

# Seasonal variation and change trends for quit smoking: evidence from Internet search engine query data

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## Research article

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# Abstract

**Background:** The outcomes of smoking have generated considerable clinical interest in recent years. Although people from different countries are more interested to the topic of quit smoking during the winter, few studies have tested this hypothesis. The current study aimed to quantify public interest in quit smoking via Google.

**Methods:** We use Google Trends to obtain the Internet search query volume for terms relating to quit smoking for major northern and southern hemisphere countries in this research. Normally search volumes for the term “quit smoking + stop smoking + smoking cessation” were retrieved within the USA, the UK, Canada, Ireland, New Zealand and Australia from January 2004 to December 2018. Seasonal effects were investigated using cosinor analysis and seasonal decomposition of time series models.

**Results:** Significant seasonal variation patterns in those search terms were revealed by cosinor analysis and demonstrated by the evidence from Google Trends analysis in the representative countries including the USA ( $p_{\text{cos}} = 2.36 \times 10^{-7}$ ), the UK ( $p_{\text{cos}} < 2.00 \times 10^{-16}$ ), Canada ( $p_{\text{cos}} < 2.00 \times 10^{-16}$ ), Ireland ( $p_{\text{cos}} < 2.00 \times 10^{-16}$ ), Australia ( $p_{\text{cos}} = 5.13 \times 10^{-6}$ ) and New Zealand ( $p_{\text{cos}} = 4.87 \times 10^{-7}$ ). Time series plots emphasized the consistency of seasonal trends with peaks in winter / late autumn by repeating in nearly all years. The overall trend of search volumes, observed by dynamic series analysis, declined from 2004 to 2018.

**Conclusions:** The preliminary evidence from Google Trends search tool showed a significant seasonal variation and decreasing trend for the RSV of quit smoking. Our novel findings in smoking cessation epidemiology need to be verified with further studies, and the mechanisms underlying these findings must be clarified.

## Introduction

Tobacco use have been identified as the leading cause of preventable diseases and death all over the world [1]. The relationship between improved popularity of smoking and augmented incidence of lung cancer has been demonstrated these years which was uncommon previously [2]. According to one original research that continued smoking after a cancer diagnosis can cause a detrimental effect on the cancer treatment effectiveness and survival [3]. Moreover, numerous studies have highlighted that smoking is responsible for 5% of global death, while smoking related diseases such as cardiorespiratory, autoimmune, malignancy, cerebrovascular and subfertility accounts for 14% of deaths among adults from the age of 30 or older [4]. A prior investigation reported that smoking in pregnancy may resulted in many adverse outcomes including stillbirth, low birth weight, miscarriage, perinatal, mobility and

mortality [5]. Given the negative impacts caused by cigarette smoking, the majority of smokers stop smoking around the age of 40. It is reported that people who quit smoking before the age of 35 enjoy a better life expectancy comparable to that who don't smoke [6]. In addition, cancer mortality in both smoking and non-smoking related cancers reduced if the smokers quit smoking after diagnosed by a cancer [7]. Therefore, we recommend smoking cessation because quit smoking leads to substantial health improvements [8]. Given the harmful effects of smoking and the benefits of quitting smoking, evaluating the global public interest in smoking cessation is extremely important. Several previous researches have studied about smoking cessation, however, few efforts have been made to identify seasonal variation patterns of quit smoking in large populations [9, 10]. This study is an attempt to fill that void.

Recently, people evaluate the public interest in health category by investigating the Internet-based search engine which has established as a major resource of information [11]. The use of the Internet has increased sharply during the past decade and almost 5% of Internet search terms are for the information of health [12]. Google Trends, a website provided by Google Inc, analyses the popularity of a particular search query term in Google Search across different regions and languages. In several previous studies, Google Trends have already been used to investigate seasonal and other time varying patterns of the topic of health conditions, including cellulitis [13], vitamin D [14] and gout [15].

Accordingly, the current study aimed to leverage Internet search query data from Google Trends to test people's interests toward the topic of quit smoking and investigate whether there was a seasonal pattern exist in this topic.

## Methods

### Google Trends interrogation and data collection

Google Trends (<http://www.google.com/trends>), based on Google Search that analyzes how often a particular query-term is entered relative to the total search-volume across the world. Instead of reporting the absolute, raw search figures, Google trends does this by presenting relative search volume (RSV). Each data point on the graph is divided by the total searches of the geography and time range it represents and multiplying by 100. The data points can be downloaded in Comma Separated Values (CSV) format and the results are normalized and scaled on a range of 0 to 100. The value of 100 represents on that day, the term had the highest number of searches within a selected region and time frame, while a score of 0 means that the term is below 1 percent of its peak popularity [16,17]. To make the selection more reliable, the system automatically excludes the repeated searches over a short period of time from the same person.

There are two options for searching keywords in Google Trends tool, searches can be divided into two sections: by "search term", which enables to search the exact keywords; or by "search topic", a broader search that containing the particular keywords or the terms that related. In this study, the later search option (searching by the particular keywords or the terms that related) was used, because there are no

definite technical terms available. Among all the relevant search choices, we choose the following search terms “quit smoking”, “stop smoking” and “smoking cessation”, which are the most searched. Those multiple terms can be searched in combination with a plus sign (+) that means “OR” and excluded with a “-” sign. In order to keep in line with the current standards for reporting Google trends data, weekly data from 2014/01/01 to 2018/12/31 were downloaded in CSV files for the United States of America (USA), the United Kingdom (UK), Canada and Ireland as well as New Zealand and Australia [18]. For the purpose of statistical analyzing, those countries were grouped in relation to the northern or southern hemisphere. The searches were performed on 6th March 2019, and before the analysis, the accuracy of the data was evaluated by two separate individuals crosschecking the data.

## **Dynamic series analysis**

Dynamic series analysis means a series of statistical indicators are arranged in sequence according to a certain time order to observe and compare the change and development trend of a certain object in time. These statistical indicators including the absolute, relative and average numbers, which were used to describe the object. The ratio of fixed base and link relative, based on the relative comparison, were used in this dynamic series analysis. Unify the index of a certain time as the cardinal number, the fixed base ratio can reflect the development of the observing object by dividing the index value of each reporting time with this cardinal number. While the link relative ratio, define the index of the previous time as the cardinal number, reflects the development direction of the object by dividing the index value of the next reporting time with the cardinal number. The commonly used dynamic series analysis indicators including the absolute growth, development speed and increment speed, average speed of development and average speed of growth.

## **Statistical analysis**

To identify seasonal variations in the search volume of quit smoking from 2004 to 2018, we utilize the seasonal decomposition of time series model to represent the trend and seasonality in a time series by decomposing these data into a trend component, a remainder component and a seasonal component.

Besides, in order to investigate the systematic seasonal variations of quit smoking, the strategy of cosinor analysis was used to test whether there was a significant seasonal variation in the volume of Internet searches for the term “quit smoking + stop smoking + smoking cessation”. The method and the program used to implement the cosinor analysis were presented in detail by Barnett et al [19]. In short, the cosinor analysis, based on the sinusoidal patterns which fitted to an observed time series, is a common parametric seasonal model that hinged on the following sinusoid:

$$St = A \cos\left(\frac{2\pi t}{c} - P\right), t = 1, \dots, n,$$

in which  $A$  indicates the amplitude of the seasonal effect and explains the size of seasonal changes,  $P$  indicates the phase of the seasonal peak,  $c$  indicates the length of the seasonal cycle, which established at 12 for monthly data,  $t$  indicates the time of each data point, and  $n$  indicates the number of observations.

Since there are two seasonal components exist in this linear model: sine and cosine, the threshold of significance was adjusted as  $p < 0.025$  so as to correct for multiple comparisons. In addition, in an effort to quantify the magnitude of seasonal peaks and troughs for countries that demonstrating significant seasonality, the percent change in search volume from winter months (USA, UK, Canada and Ireland from the northern hemisphere: December, January and February ; New Zealand and Australia from the southern hemisphere: June, July and August ) to summer months (USA, UK, Canada and Ireland: June, July and August ; New Zealand and Australia: December, January and February) was calculated, which was similar to the process in several previous studies [20]. In addition, the conformance in the seasonal variations was emphasized by time series plots.

The "season" Package in R version 3.5.1 was used to perform all the data processing and analyses.

## Results

### Dynamic series analysis of the search volumes

Table 1 shows that the overall trend of [smoking cessation + quit smoking + stop smoking] search volumes in the USA increased from 2004 to 2006, then decreased from 2006 to 2018, while the UK experienced a steadily decline from 2004 to 2018. Similar results also found in other representative countries including Canada and Ireland from the northern hemisphere and Australia from the southern hemisphere. Interestingly, New Zealand, another country from the southern hemisphere, RSV for quit smoking in this country decreased from 2008 to 2018. Before this decreasing trend, New Zealand had already experienced a little fluctuation in the first several years. RSV for quit smoking declined from 2004 to 2006, then increased from 2006 to 2008 (Table S1).

**Table 1 Dynamic series analysis of the search volumes of [quit smoking + stop smoking + smoking cession] from 2004 to 2018**

country	year	RSV	Absolute increment		development speed[%]		increment speed[%]	
			Cumulative	year on year	Fixed base ratio	link relative ratio	Fixed base ratio	link relative ratio
USA	2004	693	-	-	100.0%	100.0%	-	-
	2005	725	32	32	104.6%	104.6%	4.6%	4.6%
	2006	752	59	27	108.5%	103.7%	8.5%	-0.9%
	2007	741	48	-11	106.9%	98.5%	6.9%	-5.2%
	2008	542	-151	-199	78.2%	73.1%	-21.8%	-25.4%
	2009	527	-166	-15	76.0%	97.2%	-24.0%	24.1%
	2010	438	-255	-89	63.2%	83.1%	-36.8%	-14.1%
	2011	447	-246	9	64.5%	102.1%	-35.5%	18.9%
	2012	455	-238	8	65.7%	101.8%	-34.3%	-0.3%
	2013	418	-275	-37	60.3%	91.9%	-39.7%	-9.9%
	2014	392	-301	-26	56.6%	93.8%	-43.4%	1.9%
	2015	374	-319	-18	54.0%	95.4%	-46.0%	1.6%
	2016	369	-324	-5	53.2%	98.7%	-46.8%	3.3%
	2017	370	-323	1	53.4%	100.3%	-46.6%	1.6%
2018	356	-337	-14	51.4%	96.2%	-48.6%	-4.1%	
UK	2004	715	-	-	100.0%	100.0%	-	-
	2005	707	-8	-8	98.9%	98.9%	-1.1%	-1.1%
	2006	615	-100	-92	86.0%	87.0%	-14.0%	-11.9%
	2007	537	-178	-78	75.1%	87.3%	-24.9%	0.3%
	2008	437	-278	-100	61.1%	81.4%	-38.9%	-5.9%
	2009	431	-284	-6	60.3%	98.6%	-39.7%	17.2%
	2010	416	-299	-15	58.2%	96.5%	-41.8%	-2.1%
	2011	455	-260	39	63.6%	109.4%	-36.4%	12.9%
	2012	471	-244	16	65.9%	103.5%	-34.1%	-5.9%
	2013	434	-281	-37	60.7%	92.1%	-39.3%	-11.4%
	2014	363	-352	-71	50.8%	83.6%	-49.2%	-8.5%
	2015	350	-365	-13	49.0%	96.4%	-51.0%	12.8%
	2016	334	-381	-16	46.7%	95.4%	-53.3%	-1.0%
	2017	339	-376	5	47.4%	101.5%	-52.6%	6.1%
2018	329	-386	-10	46.0%	97.1%	-54.0%	-4.4%	

RSV : relative search volume

Seasonal decomposition of time series indicated that there was a clear and distinctive seasonal pattern of search trend for quit smoking in the northern and southern hemisphere from 2004 to 2018, the results were presented in Figure 1. The seasonal pattern in those countries mentioned above showed the cyclicity with 12 months being a circle. These statistical data are limited to those search queries under the health category that originated within the USA, the UK, Canada, Ireland, New Zealand and Australia. Meanwhile, the seasonal decomposition of time series data showed a significant decreasing trend in countries from both the northern hemisphere and the southern hemisphere.

### Cosinor analysis for the relative search volume

The results of cosinor analyses were presented in Table 2, and graphical outcomes of cosinor analyses were presented in Figure 2. The graphical results indicated that definite peaks and troughs were revealed by visual inspection of the search query data for the USA, the UK, Canada and Ireland from the northern hemisphere, New Zealand and Australia from the southern hemisphere. The cosinor analysis confirmed that there was a significant seasonal pattern exist in RSV for [quit smoking+stop smoking+smoking cessation] in the USA (Amplitude {A}=4.41; phase month {P}=, 2.1, low point month{L} =8.1,  $p_{\text{cos}} = 2.36 \times 10^{-7}$ ,  $p_{\text{sin}} = 9.43 \times 10^{-4}$ ), the UK (A = 8.57, p = 1.6, L = 7.6,  $p_{\text{cos}} < 2.00 \times 10^{-16}$ ,  $p_{\text{sin}} = 1.57 \times 10^{-4}$ ), Canada (A = 8.56, p = 1.8, L = 7.8,  $p_{\text{cos}} < 2.00 \times 10^{-16}$ ,  $p_{\text{sin}} = 7.83 \times 10^{-7}$ ), Ireland (A = 5.46, p = 1.5, L = 7.5,  $p_{\text{cos}} < 2.00 \times 10^{-16}$ ,  $p_{\text{sin}} = 0.017$ ), Australia (A = 4.85, p = 5.4, L = 11.4,  $p_{\text{cos}} = 5.13 \times 10^{-6}$ ,  $p_{\text{sin}} = 1.60 \times 10^{-7}$ ), New Zealand (A = 4.59, p = 5.6, L = 11.5,  $p_{\text{cos}} = 4.87 \times 10^{-7}$ ,  $p_{\text{sin}} = 9.15 \times 10^{-6}$ ), the northern hemisphere (A = 26.71, p = 1.7, L = 7.7,  $p_{\text{cos}} < 2.00 \times 10^{-16}$ ,  $p_{\text{sin}} = 4.27 \times 10^{-13}$ ) and the southern hemisphere (A = 9.42, p = 5.5, L = 11.5,  $p_{\text{cos}} = 1.22 \times 10^{-11}$ ,  $p_{\text{sin}} = 7.50 \times 10^{-12}$ ). Search volumes presented higher levels in the winter/late autumn months (January and February for the four northern hemisphere countries and May for the two southern hemisphere countries). Lower levels presented in the summer/late spring (July and August for the four northern hemisphere countries and November for the two southern hemisphere).

**Table2 The seasonal variation in the relative search volume of [quit smoking+stop smoking+smoking cessation]**

Country	Amplitude	Phase month	Low point month	Cosine P-value	Sine P-value
quit smoking+stop smoking+smoking cessation					
USA	4.41	2.1	8.1	$2.36 \times 10^{-7}$	$9.43 \times 10^{-4}$
UK	8.57	1.6	7.6	$< 2.00 \times 10^{-16}$	$1.57 \times 10^{-4}$
Canada	8.56	1.8	7.8	$< 2.00 \times 10^{-16}$	$7.83 \times 10^{-7}$
Ireland	5.46	1.5	7.5	$< 2.00 \times 10^{-16}$	0.017
Northern hemisphere	26.71	1.7	7.7	$< 2.00 \times 10^{-16}$	$4.27 \times 10^{-13}$
Australia	4.85	5.4	11.4	$5.13 \times 10^{-6}$	$1.60 \times 10^{-7}$
New Zealand	4.59	5.6	11.6	$4.87 \times 10^{-7}$	$9.15 \times 10^{-6}$
Southern hemisphere	9.42	5.5	11.5	$1.22 \times 10^{-11}$	$7.50 \times 10^{-12}$

## Relative search volumes on Google from January 2004 to December 2018

The consistency of seasonal trends which confirmed in the cosinor analysis was emphasized by the time series plots. Significant decreasing trend in RSV for quit smoking were observed during the overall observation period (January 2004 to December 2018) in both hemispheres. However, in recent years, the magnitude of seasonal trend changes has been reduced (Figure. 3).

## Discussion

To the best of our knowledge, the current study is by far the first of this kind highlighting the seasonal variability in Internet search volumes for quit smoking. Although the number of searches for this topic steadily decreased from 2004 to 2018, with a little fluctuation in the first two years in several countries including the USA, Canada and Australia. While New Zealand, the number of searches for quit smoking steadily decreased from 2004 to 2006 and increased to a peak in 2008, then decreased (again) from 2008 to 2018 (a similar research reported that compared with 2018, the smoking prevalence had been decreased over the last decade [21]). Consistent with our prior hypothesis, a statistically significant seasonality for these search queries were identified in the representative countries from both the northern and southern hemisphere, with a zenith in winter and late autumn, nadir in summer and late spring.

The current research provided preliminary evidence for the literature on the epidemiology of quit smoking. It indicated that Internet search queries for quit smoking varied significantly by season. There are multiple factors that may contribute to this seasonal phenomenon and the overall decreased search trend for the topic of quit smoking since 2004.

First, Lexington-Fayette Country, Kentucky implemented an ordinance on April 27, 2004 that all public places including bars, restaurants, pool halls, hotels and all other buildings open to the public should follow a smoke-free rules [22]. Some previous studies broadly assessed the effects of the bans of smoking cessation. It is described that the second-hand smoking (SHS) concentration in public venues has experienced a large reduction, ranging from 70 to 97% [23]. This may be a reasonable explanation for the reduced search volumes for the topic of quit smoking, because less people smoke since the implementation of this smoking ban. Second, according to a report from WHO that tobacco use has been a leading cause of preventable illness throughout the world [24]. Besides, the economic burden of smoking related illness is quite substantial, in Canada, annual burden of tobacco smoking estimated to be nearly 21.3 billion dollars [25]. According to some previous studies, compared with those mothers who are not a smoker, the incidence rate of early SIDS (sudden infant death syndrome) among smokers was 0.6 cases per 100,000 person-days higher [26]. A meta-analysis study in another research reported that sperm concentration has reduced by 13%, sperm motility 10% and sperm morphology 3% among

smokers [27]. All of these harmful effects caused by smoking may result in infertility. Furthermore, it has been reported that the relationship between depressive illness and smoking is that people who addicted to smoking are more likely to suffer from depression than those who are not a smoker (Breslau, Kilbey, & Andreski, 1993) [28]. Given the dreadful effects to our body health caused by smoking and the enormous economic burden carried by smoking-related illness, most people tend to quit smoking. Since most smokers have the awareness of the importance of stop smoking, less people search this topic on the Internet. Third, for many young smokers, boredom remained a reason for them to smoke at a time [29]. Additionally, in UK, it has been suggested that the young usually treat the mobile phone use and smoking as a symbol of maturity [30]. The rise in mobile phone usage may be responsible for an observed decreasing in smoking among teenagers over the past few years. Nevertheless, the association between the declining usage of cigarette and the rise in mobile phone use has not been studied in other countries [31]. With the rapidly development of our technologies during the past several years, people have more choice to spend their boring time which may be a reason for our results.

Some other factors may contribute to the seasonality of the search volumes of the topic of quit smoking. The observed seasonality may result from the increment of Internet use in winter. However, this presumption has not been corroborated [32]. The association between depression illness and smoking has already been described, the study also reported that admissions for depressive disorders peaked in the springtime and declined during the summer time [28]. Since the patients with depression are more likely to be a smoker, this may explain that people's interest towards quit smoking reached a trough in the summer months. Besides, people tend to make the decision to quit smoking in New Year's Eve, which is a widely recognized seasonal phenomenon [33]. Another research showed that cigarette sales presented a strongly seasonal pattern each year, with a peak in the summer months and reach a low in the winter months. This is almost a mirror image of the seasonality pattern for the search volumes of quit smoking, suggesting a strong association between the two phenomena [34]. Additionally, there are robust evidence to show that current smokers and those who used to be a smoker, have a significantly higher risk of developing chronic obstructive pulmonary disease (COPD) [35]. A significant increase of quit smoking willingness was presented when an awareness of COPD was raised [36]. The data showed that a higher search volume related to "COPD" was presented during the winter months, and this may be one of the reasons why the search volumes of quit smoking reached a highest in the winter months and late autumn. Since most of the countries from the southern hemisphere stand near the equator, the seasonal variation in weather may be fewer compared with the countries in the northern hemisphere. This may explain why the seasonal pattern in the southern hemisphere is slightly different with the northern hemisphere, with peak in the late autumn, nadir in the late spring.

Our current research involved statistical data of the USA, the UK, Canada, Ireland, New Zealand and Australia which represent both hemispheres. There are some advantages identified in our study, including the large and exhaustive amount of data involved, the long period of observation and inclusion of representative countries from both hemispheres. Nevertheless, there remains some inherent limitations in our research. Although a massive amount of data contained in Google Trends, and more than 65% of all queries were searched within the Google engine [37]. It only captures the search behavior of a certain

groups of people who have access to Internet and those who choose to search by Google rather than other search engines, which could result in selection bias. Besides, Google Trends only provide normalized instead of raw search volumes. The detailed information by which Google generates these data and the algorithms that Google employs to analysis this information remains unclear. So, it would be impossible for us to control other factors that may influence the total number of Internet searches. Since the data available through Google Trends does not include the demographical features and the characteristics of the individuals who entering search queries, it is also impossible to assess the seasonal variation by subgroup analysis.

## **Conclusion**

The current study provided evidence of seasonal variation in the search terms of the topic about quit smoking, with a zenith in winter and late autumn. It contributes to the literature with regard to the seasonality of quit smoking on a population basis. It suggests us that we can strengthen the propaganda of smoking cessation in the summer and late spring, take various measures to control smoking, so as to improve people's awareness thoroughly and resulting in public health benefits. Still, further researches are necessary to clarify the mechanisms underlying the seasonal variation in the topic of quit smoking.

## **Abbreviations**

RSV: relative search volume; CSV: Comma Separated Values; COPD: chronic obstructive pulmonary disease.

## **Declarations**

### **Ethics approval and consent to participate**

The search query trend data gathered from Google trends was freely available information and fully anonymized. In the health care section, we performed this research according to the Helsinki declaration and adhered the recommendation of a current overview on Google trends.

### **Availability of data and materials**

The data that support the findings of this study are available on the website of Google Trends (<http://www.google.com/trends>).

### **Competing interests**

The authors declare that they have no competing interests.

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## Author's contributions

DH and XL wrote the manuscript. NM, MZ and QX participated in the data collection and analysis. YZ collected the data. YZ and FW designed the study and revised the manuscript. FW obtained funding. All authors read and approved the final manuscript.

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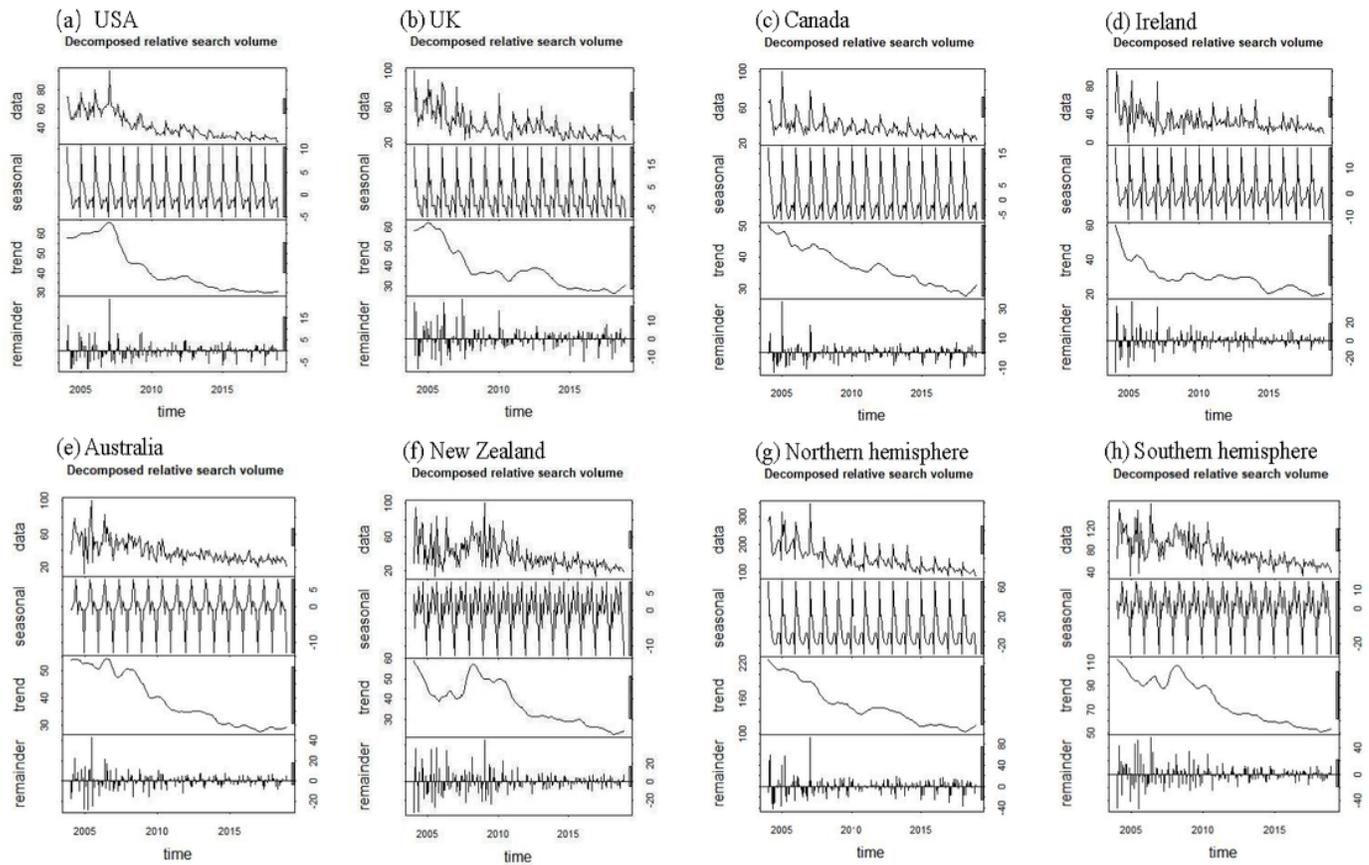
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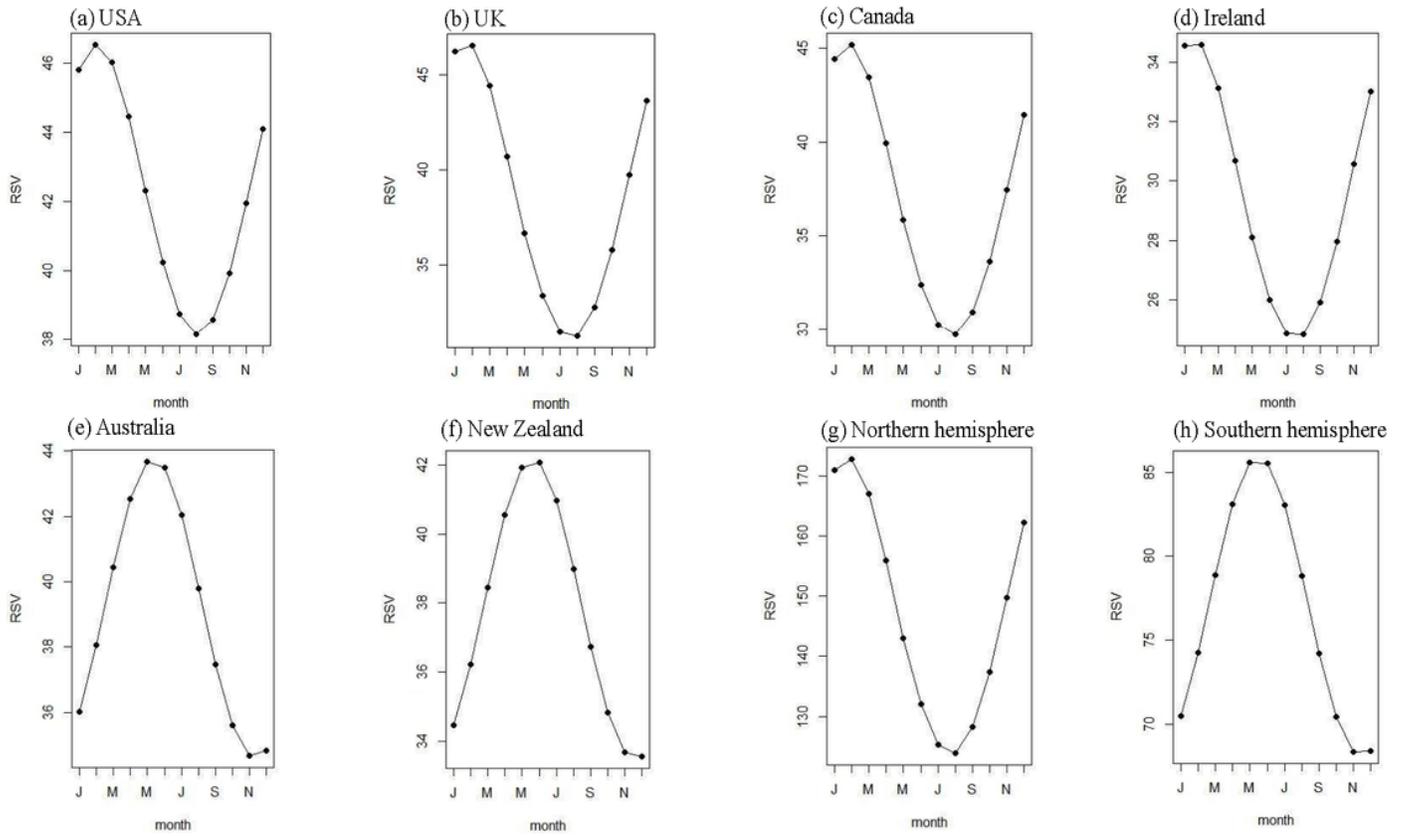
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## Figures



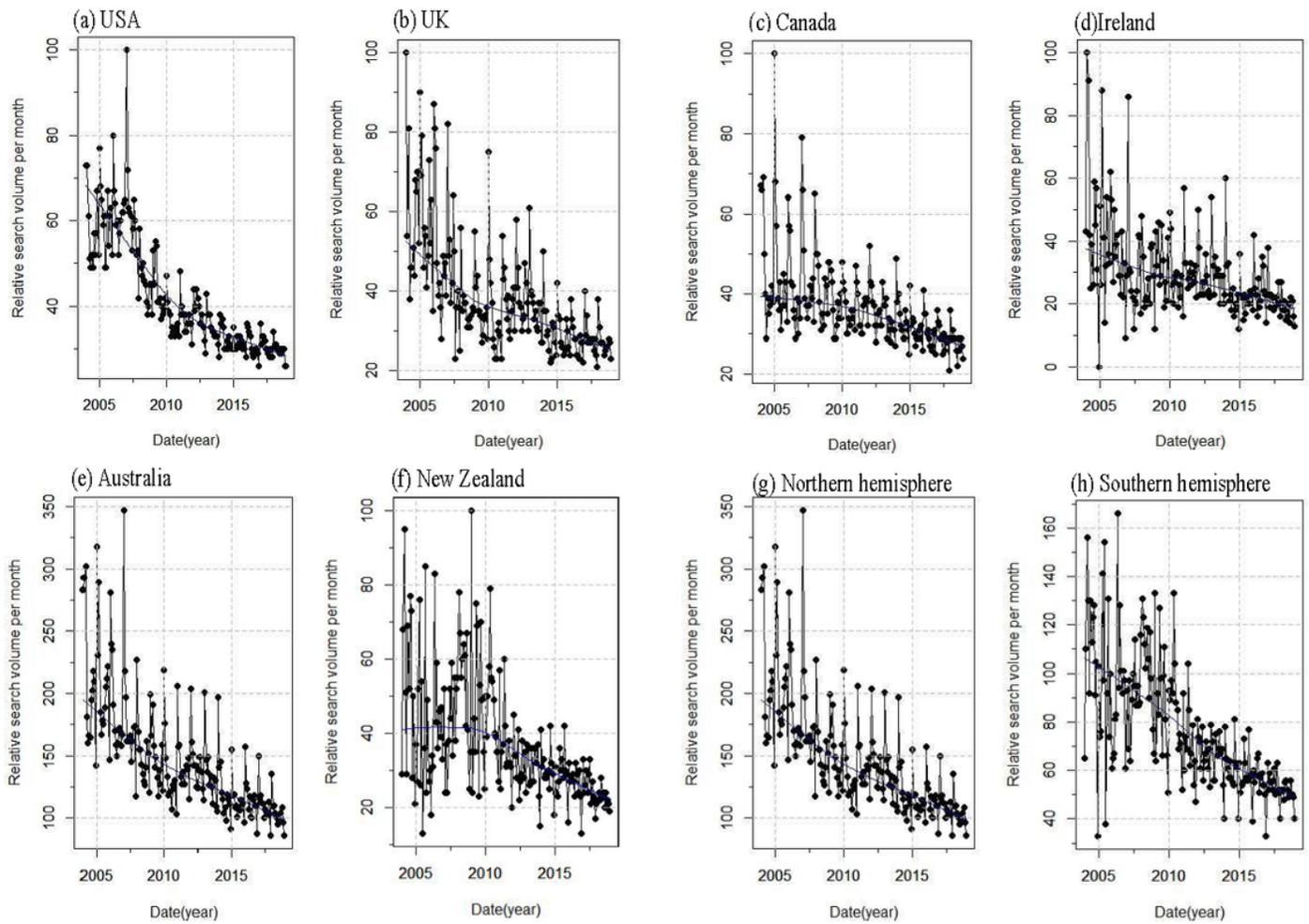
**Figure 1**

Seasonal decomposition mode of time series for the search terms [quit smoking + stop smoking + smoking cessation] from January 2004 to December 2018.



**Figure 2**

The plots of cosinor analysis models for the seasonal variation in the relative search volume of [quit smoking + stop smoking + smoking cessation].



**Figure 3**

Time series plots for the relative search volumes of [quit smoking + stop smoking + smoking cessation] from January 2004 to December 2018.

## Supplementary Files

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