

Determination of Cellulitis Seasonal Variation Using Internet Big Data and National Health Insurance Claim Data in Korea

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Abstract The crucial factor in utilizing Internet search volume data to study various health issues is the representativeness of the collected data concerning the actual prevalence of the disease. Thus, we aimed to evaluate if there are seasonal patterns in the incidence of cellulitis cases by analyzing data from the Korean Health Insurance Review & Assessment Service database, along with Internet search volume data related to cellulitis. Furthermore, we investigated the correlation between these datasets. The monthly number of cases of cellulitis was collected from the Korean Health Insurance Review & Assessment Service for the period from January 2016 to December 2022. Additionally, DataLab, an Internet search query trend service provided by the Korean portal website Naver, was used to obtain the monthly relative search volumes for three keywords related to cellulitis during the same timeframe. To determine the seasonality of monthly case numbers and corresponding search volumes, we conducted a Cosinor analysis. We utilized Pearson correlation analyses to evaluate the relationship between these variables. The incidence of cellulitis cases and the associated search volume for cellulitis-related terms both presented significant seasonality, with peaks in the summer and lows in the winter months. The seasonality was evident in both the incidence of cellulitis cases and the related Internet search data, with summer months registering the highest frequency. Significant correlations were found between Internet search volumes for cellulitis-related keywords and seasonal shifts in cellulitis incidence,

suggesting that big data from the Internet is a valuable complementary resource for cellulitis research and monitoring.

Keywords Cellulitis, Internet, Big Data, Seasonality

1. Introduction

Nowadays, individuals can conveniently and quickly retrieve desired information by entering keywords into an Internet search engine [1]. Consequently, patients and healthcare providers rely on Internet searches to locate health and medical information [2]. As of recently, significant amounts of data collected through Internet portals have been utilized for medical research. Thus, Internet information is expected to complement traditional methods of data acquisition, such as patient surveys and medical record reviews [3]. Studies utilizing search volume data from Internet queries have elucidated disease epidemiology, health-related behaviors, and public interest [2-4]. Given the rise of the Internet, many individuals seek medical information online when experiencing physical abnormalities, pain, or receiving a diagnosis of a disease. To utilize Internet search volume data in health-related research, it is crucial to understand the correlation between the Internet data and the current severity or prevalence of a disease. Consequently, several

studies have explored and documented the link between Internet search volume data and actual disease incidence data for multiple illnesses [5–10]. These studies have demonstrated that, while traditional survey methods are time-consuming, labor-intensive, and costly, Internet search data can be obtained easily and swiftly in real time, are inexpensive, and can significantly mirror the actual incidence of a disease [5–10].

Cellulitis is the most common bacterial infection of the skin and subcutaneous tissue and is characterized by skin erythema, swelling, edema, warmth, and tenderness [11,12]. Notably, cellulitis develops due to pathogens entering the dermis through disruptions of the skin barrier [12]. Predisposing factors associated with the risk of cellulitis include skin barrier disruption due to trauma such as abrasion, penetrating wound, ulcer and insect bite, chronic lymphedema, venous insufficiency, tinea pedis, and obesity [11–13]. Importantly, the development of cellulitis is influenced not only by personal risk factors but also by environmental risk factors. Several studies have reported the seasonal trends of cellulitis, with a notable increase in its incidence during the warm months [14–17]. The incidence of cellulitis may be ascertained through large-scale patient surveys; however, this method is time-intensive in terms of data collection, organization, and calculation, and it demands substantial manpower and financial resources.

The crucial factor in utilizing Internet search volume data to investigate various health issues is whether the collected data is a true reflection of the disease's actual severity or prevalence. In Korea, there have been a few studies on the relationship between search volume data using big data analysis services provided by Internet search engines and actual disease incidence [7–10]. However, no study has been reported on the relationship between the actual incidence of cellulitis in Korea and Internet search volume using Internet portal sites. Here, we used data on the number of patients with cellulitis from the Health Insurance Review and Assessment Service (HIRA) and data on search query trends for "cellulitis" from Naver (www.naver.com), the largest Internet search portal site in Korea, to determine whether there is a seasonal variation in each and to analyze the correlation between the data. Therefore, we aimed to determine how much Internet big data on cellulitis reflects actual clinical data.

2. Materials and Methods

2.1. Data Source

This was a retrospective study of the number of patients diagnosed with cellulitis based on data from the HIRA, search volume data for "cellulitis," and related search terms provided by Naver from January 2016 to December 2022. DataLab (<https://datalab.naver.com>), which offers

insights into search query trends on Naver, has provided access to data since January 2016. The medical statistics from the HIRA were accessible up to eight months before the search date; consequently, we analyzed the data through December 2022.

Approximately 98% of the total population is enrolled in Korea's National Health Insurance Service [18]. Claims data from the HIRA contain patient information corresponding to most of the Korean population [18]. The HIRA provides data such as the number of monthly patients, number of claims, number of days of hospital visits, and total cost of service by disease code according to the Korean Standard Classification of Diseases. From the medical statistics information of the HIRA, data with the disease code of cellulitis (L03) from January 2016 to December 2022 were searched by setting conditions for all genders and all ages, and the number of patients per month was confirmed. This number of patients was again divided by gender and age group and was finally confirmed. The seasonal classification was divided into spring from March to May, summer from June to August, fall from September to November, and winter from December to February. Because most of the Korean population is enrolled in the National Health Insurance Service, the data on the number of patients from the HIRA were considered representative of the actual number of patients [18].

From 2016 to 2022, Naver has the highest domestic Internet search engine market share, ranging from 64.8 to 78.1% [19]. Therefore, the number of searches on Naver best reflects domestic Internet searches. To check the relative search volume of search terms, we used DataLab, a search query big data service provided by Naver. DataLab provides a relative search volume index by summing the number of times a specific search query has been searched on Naver by day, week, and month and setting the highest search volume within the viewing period to 100. We performed the analysis using the following keywords: yeonjojig-yeom (연조직염), sellullaitiseu (셀룰라이트스), and bongsoyeom (봉소염) in Korean. "연조직염" is the Korean equivalent to "cellulitis," and "셀룰라이트스" and "봉소염" are the Korean major synonyms for "cellulitis". From January 2016 to December 2022, in DataLab's search query trends, we collected the monthly relative search volume for the above search terms after setting conditions for all genders and ages. Moreover, we changed the searcher condition to view the relative monthly search volume by gender and age. Accordingly, we verified whether the monthly incidence of cellulitis patients and the corresponding monthly relative search volume for cellulitis-related terms, as indicated in the medical statistical data from the HIRA, demonstrate seasonality. Additionally, we analyzed each patient, gender, and age group to determine whether there was a significant correlation between the number of patients per month and the relative search volume for each search term. However, as DataLab categorizes the teenage

age group into subgroups below 12 and above 13 years, a comparative analysis with HIRA's defined teenage group (10 to 19 years old) was deemed inappropriate. Consequently, teenagers were omitted from the age group analysis, and correlation analyses were exclusively conducted on individuals aged 20 and above.

2.2. Statistical Analysis

Statistical analysis was performed using R version 4.2.3 (R Foundation for Statistical Computing, Vienna, Austria) and IBM SPSS version 26.0 (IBM Corp., Armonk, NY, USA). To determine the seasonality of the number of patients and Internet search volume, Cosinor analysis was carried out. Furthermore, a Pearson correlation analysis was executed to establish the correlation between the two groups. The significance level of Cosinor analysis was set at $p < 0.025$ to suppress the false discovery rate due to multiple testing, and the significance level of Pearson correlation analysis was set at $p < 0.05$.

3. Results

Upon analyzing the monthly incidence of cellulitis diagnoses, it was observed that patient numbers peaked during summer, with August accounting for the highest number of cases, and dwindled to the lowest value in winter, specifically in February (Fig. 1A). The relative search volume for each of the search terms "연조직염," "셀룰라이트스," and "봉소염" was also highest in summer and lowest in winter (Fig. 1B, C and D). By month, the highest and lowest search volumes for all three search terms were registered in July and February, respectively. The Cosinor analysis showed a significant seasonality in the number of cellulitis patients, with a peak in August and a trough in February (amplitude [A]=25114.6, phase month [P]=7.8, low point month [L]=1.8, $p < 0.001$). In addition, significant seasonality was observed in the relative search volume of the search term "연조직염" (A=16.7, P=7.6, L=1.6, $p < 0.001$), with the highest value in August and the lowest in February. The relative search volume of the search term "셀룰라이트스" (A=10.2 P=7.2, L=1.2, $p < 0.001$) showed a significant seasonality with a peak in July and a trough in January. Similarly, the relative search volume of the search term "봉소염" (A=12.3 P=7.5, L=1.5, $p < 0.001$)

showed a significant seasonality with the highest value registered in July and the lowest in January (Figure 2 & Table 1).

The correlation analysis indicated a statistically significant positive association between the total monthly patient volume of cellulitis in HIRA and the total monthly relative search volume of the search term "연조직염" in DataLab ($r=0.74$, $p < 0.001$). Male and female monthly numbers of patients with cellulitis were significantly and positively correlated with the male and female monthly relative search volume for the search term "연조직염" ($r=0.68$, $p < 0.001$), ($r=0.63$, $p < 0.001$). Correlation analysis stratified by age revealed a significant positive correlation for individuals in their 20s ($r=0.82$, $p < 0.001$), 30s ($r=0.71$, $p < 0.001$), 40s ($r=0.25$, $p=0.021$), and those aged 60 and above ($r=0.75$, $p < 0.001$). In contrast, no significant correlation was observed for those in their 50s ($r=0.18$, $p=0.110$) (Table 2).

The correlation analysis revealed a significant positive association between the total monthly patient volume of cellulitis in HIRA and the total monthly relative search volume of the search term "셀룰라이트스" in DataLab ($r=0.68$, $p < 0.001$). Male and female monthly numbers of patients for cellulitis were significantly and positively correlated with the male and female monthly relative search volume for the search term "셀룰라이트스" ($r=0.51$, $p < 0.001$), ($r=0.69$, $p < 0.001$). Furthermore, there was a substantial definitional correlation found using age-related correlation analysis among individuals in their 20s ($r=0.73$, $p < 0.001$), 30s ($r=0.61$, $p < 0.001$), 40s ($r=0.41$, $p < 0.001$), and 60s or older ($r=0.35$, $p=0.001$), except for those in their 50s ($r=0.18$, $p=0.108$) (Table 3).

The correlation analysis showed a significant positive correlation between the total monthly patient volume of cellulitis in HIRA and the total monthly relative search volume of the search term "봉소염" in DataLab ($r = 0.49$, $p < 0.001$). Male and female monthly numbers of patients with cellulitis were significantly and positively correlated with male and female monthly relative search volume for the search term "봉소염" ($r=0.46$, $p < 0.001$), ($r=0.46$, $p < 0.001$). Finally, there was a significant definitional correlation among individuals in their 20s ($r=0.34$, $p=0.001$), 30s ($r=0.54$, $p < 0.001$), 40s ($r=0.22$, $p=0.047$), and 60s or older ($r=0.70$, $p < 0.001$), but not among those in their 50s ($r=0.21$, $p=0.051$), as evidenced by age-based correlation analysis (Table 4).

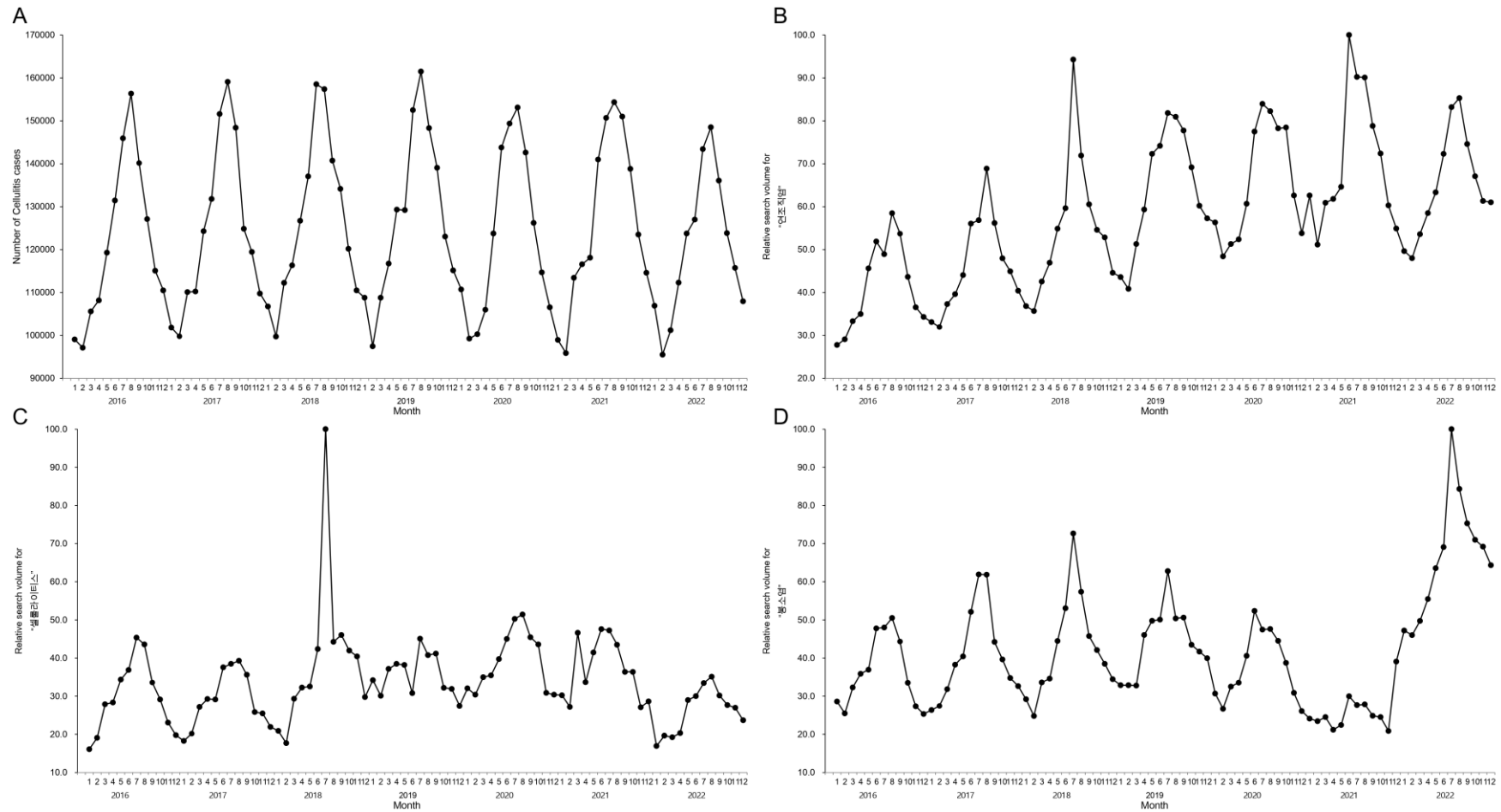


Figure 1. Time series plots for cellulitis from January 2016 to December 2022. (A) The number of cellulitis cases. (B) The relative search volume for "연조직염" ("cellulitis" [in Korean]). (C) The relative search volume for "셀룰라이트스" (synonym of "cellulitis" [in Korean]). (D) The relative search volume for "봉소염" (synonym of "cellulitis" [in Korean]).

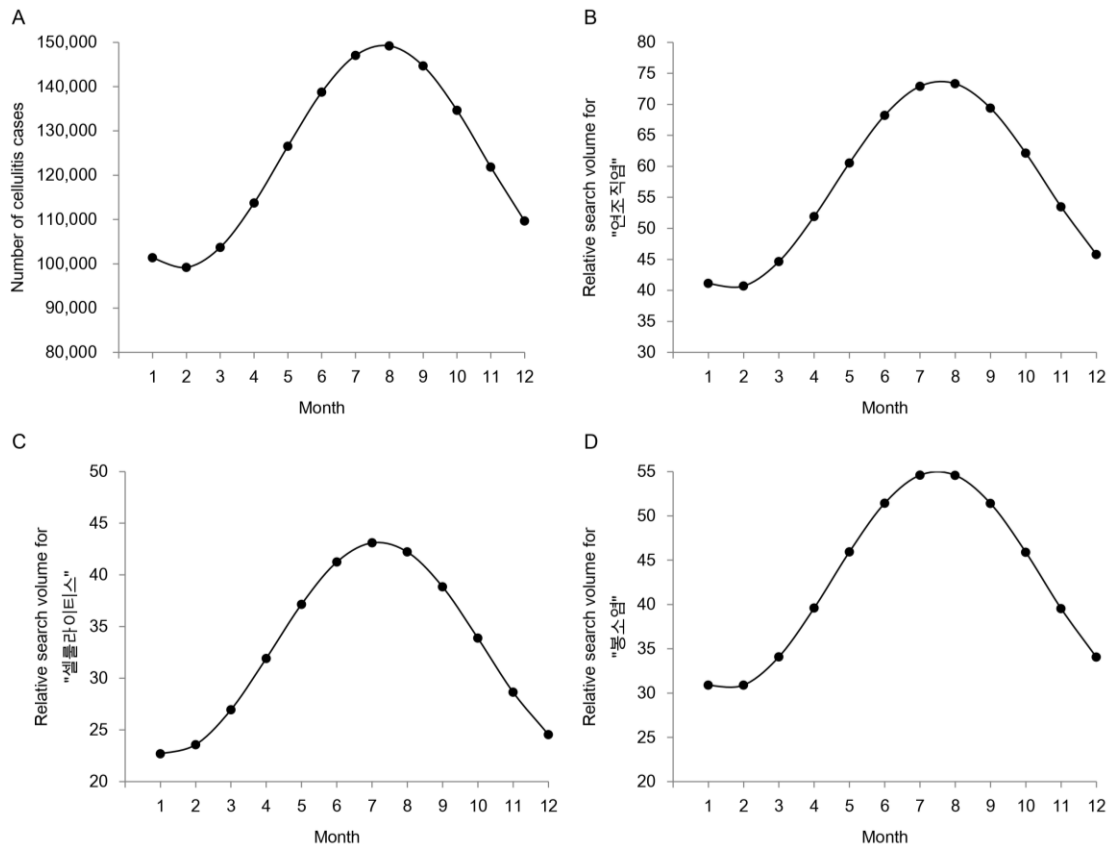


Figure 2. The plots of the Cosinor model for the seasonal variation of cellulitis. (A) The number of cellulitis cases. (B) The relative search volume for "연조직염" ("cellulitis" [in Korean]). (C) The relative search volume for "셀룰라이트스" (synonym of "cellulitis" [in Korean]). (D) The relative search volume for "봉소염" (synonym of "cellulitis" [in Korean]).

Table 1. Cosinor analysis of seasonal variation in the number of cellulitis cases and in the relative search volume by Naver from 2016 to 2022

	Amplitude	Phase month	Low-point month	p value
Number of Cellulitis cases	25114.6	7.8	1.8	<0.001
RSV of "연조직염"	16.7	7.6	1.6	<0.001
RSV of "셀룰라이트스"	10.2	7.2	1.2	<0.001
RSV of "봉소염"	12.3	7.5	1.5	<0.001

Note: "연조직염" ("cellulitis" [in Korean]), "셀룰라이트스" (synonym of "cellulitis" [in Korean]), and "봉소염" (synonym of "cellulitis" [in Korean]), RSV: relative search volume

Table 2. Correlation between the number of cellulitis cases and the relative search volume for "연조직염" ("cellulitis" [in Korean]) by Naver

Group		Correlation coefficient	p value
Total		0.74	<0.001
Sex	Male	0.68	<0.001
	Female	0.63	<0.001
Age	20–29	0.82	<0.001
	30–39	0.71	<0.001
	40–49	0.25	0.021
	50–59	0.18	0.110
	≥60	0.75	<0.001

Table 3. Correlation between the number of cellulitis cases and the relative search volume for "셀룰라이트스" (synonym of "cellulitis" [in Korean]) by Naver

Group		Correlation coefficient	p value
Total		0.68	<0.001
Sex	Male	0.51	<0.001
	Female	0.69	<0.001
Age	20–29	0.73	<0.001
	30–39	0.61	<0.001
	40–49	0.41	<0.001
	50–59	0.18	0.108
	≥60	0.35	0.001

Table 4. Correlation between the number of cellulitis cases and the relative search volume for "봉소염" (synonym of "cellulitis" [in Korean]) by Naver

Group		Correlation coefficient	p value
Total		0.49	<0.001
Sex	Male	0.46	<0.001
	Female	0.46	<0.001
Age	20–29	0.34	0.001
	30–39	0.54	<0.001
	40–49	0.22	0.047
	50–59	0.21	0.051
	≥60	0.70	<0.001

4. Discussion

This study confirms the seasonal variability in the monthly number of cellulitis cases based on HIRA data from 2016 to 2022, with the highest increase in summer and the lowest in winter. Several previous studies have reported that cellulitis has a seasonal predilection for warmer months [14–17]. Manning et al. [14] reported a seasonal pattern in which the incidence of lower leg cellulitis increased during summer in most non-tropical regions of Western Australia. Accordingly, Simonsen et al. [15] confirmed the incidence of cellulitis using a medical insurance claims database in some regions of the United States, finding a seasonal pattern with the highest and lowest incidence of cellulitis in the summer and winter months, respectively. Furthermore, Haydock et al. [16] found that admissions for non-necrotizing cellulitis of the leg in the UK increased predominantly in the late spring and summer months. Importantly, several factors could contribute to this seasonal variation, including environmental, lifestyle and biological factors. In summer, temperatures rise, and humidity levels increase, creating a more favorable environment for bacteria to grow and multiply [20]. High temperatures cause people to sweat, and when sweat mixes with dirt or other contaminants on the skin's surface, it can create a breeding ground for

bacteria. This, in turn, increases the risk of skin infections such as cellulitis. In addition, lymphedema, venous insufficiency, and tinea pedis, which are major risk factors for cellulitis, are exacerbated in high-temperature environments, which can lead to the occurrence of cellulitis [14,16]. Notably, summer is a season associated with outdoor activities such as swimming, hiking, camping, and sports. Engaging in these activities can lead to minor cuts, abrasions, and insect bites, which can serve as entry points for bacteria to infect the skin [14,20]. Understanding the seasonal factors that contribute to cellulitis can help healthcare providers and the public take the necessary steps to minimize the risk of cellulitis during the summer months.

Studies using Internet search data for various diseases have shown that Internet search volume significantly reflects the occurrence of diseases [5–10]. Xu et al. [5] examined the association of published cancer incidence and mortality data in the United States with Internet search volume for lung cancer. The authors reported that Internet search trends related to lung cancer are reflective of lung cancer incidence trends. This demonstrates that Internet search data can be utilized for monitoring and predicting even chronic diseases. Chen et al. [6] confirmed a positive association between cases of avian influenza A and Internet search queries and social media data, both spatially

and temporally. Shin et al. [7] reported a significant correlation between the spread of Middle East respiratory syndrome and trends in Google searches and Twitter, demonstrating the feasibility of using digital surveillance systems for outbreak monitoring. Furthermore, numerous studies have analyzed Internet search data to investigate the seasonality of various diseases, including gout [21], obstructive sleep apnea [22], psoriasis [23], and bruxism [24].

In this study, the monthly relative search volume of the search terms "연조직염," "셀룰라이트스," and "봉소염" provided by DataLab on Naver showed a significant correlation with the monthly number of patients with cellulitis from the HIRA. As the incidence of cellulitis patients rises, there is a corresponding increase in search queries related to cellulitis. Furthermore, the correlation analysis stratified by gender indicated a high positive correlation in both men and women. Notably, in the age-specific correlation analysis for individuals aged 20 years and above, statistically significant positive correlations were consistently observed across the age brackets of the 20s, 30s, 40s, and 60s or older, with the exception of the 50s cohort. In the 50s age group, a positive correlation was noted, albeit not reaching statistical significance. Importantly, it was confirmed that Internet search behaviors did not differ between men and women upon the manifestation of symptoms. However, there was variability in the correlation coefficients related to the search terms among the different age groups. These findings may be attributable to the diverse search terms commonly employed by various age categories.

The International Telecommunication Union's Digital Development Dashboard [25] reports that as of 2022, 97% of individuals in Korea use the Internet, one of the highest rates in the world, and most people have easy access to and use the Internet. Therefore, it can be stated that Internet searches in Korea sufficiently reflect the behavior of the majority of people. In recent years, a growing number of individuals have turned to Internet searches to obtain information related to symptoms and diseases. As the Internet evolves and search frequencies rise, it is anticipated that search data will accurately mirror real-world data. Traditional clinical information collection methods are accurate because they look at real data but are time-consuming, expensive, and labor-intensive. However, Internet big data is mostly available in real-time and can be obtained at a low cost. Here, the HIRA dataset yields precise and detailed insights into disease patterns, yet there is an eight-month delay in accessing this information owing to the requisite time for data compilation and processing. Conversely, trend data from search queries sourced from Internet portals are accessible instantaneously. Notably, the clinical significance of this research lies in its pioneering analysis in Korea of the association between seasonal trends in cellulitis, juxtaposing patient data from the HIRA, a conventional data source, and emergent big data from Internet portals.

This study confirmed that applying Internet information technology in medical research facilitates the rapid acquisition of data on disease occurrence and epidemiology, thereby providing a foundation for real-time information provision and monitoring. Moreover, it is posited that patients' interests in specific diseases and associated behaviors can be discerned using keywords that exhibit high search frequency among disease-related search terms. Looking ahead, it is anticipated that the increasingly abundant and granular Internet big data will be leveraged in diverse ways for the advancement of medical research.

5. Conclusions

The strength of our study is that it is the first to examine the association of Internet search volume data with conventionally collected national insurance data on seasonal trends of cellulitis in Korea. The present study has clinical implications for the role of Internet search volume data as an effective tool for investigating and monitoring the activity of cellulitis in addition to traditional methods. However, there are limitations to consider when interpreting the results of this study. Initially, Internet search data may not accurately reflect the status of individuals who use the Internet infrequently or do not have access to it. Furthermore, individual characteristics such as age, education, and socioeconomic status impact the ability to seek health-related information on the Internet. However, DataLab does not provide identifying information on individuals who conduct Internet searches; therefore, their personal characteristics cannot be verified. This limits the representation of the entire patient population to only Internet users, hindering the generalizability of the results. The public's search behavior regarding health-related information on the Internet could be influenced by numerous circumstances, including symptom occurrences, media coverage of the disease, social health campaigns, celebrity diagnoses of the disease, and academic or research purposes. However, this study failed to identify any particular circumstance that could affect search behavior. Furthermore, this study exclusively utilized Naver as its Internet search portal. While Naver is the leading search engine in Korea, there are numerous other internet search sites available. Therefore, this research may have selection bias as it only focuses on Naver users.

In conclusion, this study confirms the seasonal variation of both the number of cellulitis patients and the Internet search volume data of search terms related to cellulitis in Korea, with a high peak in summer. Moreover, a strong positive correlation was found between the Internet search volume data on the seasonality of cellulitis and the actual number of patients. It was found that Internet big data can be a complementary resource for medical research and surveillance of cellulitis. Additional

research is necessary to clarify the mechanisms that underlie the seasonal trends of cellulitis.

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