Seasonal Variation in the Google Searches for Cancer Recurrence in Developed Countries: An Infodemiological Study

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Abstract

While few clinical and epidemiological studies have assessed how seasonality affects cancer recurrence, it has not been studied with the utility of the internet data. In this study, we aim to test whether cancer recurrence presents seasonality on a population level, utilizing internet search query data. This infodemiological study used Google Trends to find query data for the term “cancer recurrence” from January 01, 2004, to December 31, 2018 in the USA, the UK, Canada, and Australia. Time series seasonal decomposition and the cosinor analysis were used to analyze and describe the seasonal trends for cancer recurrence. A general upward trend in UK and northern hemisphere were observed. Statistically significant seasonal trends on “cancer recurrence” in the USA ($p=1.33\times10^{-5}$), the UK ($p=0.012$), and northern hemisphere ($p=5.67\times10^{-7}$) were revealed by cosinor analysis, with a peak in early summer and nadir in early winter. Besides, a seasonal variation was also found in Australia ($p=2.3\times10^{-4}$), with a peak in late summer and nadir in late winter. The evidence from internet search query data showed a seasonal variation in cancer recurrence, with a peak in early summer (northern hemisphere)/late summer(southern hemisphere). Besides, the relative search volume of “cancer recurrence” appeared a general upward trend in UK and northern hemisphere in recent years.

Keywords: Cancer recurrence, Seasonality, Google trends, Infodemiological.

Introduction

Cancer, the abnormal proliferation of cells, starts from any organ or tissue and is constituted of tiny cells that unable to form normal functional structures. It is one of the most horrible diseases of the 20th century and spreading further with continuance and rising trend in the 21st century. A quarter of people worldwide are having a risk of cancer during all his or her life [1]. Cancer screening and the early detection of cancer offers the opportunity to diagnose cancer early and with an increased opportunity for treatment and curative intent. Nowadays, the improvement of genetic and surveillance technologies, including tumor
The aim of this study was to test whether cancer recurrence affects cancer recurrence, and it has not been analysed with epidemiological studies have assessed how seasonality presents seasonality on a population level, using internet search query data.

Materials and Methods

Ethics statement

This infodemiological study was carried out in conformity to the Declaration of Helsinki, and the Google’s privacy policy [14]. It was not necessary for us to require written confirmation of the Medical Ethics Review Committee. The data used in this investigation was publicly available and anonymous data, and involved no personally information such as identity, IP address.

Google trends search and data collection

Google Trends (www.google.com/trends) is an online publicly available tracking system, which can automatically record the search volumes of a given term. It is a facility used to assess people’s interest in a user-specified term given a particular location, time period, or category. When people put terms in the Google Trends engine search box, they get data about the frequency of search terms [15]. Google Trends allows a random user to compare up to five terms contemporaneously. To make comparisons easier between the terms, it adjusts search data to depict the prevalence of a certain search term within a given time period and geographic region [16]. Data points are displayed from 0 to 100 based on a term’s proportion to the total number of searches on all terms [16]. Therefore, the data displayed not the actual search times but percentages relative to the total search queries across the given region and time window. The higher the scores, the higher relative search volume (RSV) [15]. RSV are easily exported into comma-separated values (CSV) format. In summary, quantitative method was adopted in this study to test the seasonality of cancer recurrence.

In Jan 18, 2019, Google Trends was mined from inception (01 January 2004) to 31 December 2018 in six different English-speaking countries: the USA, the UK, Canada, Ireland, Australia, and New Zealand. For our study, we searched the query term “cancer recurrence”. Furthermore, to narrow the range of our search, we utilized the “health” category. We were allowed to focus and evaluate interest in the area of health by means of the Health category filter. In this study, the search term ‘cancer recurrence’ was examined utilizing Google Trends. We reasoned that using cancer recurrence as the search term would catch more people who have interested in cancer recurrence. This supposition was validated by the fact that ‘cancer recurrence’ on Google Trends revealed a higher RSV than all other combinations of these terms (e.g. cancer, tumor, carcinoma, neoplasm, recurrence, relapse, recur, recurdescence, recrudescence, reappearance, reappear). The USA, the UK, Canada and Ireland were chosen to represent the native English-speaking countries in the Northern hemisphere, and Ireland and Australia were representatives of Southern hemisphere accordingly. However, two countries (Ireland, New Zealand) were ruled out in the analysis. The reasons excluding Ireland were limited Google Trends data and near-zero search volume more than 12 months in a row.
Analyses of seasonal variations and trends for cancer recurrence in the USA, UK, Canada, Australia, and northern hemisphere were presented in figure 1. It was obvious to see that the variation of the RSV of cancer recurrence in the four countries and northern hemisphere mentioned above showed the cyclicity with 12 months being a circle, and showed a clear seasonal patterns from 2004 to 2018. Meanwhile, we detected a general upward trend in UK and northern hemisphere, and the general upward trend of the northern hemisphere mainly resulted from the increasing RSV of UK.

Cosinor analysis for the relative search volume

The results of the cosinor analysis were shown in table 1, and the plots of cosinor models were displayed in figure 2. The search query data for the United States, the United Kingdom, Canada, northern hemisphere, and Australia showed clear peaks and nadirs, which could be assessed by visual inspection. Cosinor analysis largely validated this with statistically significant seasonal trends on 'cancer recurrence' in the USA (amplitude \( A = 3.54 \), phase month \( P = 6.4 \), low point month \( L = 12.4, p = 1.33 \times 10^{-5} \)), the UK (\( A = 1.73, P = 6.3, L = 12.3, p = 0.012 \)), northern hemisphere (\( A = 6.44, P = 6.4, L = 12.4, p = 5.67 \times 10^{-7} \)), and Australia (\( A = 2.22, P = 2.0, L = 8.0, p = 2.3 \times 10^{-4} \)). Obviously, the peak for both countries was in the summer (June or early summer for the northern hemisphere countries; February or late summer for the southern hemisphere country) and nadir in the winter (December or early winter for the northern hemisphere countries; August or late winter for the southern hemisphere country). The peaks (early summer/late summer) and nadirs (early winter/late winter) were out of phase by approximately 6 months in the northern hemisphere countries compared with the southern hemisphere country. Meanwhile, as shown in table 1, in USA, UK, and Canada, the top ranking search cancer was breast cancer consistently. Therefore, the seasonal patterns of cancer recurrence may be embodied in breast cancer. According to time series plots shown in figure 3, Google searches for the term 'cancer recurrence' showed a general upward trend throughout the study period (from 2004 to 2018) in UK, Australia and northern hemisphere, and others countries (the USA, Canada) in northern hemisphere didn’t show such trend. Given the above, there were mutual authentication relationship between analyses of systematic seasonal variations and trends and cosinor analysis, both of them showing a general upward trend over the study period (from 2004 to 2018) in UK and northern hemisphere. Whereas, compared with time series seasonal decomposition analysis, Cosinor analysis provided more detailed information to us, and it elaborated the amplitude, peak month, low point month and \( p \) value.

Discussion

This study analyzed the seasonality of "cancer recurrence" across several countries, utilizing internet search query data. Results showed a significant seasonal trend for 'cancer recurrence' in the USA, UK, Australia, and northern hemisphere, with a peak in early summer/late
Figure 1: Seasonal and trend decomposition for the relative search volume of [cancer recurrence] from January 01, 2004 to December 31, 2018.
<table>
<thead>
<tr>
<th>Country</th>
<th>Amplitude</th>
<th>Phase month</th>
<th>Low point month</th>
<th>$P$-value</th>
<th>Top ranking search cancer</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>3.54</td>
<td>6.4</td>
<td>12.4</td>
<td>$1.33 \times 10^{-5}$</td>
<td>Breast cancer</td>
</tr>
<tr>
<td>UK</td>
<td>1.73</td>
<td>6.3</td>
<td>12.3</td>
<td>0.012</td>
<td>Breast cancer</td>
</tr>
<tr>
<td>Canada</td>
<td>1.19</td>
<td>6.4</td>
<td>12.4</td>
<td>0.100</td>
<td>Breast cancer</td>
</tr>
<tr>
<td>Northern hemisphere</td>
<td>6.44</td>
<td>6.4</td>
<td>12.4</td>
<td>$5.67 \times 10^{-7}$</td>
<td>-</td>
</tr>
<tr>
<td>Australia</td>
<td>2.22</td>
<td>2.0</td>
<td>8.0</td>
<td>$2.3 \times 10^{-4}$</td>
<td>No data</td>
</tr>
</tbody>
</table>

**Table 1:** The seasonal variation in the relative search volume of “cancer recurrence”.

**Figure 2:** The plots of Cosinor models for the seasonal variation in the relative search volume of [cancer recurrence].
summer and nadir in early winter/late winter. The peaks (early summer/late summer) and nadirs (early winter/late winter) were out of phase by approximately 6 months in the northern hemisphere countries compared with the southern hemisphere country. Besides, we also detected a general upward trend in UK and northern hemisphere, and the general upward trend of northern hemisphere mainly resulted from the increasing relative search volume of UK. As our results suggested, in USA, UK, and Canada, the top ranking search cancer is breast cancer, so the seasonal variation that we found in cancer recurrence may be primarily due to breast cancer.

So far, this is the first study exploring the seasonality of cancer recurrence. Though, the mechanisms underlying the seasonal trends of cancer recurrence detected in our study cannot be assessed, there are several possible factors (e.g., diet, physical exercise, smoke, alcohol, air pollution, infections, immunity and endocrine dyscrasia) that may associated with the seasonality of cancer recurrence. Firstly, the immune functional activity of neutrophils was increased in summer, which was associated with poor recurrence-free survival [25,26]. Secondly, as our results suggested, in USA, UK, and Canada, the top ranking search cancer is breast cancer, so the seasonal variation that we found in cancer recurrence may be primarily due to breast cancer. Previous study has indicated that melatonin, a kind of indole hormone produced mainly by the pineal body, could result in growth inhibition of all three estrogen-responsive human breast tumor cell lines (MCF-7, T47D, ZR-75-1) [27]. Therefore, an increase in melatonin levels is not conducive to recurrence of breast cancer. However, melatonin levels are lower in summer than in winter [28,29]. This provides another piece of proof for the unanimous seasonal trends in cancer recurrence. Furthermore, alcohol use in spring and summer is higher than in fall and winter [30,31], which may lead

Figure 3: Time series plots for the relative search volume of [cancer recurrence] from January 01, 2004 to December 31, 2018.
to the increasing risk of breast cancer recurrence to some extent [32]. Thirdly, alcoholism, which prevail in spring and summer [30,31], promotes the risk of HCC recurrence amongst non-B or non-C (NBNC) hepatocellular carcinoma (HCC) patients [33,34]. Fourthly, the peak of urinary tract infection (UTI) is in summer [35], and Kim et al. have demonstrated that pyuria is a risk factor for bladder cancer recurrence during short-term follow-up after urethral and bladder tumor resection (TURBT) [36]. Lastly, compared with winter, the increase of PSA in the body in summer is more common, and the increase of PSA indicates the recurrence of prostate cancer after the initial treatment, leading to a higher recurrence rate of prostate cancer in summer [37-39].

According to time series seasonal decomposition and the cosinor analysis, the relative search volume of cancer recurrence revealed a general upward trend in UK and northern hemisphere, and the general upward trend of the northern hemisphere mainly resulted from the increasing relative search volume of UK. Over the past decade, the morbidity rates of all cancers combined have increased by 7% in the UK [40], resulting in high relative search volume of cancer recurrence, and then causing the upward trend. Consistently demonstrated by Eurocare and the International Cancer Benchmarking Partnership (ICBP), the survival rates of cancer patients in the UK were greatly lower than in other developed countries, which may be explained by the increasing cancer recurrence rates.

There are several advantages in our study including the substantial and detailed mass of data, the long-term of observation, the wide areas of coverage (including countries on both sides of the equator), and the lack of reporting and observer bias. Despite the strengths mentioned above, there are inherent disadvantages in our study remain to be discussed. Firstly, the data do not supply the demographics of people who participate in the web search query, and thus significant inter-individual differences (e.g., age, gender, etc.) that may be associated with the likelihood of utilizing net-based health information cannot be evaluated. Therefore, this study only in favor of population-level seasonal variations of cancer recurrence. Secondly, inherent to the use of web-based query data in the study of disease is the assumption that such queries represent the prevalence of disease and/or the severeness of disease, the veracity of which cannot be evaluated. Thirdly, the reason why selection bias exist in the process of statistical analysis is that we used data from a single search engine, Google. Nevertheless, this risk is alleviated by the truth that Google makes up more than 65% of all web searches worldwide [41]. Lastly, we did not carry out real studies on the time of cancer recurrence, so the findings of Google searches could not be verified.

Conclusion

In conclusion, Internet queries for cancer recurrence display significant seasonality, with a peak in the summer, and nadir in the winter. Further studies are needed to elucidate the mechanisms of the seasonal variations in cancer recurrence in the population. These seasonal effects may exert influence on clinical practice. We can take many measures during the summer to decrease the recurrence rates, such as increase the frequency of reexamination, limit alcohol intake, and reinforce prevention measures for UTI.

Acknowledgement

The findings in this research demonstrated that a significant seasonal variation of cancer recurrence was observed in the USA, the UK, northern hemisphere and Australia. The peak is in early summer (northern hemisphere) / late summer (southern hemisphere). Furthermore, a general upward trend in UK and northern hemisphere were observed. The authors acknowledge the Grants for Scientific Research of BSKY from the First Affiliated Hospital of Anhui Medical University and Grants for Outstanding Youth from the First Affiliated Hospital of Anhui Medical University.

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40. Cancer Research UK. Incidence trends over time for all cancers combined.

41. Internet LiveStats, Google Search Statistics.