1   **Seasonality of cellulitis: evidence from Google Trends**

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14   **Abstract**

15   According to our clinical experience, cellulitis is common in summer; however, very few

16   studies have mentioned this trend. Using Google Trends, we analyzed the monthly data of

17   Google searches for 'cellulitis' from 31 countries on six continents. Seasonality explained

18   34%-92% of the variability in search volume, with peaks occurring in summer months. The

19   analyses offered new insights into the epidemiology of cellulitis on national and international

20   scales. Clinical data are needed to validate the Internet search data.

21

22 **Introduction**

23 Cellulitis is a common bacterial infection involving the skin and its underlying connective

24 tissue, manifesting symptoms of redness, pain and lymphangitis. According to our clinical

25 experience, cellulitis is more common in summer; yet, very few studies in the publicly

26 available literature have mentioned its seasonal variation(Ellis Simonsen et al. 2006).

27   As Internet availability and use has increased worldwide, Internet-based search

28 engines have become an important source for health information for people from all walks of

29 life(Rice 2006). Analyzing data on search behaviors and other online resources in turn

30 provides a new approach for detection and monitoring of diseases and symptoms(Milinovich

31 et al. 2014). This method is especially suitable for studying time-varying patterns of health

32 conditions and has already been successfully applied to influenza(Ginsberg et al. 2009), ankle

33 swelling(Liu et al. 2016), mental illness(Ayers et al. 2013), and sleep disorders(Ingram &

34 Plante 2013). Herein, we describe the use of such an approach to examine the seasonal

35 variation of the public's interest in cellulitis, as measured by the volume of Internet searches

36 in Google.

37

38 **Materials & Methods**

39 Google Trends (www.google.com/trends), provided by Google Inc., is a publicly available

40 data service that shows the relative number of searches globally or within a particular region

41 for a specific search term. The numbers are scaled in a range of 0 to 100, based on the

42 proportion of overall searches that the queried term represents. Using Google Trends, we

43 obtained monthly data from January 2004 to December 2016 for the search term "cellulitis".

44 After exclusion of countries with unavailable data or showing no regular pattern over time

45 (see Supplementary Figure 1), a total of 31 countries were included in the analyses.

46   The monthly data were plotted according to time for each of the 31 countries and

47   regression analysis was performed using GraphPad Prism 7 (GraphPad Software Inc., United

48   States (US)). The regression analysis was carried out with a seasonal model, as described

49   previously(Liu et al. 2016), consisting of a straight line function and a sinusoid function as

50   follows:

51   Search_volume = intercept + slope × time + amplitude × sin(2π × time/12 + phase shift)

52   In cases where a country's data in the early years did not fit well, only the data in the latter

53   years was fit for the analysis.

54

55   **Results**

56   Seasonality explained 34%-92% of the variability in search volume (Table 1) for the 31

57   countries included in this study. In the Northern Hemisphere, the search volume peaked at

58   mid-April to mid-July, while in the Southern Hemisphere it peaked at October to January

59   (Figure 1). Geographically nearby countries usually shared similar peak months of search

60   volume. The peak months were around May in continental Europe, at the end of June in the

61   United Kingdom and Ireland, at the beginning of June in Israel and Turkey, close to the

62   beginning of July in the US and Canada, and around November in South America.

63

64   **Discussion**

65   The present study examined the seasonal variation of the public's interest in cellulitis

66   worldwide by using Google internet search data. In accordance with our hypothesis, the

67   results demonstrated a significant seasonality of this interest with peaks in summer for the 31

68   countries from six continents examined.

69   To date, only one epidemiology study has mentioned the seasonality of cellulitis(Ellis

70   Simonsen et al. 2006). That study used data collected from a medical insurance database

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71   involving eight US states and found that the incidence of cellulitis was 1.32 times higher

72   during the summer months than during the winter months(Ellis Simonsen et al. 2006). By

73   analyzing Google search data from throughout the US, we found a similar trend, in that

74   cellulitis attracted more public interest during the summer months than during the winter

75   months in each year from 2004 to 2016.

76   The lower extremities represent the most frequent sites of cellulitis(Morris 2008).

77   Several analyses have shown that a disruption of the cutaneous barrier, such as in the common

78   conditions of leg ulcer, wound, tow-web intertrigo, dermatosis, athlete's foot and leg edema,

79   is an important risk factor for developing cellulitis of the leg(Dupuy et al. 1999; Roujeau et al.

80   2004). Hot weather, sweating, moisture, insect bites and skin exposure may make these

81   conditions more common and/or severe during the summer season. For example, some lines

82   of evidence indicate that a warmer climate tends to aggravate venous ulcers of the leg and a

83   rainy season facilitates outbreaks of chronic leg ulcers, as shown particularly in tropical

84   areas(Kotrajaras & Limpakarnjanarat 1982; Pierard-Franchimont et al. 2012). In shoe-wearing

85   populations, interdigital athlete's foot is mainly a seasonal disease, with peaks in hot

86   weather(Leyden & Kligman 1977). Itch, sunburn, erythema multiforme and many skin

87   diseases caused by organisms also favor warmer weather(Grandhi et al. 2017; Kaffenberger et

88   al. 2017). And, a recent analysis found that public interest in ankle swelling, as measured as

89   Google search volume, is highly seasonal, with peaks in summer in the US and Australia(Liu

90   et al. 2016). Altogether, these trends may help to understand why cellulitis is more common

91   in summer.

92   In this electronic search study of trends of interest, the seasonality of public interest in

93   cellulitis was able to be determined for 31 countries from six continents, suggesting that it is a

94   global phenomenon. The seasonality trend detected (i.e. summer) may also exist in the

95   countries that were not included in the analysis; small population, low level of internet

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96   availability and use, small market share of Google, and differences in search language and

97   queries may have obscured the detection of seasonal trend for these countries. The impact of

98   Internet availability and use can be supported by the fact that for most of the 31 countries that

99   showed seasonal variation the search volume was very irregular in the early years and up to

100   the later years when the seasonal trend became obvious. By repeating this study in languages

101   other than English and with search engines other than Google, the seasonality may be

102   detected in more countries. For example, no regular pattern of search volume for cellulitis was

103   found for China using Google Trend but a significant seasonal trend (with peaks in summer)

104   was detected using search data from Baidu (see Supplementary Figure 2), a Chinese search

105   engine that accounts for the vast majority of Chinese web users.

106   Besides the ability to cover a large geographic area, the strengths of this study also

107   include the long time range of observation, observations above and below the equator, and

108   observations of geographically nearby countries. Mexico and Peru seem to be exceptions, as

109   the regions within each representing the search peaks were at a relatively far distance from

110   those within the proximal countries (for Mexico compared with the US and Canada; Peru

111   compared with other countries of South America). However, when the geographic distribution

112   of the population for each of these countries is considered, the trends fall back in line.

113   This study has several limitations that need to be considered when interpreting the

114   results. First, the study reveled the seasonal trend of public interest in cellulitis but not the

115   seasonal trend of cellulitis itself. Besides the suspicion of cellulitis or receiving a clinical

116   diagnosis, news reports, academic conferences, medical courses and any other information

117   about cellulitis may also excite one's interest in it. Moreover, the individual performing the

118   search is not necessarily the one suffering from the disease. Clinical data are needed to

119   validate the Internet search data from this study. Second, although most of the Internet

120   searches are performed using Google, data from other search engines should be analyzed if

121 possible, especially for regions where Google is not popular. Third, the demographic

122 characteristics were not available for the users who were performing the search. Thus,

123 important covariates that may affect the development of cellulitis or search behaviors could

124 not be assessed.

125

126 **Conclusion**

127 In summary, using Google Trends we demonstrated that the public's interest in

128 cellulitis exhibits significant seasonal variability, with peaks in summer. Clinical data are

129 needed to validate the Internet search data and further research is indicated to clarify the

130 mechanisms underlying seasonal patterns of cellulitis.

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180 **Table 1. Fit of a sinusoid model against Google Trends Internet search volume for**

181 **cellulitis in 31 countries**

Country	R^2	Peak month	Time range
Northern Hemisphere			
USA	0.92	7.1	2004-2016
Spain	0.85	5.2	2004-2016
UK	0.84	6.8	2004-2016
Poland	0.80	4.5	2007-2016
France	0.80	4.8	2004-2016
Belgium	0.75	5.2	2008-2016
Mexico	0.71	5.7	2004-2016
Canada	0.70	6.7	2007-2016
Greece	0.69	5.0	2011-2016
Netherland	0.66	5.3	2004-2016
Switzerland	0.64	5.0	2011-2016
Germany	0.60	5.8	2012-2016
Germany	0.56	5.2	2005-2010
Ireland	0.59	6.8	2008-2016
Israel	0.57	6.1	2011-2016
Portugal	0.55	5.2	2012-2016
Romania	0.52	5.3	2011-2016
Turkey	0.52	6.0	2012-2016
Austria	0.51	5.0	2004-2016
Italy	0.49	5.4	2007-2016
Puerto Rico	0.44	6.2	2013-2016
Hungary	0.42	4.9	2012-2016
Thailand	0.38	7.6	2012-2016
Denmark	0.35	5.5	2010-2016
Southern Hemisphere			
Australia	0.82	1.1	2007-2016
Argentina	0.79	10.9	mid-2004-2016
Brazil	0.74	11.3	2005-2016
Chile	0.68	11.8	2007-2016
Uruguay	0.55	10.9	2004-2016
Peru	0.49	1.3	2008-2016
Paraguay	0.41	11.8	2012-2016
South Africa	0.34	1.3	2011-2016

182 R^2 represents the proportion of variation in the search volume explained by the model.

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185 **Figure legends**

186 **Figure 1. Google Trends Internet search volume for cellulitis in the United States and**

187 **Argentina from January 2004 to December 2016.** The red line represents search volume in

188 the United States. The green line represents search volume in Argentina. The black lines are

189 the best-fit sinusoid.
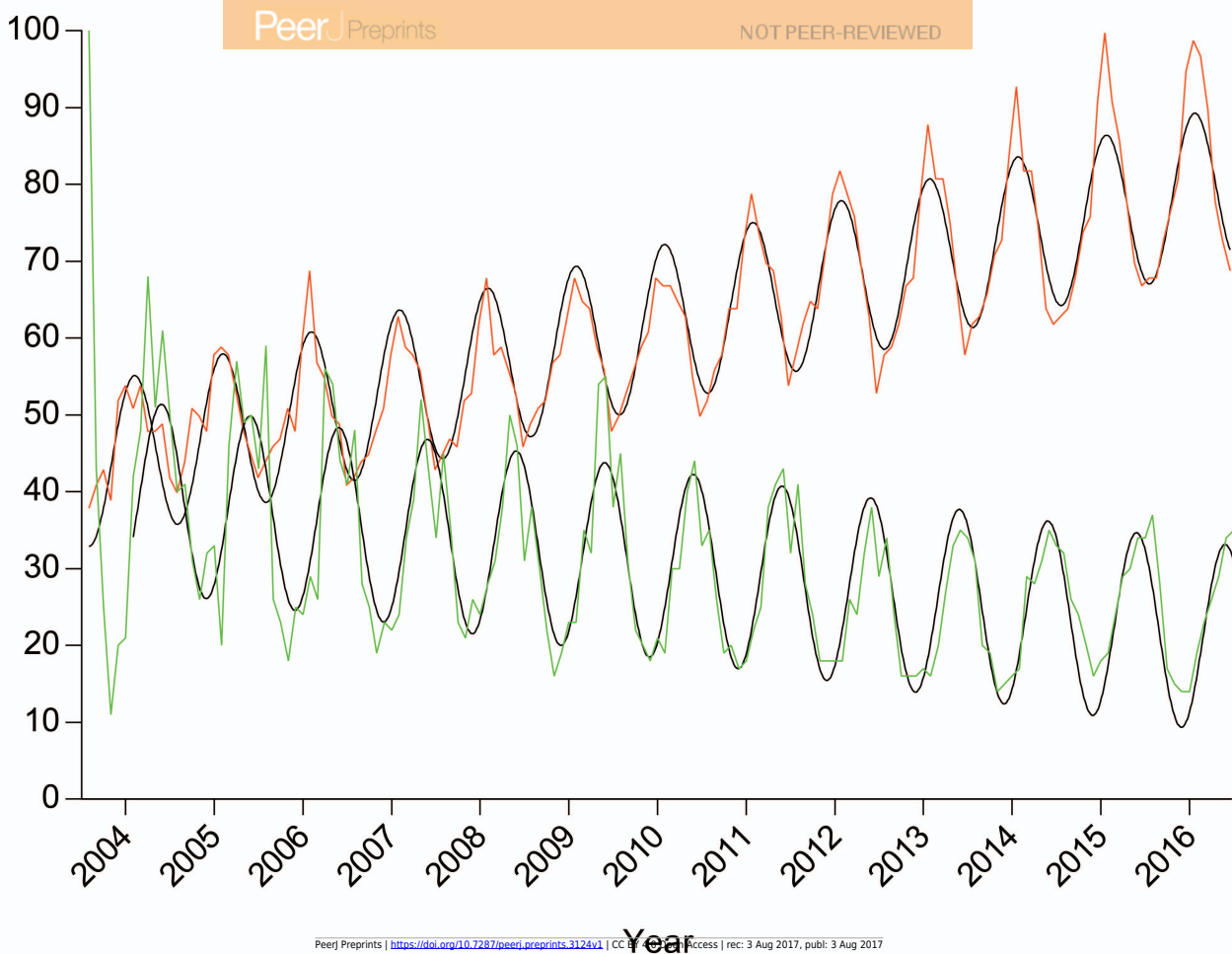
Supplementary Figure 1. Google Trends Internet search volume for cellulitis in Puerto

Rico from January 2004 to December 2016.

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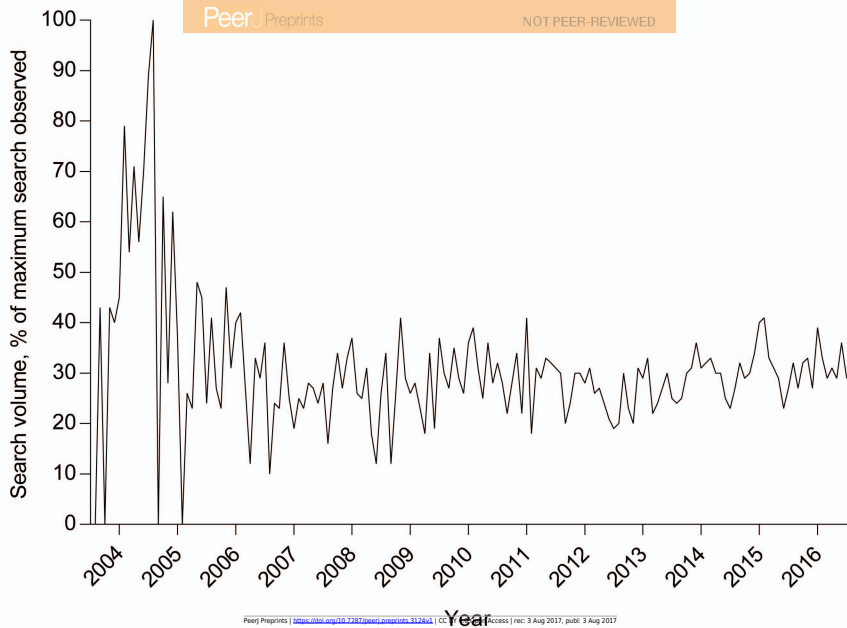
Supplementary Figure 2. Baidu Index Internet search volume for cellulitis in China

from June 1, 2006 to June 4, 2017.