3, while the others by single countries had a lower average TC of 18.1. Therefore, it would be reasonable to assume that more international collaboration would lead to more powerful articles due to the sharing of ideas and workloads.

The top 25 countries/territories were ranked by number of publications, including the number and TC of single country articles and international collaborated articles (Table 2). Two North American countries, 12 European countries, 8 Asian countries/regions, 2 Latin American country and Australia were ranked the top 25 of publications. There are still no African countries getting into the top 30 productive countries. These 25 productive countries occupied 83% of international collaborated articles, which indicated their great ability in the laparoscopy research fields. Although the USA was the most productive countries in both independent and international collaborative papers, the countries/regions with the highest average TC scores for independent articles were France and the United Kingdom scored the highest in average TC for international collaborative papers. Iran and South Korea had the lowest average TC per article among the top 25 countries/regions in independent articles and international collaborative articles, respectively. As been stated above, the average TC indicators for international collaborative articles of all 25 countries are higher than their national independent articles, except for Turkey, Australia, South Korea, Brazil, France, Sweden, Denmark, Mexico. Large increase in average TC can be easily found between the independent and international collaborative articles of USA, the United Kingdom, Switzerland, and Finland, which indicates that these countries benefit a lot in the international cooperation.

3.3. Distribution of output in journals
In total, 50,246 articles were published in 5156 journals, including not only specialty journals, but also journals of other disciplines. The top 20 productive journals through the recent 19
years are presented in Table 3. As the leading journal of this particular research field, Obesity Surgery published 1414 articles, comprising 2.81% of all the articles, followed by International Journal of Obesity and Obesity, contributing 1.14 and 0.81% of all the journal articles, respectively, with impact factor is 3.386, 5.453, and 4.181. Remarkably, 60% (12/20) of journals publishing on obesity are “Endocrinology & Metabolism” and “Nutrition & dietetics,” with the remaining (8/20, 40%) belonging to other fields such as surgery or public health, which may indicate the significant relationship between weight loss and

Table 2

| Country/Region | TP | IP | TC | Av.TC | CP | TC | Av.TC | CP/TP |
|----------------|----|----|----|-------|----|----|-------|-------|
| USA            | 14632 | 13213 | 327430 | 24.8 | 1419 | 47424 | 33.4 | 9.70% |
| Japan          | 3492 | 3261 | 62935 | 19.3 | 231 | 5494 | 23.8 | 6.62% |
| Italy          | 2562 | 2221 | 44820 | 20.2 | 341 | 7901 | 23.2 | 13.31% |
| The United Kingdom | 2488 | 1858 | 42865 | 23.1 | 630 | 26722 | 24.2 | 25.32% |
| Turkey         | 1855 | 1809 | 17500 | 9.7 | 46 | 398 | 8.7 | 2.48% |
| Peoples R China | 1760 | 1513 | 12423 | 8.2 | 247 | 2428 | 9.8 | 14.03% |
| Australia      | 1745 | 1402 | 24331 | 17.4 | 343 | 5750 | 16.8 | 19.66% |
| South Korea    | 1651 | 1494 | 13757 | 9.2 | 157 | 1146 | 7.3 | 9.51% |
| Germany        | 1526 | 1204 | 23152 | 20.2 | 322 | 7800 | 24.2 | 21.10% |
| Brazil         | 1389 | 1267 | 11260 | 9.1 | 427 | 1075 | 8.8 | 8.78% |
| France         | 1335 | 1070 | 27394 | 25.6 | 265 | 6733 | 25.4 | 19.85% |
| Canada         | 1295 | 1025 | 15816 | 15.4 | 270 | 5621 | 20.8 | 20.85% |
| Spain          | 1182 | 992  | 14152 | 14.3 | 190 | 3833 | 19.1 | 16.07% |
| India          | 1133 | 1043 | 8439  | 8.1 | 90  | 1072 | 11.9 | 7.94% |
| Netherlands    | 1109 | 900  | 21444 | 23.8 | 209 | 6279 | 30   | 18.85% |
| Poland         | 782  | 707  | 5094  | 7.2 | 75  | 598  | 8   | 9.59% |
| Iran           | 741  | 675  | 3613  | 5.4 | 66  | 408  | 7.5 | 9.91% |
| Greece         | 679  | 613  | 9665  | 17.2 | 116 | 2367 | 20.4 | 17.08% |
| Taiwan         | 673  | 613  | 6269  | 10.2 | 60  | 757  | 12.6 | 8.92% |
| Sweden         | 611  | 469  | 9827  | 21   | 142 | 2833 | 20   | 23.24% |
| Israel         | 609  | 519  | 9654  | 19   | 90  | 1717 | 19.1 | 14.78% |
| Denmark        | 464  | 380  | 7992  | 21   | 84  | 1618 | 19.3 | 18.10% |
| Switzerland    | 444  | 302  | 7481  | 24.8 | 142 | 5662 | 39.2 | 31.98% |
| Mexico         | 391  | 336  | 3082  | 9.2  | 55  | 406  | 7.4  | 14.07% |
| Finland        | 359  | 292  | 6000  | 20.5 | 67  | 1977 | 29.5 | 18.66% |

Av.TC = average number of Times Cited per article; CP = the number of international collaborative articles; CP/TP = the percentage of international collaborative publications in total publications; TP = the number of independent articles; TP = total articles.
Obesity is further categorized into grade I (BMI 30–34.9), grade II (BMI 35–39.9), and grade III (BMI $\geq$40). Although these categories for defining overweight and obesity are widely used, it is noteworthy that the BMI values for overweight and obesity are different for Asians. Apart from “obesity” and “Body Mass Index,” the most frequently searching keyword was “Diabetes Mellitus, Type 2” (2808, 5.59%). Surgeon Pories is the first person in history to associate diabetes with obesity. In 1981, Pories accidentally found that obese patients with type 2 diabetes mellitus received bariatric surgery, whose blood sugar quickly returned to normal dancing to significant weight loss. After 14 years of clinical research, an article named “Who would have thought it? An operation proves to be the most effective therapy for adult-onset diabetes mellitus” has attracted attention. Many observational studies have shown glycemic lasting improvement in obese patients with type 2 diabetes mellitus after bariatric surgery. Although surgical efficacy is better than pharmacological or behavioral intervention, however, surgery is not an attractive therapeutic option for many individuals suffering from obesity and its consequences. Therefore, it is both scientifically and clinically imperative that we identify molecular mechanisms responsible for weight loss and other metabolic improvements so we can target affected pathways in a less-invasive manner.

### 4. Discussion

Obviously, the 2 most frequent occurrences in the search term are “obesity” (10,077, 20.06%) and “body mass index” (3121, 6.21%). The diagnosis of obesity is often based on body mass index (BMI), calculated as weight in kilograms divided by height in meters squared (kg/m$^2$). Individuals with BMI 18.5 to 24.9 are considered having normal weight, those with BMI 25 to 29.9 are considered overweight, and those with BMI $>30$ are considered obese.
Obesity is the main cause of cardiovascular diseases (352, 0.70%), polycystic ovary syndrome (497, 0.99%), and depression (356, 0.71%), which indicates obesity is mainly studied as a cause, not a disease itself at present. However, another question which Obesity can cause inflammation, why inflammation will induce cardiovascular disease, diabetes, cancer, and other diseases is coming. Takii[26] owned the main mechanism of inflammation to gene mutation and protein inactivation as a risk factor for multiple diseases. Further analysis found that “metabolic syndrome,” “depression,” and “polycystic ovary syndrome” grew at a faster rate in the studies of obesity-related disease, but “hypertension” had a downward trend, which may indicate the main research direction and hot spots of obesity-related complications in future.

Another important finding is the shift in obesity treatment. “diet” and “exercise” maintain a clear leading position in both ranking and percentage of all author keywords in the study period, which suggests that lifestyle management is still the main way to lose weight today. Ochter et al[27] found that approximately 80% to 95% of the obese people will activate the shift in obesity treatment.

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the uncertain impact of diet and exercise, most individuals that lose weight with bariatric surgery (1375, 2.74%) maintain reduced levels of body fat for many years. In 1967, Mason and Ito introduced “gastric bypass” (703, 1.40%) surgical procedure into weight loss, after occasionally noting that patients with peptic ulcer had a sustained weight loss after “gastric bypass.” Surprisingly, postoperative significant effect of weight loss makes “gastric bypass” surgical procedure become the standard surgery for bariatric surgery. In 2004, Almogy et al. reported some patients gain significant weight loss with sleeve gastrectomy (429, 0.85%), who failed to implement gastric bypass due to special reasons. Since then, a many literatures reported that the 3 to 5-year follow-up results show that sleeve gastrectomy, as an independent surgery, is not inferior to other surgical procedures in weight loss and complications improvement. Compared with gastric bypass, sleeve gastrectomy has the advantages of simple operation, short learning curve, short operation time, less postoperative complications, and single variable, so that it is widely used in clinical and experimental research, which can be seen from Table 4.

**Author contributions**

Ning Zhao and Zefeng Xia made contributions to the study design. Ning Zhao and Kaixiong Tao completed the literature search, collection of the data, data analysis, and the initial manuscript. Zefeng Xia and Guobin Wang reviewed and revised the final manuscript.

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