

Public Interest in Dry Eye Disease and Their Association with Environmental Parameters in Taiwan: A Google Trends Infodemiology Study

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Abstract

Background: In Taiwan, high prevalence of dry eye disease (DED) intensifies public health concerns. With the growing reliance on online resources for health information, platforms like Google Trends offer a valuable method to capture public interest. This approach also allows for the exploration of potential associations between DED public interest and environmental parameters, which may further illuminate underlying factors contributing to the disease's rising prevalence.

Objective: To analyze public interest in DED in Taiwan using Google Trends (GT) data, investigate correlations with environmental parameters, and identify shifts in public interest through rising related queries.

Methods: We analyzed GT data from December 2018 to July 2024, focusing on relative search volume (RSV) for dry eye syndrome across Taiwan and its six special municipalities. Temporal trends were analyzed using spline regression models, and monthly variations were analyzed using the Kruskal-Wallis test. Spearman's correlation was utilized to evaluate the relationship between RSV and environmental parameters, while Dynamic Time Warping (DTW) analysis clarified the temporal alignment of RSV with these parameters. Rising related search queries were analyzed to identify shifts in public interest and compared with available online information.

Results: A significant increasing trend in RSV for dry eye syndrome was observed over the study period in Taiwan (mean instantaneous derivative = 0.445; $p < 0.001$) and across all six special municipalities. Environmental parameters such as methane (CH₄), total hydrocarbons (THC), and non-methane hydrocarbons (NMHC) were identified as novel pollutants strongly correlated with RSV ($p < 0.001$), along with known pollutants such as NO, NO₂, SO₂, NO_x, and CO. DTW analysis revealed the strongest temporal alignment between RSV and hydrocarbons including CH₄ and THC, further emphasizing their potential role in influencing public interest. Rising search queries shifted from diagnostic and treatment methods before COVID-19 to natural remedies during COVID-19, and self-diagnosis and treatment options after COVID-19; while gaps were identified between public interest and the availability of online information.

Conclusions: Public interest in DED has increased significantly in Taiwan from 2018 to 2024, with hydrocarbons emerging as novel environmental parameters. The shifts in related queries reflect changing public interest, accentuating the need for healthcare information that aligns with public interests and addresses gaps in available resources.

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Original Manuscript

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Abstract

Background: In Taiwan, high prevalence of dry eye disease (DED) intensifies public health concerns. With the growing reliance on online resources for health information, platforms like

Google Trends (GT) offer a valuable method to capture public interest. This approach also allows for the exploration of potential associations between DED public interest and environmental parameters, which may further illuminate underlying factors contributing to the disease's rising prevalence.

Objective: To analyze public interest in DED in Taiwan using GT data, investigate correlations with environmental parameters, and identify shifts in public interest through rising related queries.

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Results: A significant increasing trend in RSV for dry eye syndrome was observed over the study period in Taiwan (mean instantaneous derivative = 0.445; $p < 0.001$) and across all six special municipalities. Environmental parameters such as CH₄, total hydrocarbons (THC), and non-methane hydrocarbons were identified as novel pollutants strongly correlated with RSV ($p < 0.001$), along with known pollutants such as NO, NO₂, SO₂, NO_x, and CO. DTW analysis revealed the strongest temporal alignment between RSV and hydrocarbons including CH₄ and THC, further emphasizing their potential role in influencing public interest. Rising search queries shifted from diagnostic and treatment methods before COVID-19 to natural remedies during COVID-19, and self-diagnosis and treatment options after COVID-19; while gaps were identified between public interest and the availability of online information.

Conclusion: Public interest in DED has increased significantly in Taiwan from 2018 to 2024, with hydrocarbons emerging as significant associated environmental parameters. The shifts in related queries reflect changing public interest, accentuating the need for healthcare information that aligns

with public interests and addresses gaps in available resources.

Introduction

Dry eye disease (DED) is a multifactorial ocular surface disease, with symptoms ranging from discomfort to significant visual impairment [1]. The prevalence of DED ranged from 5 to 50% globally and appeared to be higher in Asian than in Caucasian populations [2, 3]. In a recent meta-analysis, the prevalence and incidence of DED in any population in Asia was estimated to be 20.1% and 16.7%, respectively [4]. High prevalence of DED leads to substantial economic and humanistic burden, both worldwide and in Asia. In Taiwan, 33.7% of patients older than 65 years old were estimated to have DED and the incidence rates of DED increased at least 2-fold from 2001 to 2015, indicating the growing burden of the disease [5, 6].

Despite the growing burden of DED, understanding the patterns of public awareness and information-seeking behavior is crucial for tracking epidemiological pattern of a disease as well as improving patient education and care strategies [7]. With the rise of internet usage, people increasingly rely on online resources for health information. Thus, infodemiology research allows researchers to track disease awareness and behavioral trends at a population level. By analyzing search patterns, we can capture the public's real-time interest, helping to identify gaps between

public knowledge and clinical understanding [8]. Google Trends (GT), a tool that tracks real-time search queries, has emerged as a valuable platform for analyzing public interest in health conditions [9]. It has been leveraged as an effective tool in analyzing DED epidemiological pattern including geographically mapping, correlation with environmental factors and seasonality [10, 11]. In current study, we aim to explore the public interest in DED in Taiwan using GT data. Specifically, we seek to analyze temporal and seasonal trends, investigate the correlation between search patterns and environmental parameters, and assess the rising search queries related to DED. Furthermore, we will evaluate whether the information provided by online resources aligns with the public's interests, as reflected in the search data.

Methods

Data Collection – Google Trends

Our data was sourced from GT (<https://trends.google.com/trends/>), which provides Relative Search Volume (RSV)—a metric that reflects the level of search interest relative to the total number of search queries within a specific time frame and geographic location. RSV values are normalized between 0 and 100, enabling straightforward comparisons of search interest over time.

A unique feature of GT is its use of “Topics”, which groups related searches across various languages and search term variations. For instance, a search for “dry eye” will return results under the "Dry Eye Syndrome" topic, encompassing all searches linked to the condition, regardless of how users phrase their queries. Additionally, the “rising queries” feature emphasizes search terms that have seen a substantial increase in volume over a specified time frame compared to the previous period, making it particularly useful for identifying emerging trends in public interest.

We initially identified global topics related to DED from 2004 onwards, with two key topics emerging: “Dry Eye Syndrome” and “Dry Eye”. Upon comparison, Taiwan exhibited the highest RSV for the “Dry Eye Syndrome” topic worldwide, indicating a significant public interest in the

condition within the region. Consequently, we focused our analysis on the “Dry Eye Syndrome” topic for this study.

For the query analysis, we retrieved recent GT data from December 2018 to July 2024. The pre-COVID period spanned from December 2018 to April 2021; the COVID lockdown period corresponded to Taiwan's Level 3 alert from May 2021 to February 2022; and the post-COVID period covered March 2022 to July 2024. Additionally, we used the “rising queries” feature in GT to analyze public interest in DED across these periods. The top rising queries in each period were identified and compared to the changes in public interest toward DED throughout the COVID-19 pandemic.

Data Collection – Environmental Parameters in Taiwan

We collected environmental and climate data for the six special municipalities in Taiwan (Taipei City, New Taipei City, Taoyuan City, Taichung City, Tainan City, and Kaohsiung City) corresponding to the same period as the GT data (December 2018 to July 2024). The data were downloaded from the official websites of two primary agencies: the Central Weather Bureau of Taiwan and the Ministry of Environment Environmental Information Open Platform in Taiwan.

The data collection process involved downloading monthly reports from the official websites of relevant agencies. Meteorological data were retrieved from the Central Weather Bureau. Atmospheric pollutant data were downloaded from the Ministry of Environment Environmental Information Open Platform. Monthly averages for each environmental parameter were aligned with the corresponding monthly RSV data for each city. Direct comparison between environmental parameters and public search interest was then assessed.

Falsification outcomes are commonly used to evaluate the likelihood of false-positive results in main study outcomes that may arise from unmeasured confounders or limitations in internal validity [12].

We considered public interest in glaucoma, a common ocular disease, as a falsification outcome in

our GT analysis.

Statistical Analysis

All statistical analyses were conducted using RStudio (R version 4.3.0). To evaluate temporal trends in RSV, we employed spline regression models to capture potential non-linear patterns over time. The first derivative of fitted spline was computed to obtain the mean instantaneous derivative (MID) on a monthly scale. A residual bootstrap (1,000 iterations) provided 95% confidence intervals and p-values for MID. Monthly variations in RSV were examined using the Kruskal-Wallis test, and RSV data was grouped by month for Taiwan and its six special municipalities. The results were visualized using box plots to illustrate the distribution of RSV across different time frames.

To assess the relationship between RSV for dry eye syndrome and environmental parameters, we used Spearman's correlation. The analysis was conducted for each environmental parameter and RSV data across Taiwan and its six special municipalities, with significant correlations ($p < 0.05$) indicating a potential influence of the corresponding environmental parameters on public interest. In addition, dynamic time warping (DTW) analysis was used to evaluate the temporal alignment between RSV and multiple environmental parameters across six special municipalities in Taiwan. DTW distances were calculated for each pair of RSV and environmental parameters, with smaller distances indicating stronger temporal correlation.-

Rising related queries of GT from December 2018 to July 2024 were categorized into five groups: symptoms, treatment, etiology or related diseases, diagnosis, and others. To assess the availability of public information, we searched Taiwan's Google website using Chinese keywords related to dry eye syndrome, such as "干眼" (dry eye), "干眼症" (dryness), "干眼综合征" (dry eye syndrome), "干眼症状" (dry eye symptoms), "眼干" (eye dryness). The top 20 search results for each Chinese keyword were analyzed, and duplicate websites were identified and removed. The content of the remaining websites was reviewed and compared with rising queries from GT. The frequency of each related term which

appeared in both the website and rising queries was recorded.

Results

Trends in RSV for Dry Eye Syndrome from 2018 to 2024 in Taiwan and Six Special Municipalities—Temporal and Monthly Variation

Figure 1 presented the trends in RSV for "Dry Eye Syndrome" from December 2018 to July 2024 in Taiwan. The spline regression analysis for Taiwan showed an adjusted R^2 of 0.619 with $p = 1.881 \times 10^{-13}$, as detailed in Figure 1 and Supplementary Table 1. Spline regression models for each city demonstrated significant positive trends in RSV over time, which was illustrated as Supplementary Figure 1. The adjusted R^2 values varied among cities, with Taipei City having the highest (adjusted $R^2 = 0.598$; $p = 1.019 \times 10^{-12}$) and Taoyuan City the lowest (adjusted $R^2 = 0.228$; $p = 3.953 \times 10^{-4}$). Significant positive trends in RSV were also observed in most cities. As a falsification outcome, glaucoma demonstrated no statistically significant trend over the study period (MID = 0.120, $p = 0.118$; Supplementary Figure 2). Analysis for Taiwan also revealed no significant monthly differences (Figure 2).

Correlation Between RSV and Environmental Parameters

Results of Spearman's correlation revealed significant associations between RSV for dry eye syndrome and multiple environmental parameters across Taiwan and its six special municipalities. In Taipei (Table 1), air pollutants including methane (CH_4), total hydrocarbons (THC), sulfur dioxide (SO_2), carbon monoxide (CO), nitric oxide (NO), and non-methane hydrocarbons (NMHC) demonstrated the strongest significantly positive correlation with RSV ($p < 0.001$), followed by nitrogen dioxide (NO_2), NO_x (nitrogen oxides), and average wind speed (AWS) ($p < 0.05$). For other special municipalities across Taiwan, similar trends were also observed. CH_4 , SO_2 , NMHC were significantly correlated to RSV in at least 5 of the 6 special municipalities (Supplementary Table 2). The results emphasized a relationship between air quality and public interest in DED. DTW analysis

was used to assess the temporal alignment between RSV and environmental parameters across six special municipalities in Taiwan. In Supplementary Table 3, DTW analysis revealed CH₄, THC, average dew point temperature (ADT), average temperature (AT), global solar radiation (GSR), average relative humidity (ARH) as having the smallest DTW distances with RSV for dry eye syndrome. Figure 3 visually illustrated the DTW distance data between RSV and the statistically significant environmental parameters identified in the Spearman's analysis. Some parameters showed unique significance in specific cities. For instance, AWS had a relatively low DTW distance in Tainan, and ozone (O₃) appeared among the top parameters in Taichung and Kaohsiung, indicating regional differences in environmental parameters influencing RSV across time.

Table 1. Spearman's Correlation Between RSV and Environmental Parameters across Taipei

Parameter	Correlation coefficient ^a	Parameter	Correlation coefficient ^a	Parameter	Correlation coefficient ^a
AT	0.032	THC	0.580**	NO _x	-0.400*
ADT	0.082	ACC	-0.071	AWD	0.123
EP	0.107	NO ₂	-0.314*	CO	-0.412**
GSR	0.206	O ₃	0.030	CH ₄	0.644**
PP	-0.038	PM ₁₀	-0.060	SO ₂	-0.624**
DP	-0.191	AWS	-0.315*	NO	-0.473**
PM _{2.5}	-0.075	ARH	0.134	NMHC	-0.595**

^a Significant correlations ($p < 0.05$) are marked as one asterisk, and significant correlations ($p < 0.001$) are marked as two asterisks.

Abbreviations: RSV: Relative Search Volume; AT: Average Temperature; ADT: Average Dew Point Temperature; EP: Evaporation; GSR: Global Solar Radiation; PP: Precipitation; DP: Days with Precipitation; PM_{2.5}: Particulate Matter (diameter less than or equal to 2.5 micrometers); THC: Total Hydrocarbons; ACC: Average Cloud Cover; NO₂: Nitrogen Dioxide; O₃: Ozone; PM₁₀: Particulate Matter (diameter less than or equal to 10 micrometers); AWS: Average Wind Speed; ARH: Average Relative Humidity; NO_x: Nitrogen Oxides; AWD: Average Wind Direction; CO: Carbon Monoxide; CH₄: Methane; SO₂: Sulfur Dioxide; NO: Nitric Oxide; NMHC: Non-Methane Hydrocarbons.

Rising Related Queries from Google Trends for Dry Eye Syndrome in Taiwan

Rising search queries from GT across different periods showed shifting interests, as presented in Table 2. In the pre-COVID period, the focus was primarily on diagnostic and treatment methods like intense pulse light (IPL) and Schirmer test. During COVID lockdown, there was increased interest in natural remedies, including omega-3 fatty acids, natural eyedrops, and lutein. In the post-COVID

period, searches for self-diagnosis and treatment options such as dry eye self-diagnosis, forums, and sicca syndrome became more frequent. The Chinese keywords corresponded to each English terms were listed in Supplementary Table 4.

The alignment between rising related queries from GT and accessible online information revealed a strong focus on DED symptoms, treatments, and self-care (Supplementary table 5). The most frequently mentioned terms were "dry eye," "dry eye symptoms," and "dryness," each appearing 80 times. Treatment-related queries were also prominent, including "eyedrops," (60 times), "artificial tears," (58 times), "essential fatty acids" (34 times). Invasive treatments like "intense pulse light (IPL)" (18 times) and "dry eye surgery" (22 times) were commonly mentioned. Other terms such as "contact lens" (53 times) and "Schirmer test" (23 times) were also popular. However, treatments such as "Chinese medicine" appeared only 5 times, and "cost of IPL" was absent.

Table 2. Top Rising Related Queries of Google Trends Interest for Dry Eye Syndrome in Taiwan

Ranking	Pre-COVID (2018/12/01- 2021/05/18)	Rising	Ranking	COVID (2021/05/19- 2022/02/28)	Rising	Ranking	Post-COVID (2022/03/01- 2024/07/31)	Rising
1	Intense pulse light	Breakout	1	Omega 3	Breakout	1	Dry eye self-diagnosis	Breakout
2	Will dry eye syndrome get better	Breakout	2	Natural eyedrops	Breakout	2	Dry eye forum	Breakout
3	Schirmer test	Breakout	3	Lutein	450%	3	Sicca syndrome icd10	Breakout
4	Dry eye treatment	Breakout	4	Dry eye symptoms	170%	4	Dry eye treatment near me	Breakout

^aThe top four rising rankings in the related queries for relative search volume (RSV) during the respective time periods are included.

^bThe "Breakout" label indicates a sharp increase in RSV, with popularity growing by more than 5000%.

Discussion

Current studies exploring public interest for DED using GT data were limited [11, 13]. In our study, we observed trends in RSV for dry eye syndrome and examined correlations with environmental parameters. We also identified public concerns and gaps in available medical information from google search regarding dry eye syndrome-related queries.

Although the topic presented in Google Trends was “dry eye syndrome”, we used the term DED interchangeably to align with terminology commonly used in previous studies [14-16]. Our findings indicated that Taiwan has the highest RSV for dry eye syndrome globally according to GT data, which corresponded to the higher prevalence of DED in Taiwan compared to worldwide [17, 18]. The rising RSV and higher prevalence for DED in Taiwan may be attributed to several factors, including increasing environmental pollution, the widespread use of digital devices, and cultural habits such as extensive air conditioner usage [4, 19-21]. The higher prevalence of DED in Taiwan compared to Western countries emphasized the impact of environmental and lifestyle differences among the region [4, 5, 21]. For comparison, glaucoma in GT demonstrated no statistically significant trend, suggesting that the significant rise in dry eye syndrome-related RSV is less likely to results from unmeasured confounding factors and instead reflects a significant increase in public interest. This supports the robustness of the observed increase in RSV for dry eye syndrome.

Our study using Kruskal-Wallis test found no significant monthly differences in RSV for dry eye syndrome in Taiwan. Previous research on seasonal variation in DED had mixed findings, with seasonal variations observed in high-altitude regions but not in low-altitude regions [19, 22, 23]. In high-altitude regions, DED revealed the most severe symptoms, including discomfort, burning, and dryness, and highest prevalence in spring, with the opposite pattern observed in summer [22, 23]. One systematic review in China also revealed that seasonal trend in DED were more evident in the northern regions than in southern regions [24]. Taiwan's low latitude, causing relatively mild seasonal temperature changes, accompanied with Taiwan's consistently rainy weather that maintains

high humidity throughout the year, may contribute to the lack of seasonal variation in DED [19]. The factors may also indirectly influence RSV for dry eye syndrome.

Environmental factors play a crucial role in the development and exacerbation of DED in Taiwan [19]. Previous studies have identified pollutants such as particulate matter (PM_{2.5}), NO₂, CO, SO₂, and O₃ as contributing to ocular surface inflammation and DED symptoms [19, 25-27]. In our study, Spearman's correlation revealed that higher concentrations of NO, NO₂, SO₂, NO_x, and CO were significantly associated with the increase of RSV, consistent with the pollutants identified from previous studies [19, 25-27]. Importantly, we identified new air pollutants which may contribute to the occurrence of DED: CH₄, THC, and NMHC, all of which demonstrated a strong positive correlation with RSV ($p < 0.001$). Previous studies have already found that hydrocarbons are associated with increased risks of ocular disease including eye irritation and uveitis [28, 29]. Our novel findings reveal a significant and previously unrecognized impact of hydrocarbons on public interest in DED, suggesting their potential role as emerging environmental risk factors for the disease.

To further clarify the temporal alignment between RSV and the environmental parameters significantly correlated in the Spearman's analysis, we used DTW analysis [30, 31]. Our findings revealed that CH₄ and THC had the smallest DTW distances with RSV, indicating a strong temporal correlation. The strong correlation between RSV and hydrocarbons like CH₄ and THC suggests that these pollutants may significantly impact public interest in DED. These results, combined with the strong positive correlations observed in the Spearman's analysis, suggest that hydrocarbons may play a significant role in influencing public interest in DED. Hydrocarbons are emitted from various sources, including vehicles, industrial processes, and agricultural activities. Exposure to high levels of hydrocarbons may cause ocular irritation, tear film instability, and inflammation of the ocular surface, leading to potential DED symptoms [29, 32]. This may prompt individuals to seek information online, contribute to our result about increased RSV for dry eye syndrome.

Regarding public interest in DED, previous studies showed that public trends toward DED often involved treatment information and home remedies but lacked information about treatment risks and necessity [33]. One study examined public trends toward DED based on the Baidu Index, showing that treatment options, subjective symptoms, and associated ocular diseases such as conjunctivitis and keratitis are the most popular terms related to DED [34]. In contrast, our analysis of rising search queries revealed a shift in public interest over time. The trend during COVID-19 pandemic likely reflected a shift toward self-care options and preventive health practices during a time when access to traditional healthcare services was limited. In the post-COVID period, the trend moved towards self-diagnosis and treatment options. This indicated increased health literacy and patient autonomy in health management. We also identified a gap between public interest and the availability of online medical information. While topics like "Chinese medicine" and "cost of IPL" emerged as rising queries were lacking in available online resources (Supplementary Table 4 and Supplementary Table 5). Healthcare providers and public health organizations should provide educational materials to address these gaps.

Our study has several limitations. Firstly, RSV data from GT may not directly correlate with actual disease prevalence or diagnoses of DED, as media coverage and important news events could influence search behavior. Second, the analysis is limited to Taiwan, so the findings may not be generalizable to other regions, and other unmeasured factors may also influence DED symptoms and public interest. Despite these limitations, our study provides a comprehensive statistical analysis based on GT data, demonstrating a significant increase in public interest in dry eye disease in Taiwan from December 2018 to July 2024. Novel air pollutants, particularly hydrocarbons such as CH₄, THC, and NMHC, were identified as potential contributors strongly related to public interest in DED, while other air pollutants including NO, NO₂, SO₂, NO_x, and CO were also associated with public search trends. Our findings also emphasize the necessity for health education to bridge the gap between public interest and available public information. Further research should explore the

mechanisms by which hydrocarbons influence ocular surface and contribute to DED pathogenesis.

Data Availability

All data generated or analyzed during this study are contained within this published article and its supplementary files.

Conflicts of Interest

None declared.

Abbreviations

ACC: Average Cloud Cover

ADT: Average Dew Point Temperature

ARH: Average Relative Humidity

AT: Average Temperature

AWS: Average Wind Speed

AWD: Average Wind Direction

CH₄: Methane

CI: Confidence Interval

CO: Carbon Monoxide

DED: Dry Eye Disease

DP: Days with Precipitation

DTW: Dynamic Time Warping

EP: Evaporation

GSR: Global Solar Radiation

GT: Google Trends

IPL: Intense Pulse Light

MID: Mean Instantaneous Derivative

NMHC: Non-Methane Hydrocarbons

NO: Nitric Oxide

NO₂: Nitrogen Dioxide

NO_x: Nitrogen Oxides

O₃: Ozone

PM₁₀: Particulate Matter (diameter $\leq$ 10 micrometers)

PM_{2.5}: Particulate Matter (diameter $\leq$ 2.5 micrometers)

PP: Precipitation

RSV: Relative Search Volume

SO₂: Sulfur Dioxide

THC: Total Hydrocarbons

References

1. Craig JP, Nichols KK, Akpek EK, Caffery B, Dua HS, Joo C-K, et al. TFOS DEWS II definition and classification report. *The ocular surface*. 2017 Jul;15(3):276-83. [doi: 10.1016/j.jtos.2017.05.008]
2. Stapleton F, Alves M, Bunya VY, Jalbert I, Lekhanont K, Malet F, et al. Tfos dewes ii epidemiology report. *The ocular surface*. 2017 Jul;15(3):334-65. [doi: 10.1016/j.jtos.2017.05.003]
3. Hung N, Kang EY-C, Lee T-W, Chen T-H, Shyu Y-C, Sun C-C. The risks of corneal surface damage in aqueous-deficient dry eye disease: A 17-year population-based study in Taiwan. *American Journal of Ophthalmology*. 2021 Feb;227:231-9. [doi: 10.1016/j.ajo.2021.01.008]
4. Cai Y, Wei J, Zhou J, Zou W. Prevalence and incidence of dry eye disease in Asia: a systematic review and meta-analysis. *Ophthalmic Research*. 2022 Sep;65(6):647-58. [doi: 10.1159/000517287]
5. Lin P-Y, Cheng C-Y, Hsu W-M, Tsai S-Y, Lin M-W, Liu J-H, et al. Association between symptoms and signs of dry eye among an elderly Chinese population in Taiwan: the Shihpai Eye Study. *Investigative ophthalmology & visual science*. 2005 May;46(5):1593-8. [doi: 10.1167/iovs.04-0835]
6. Lin I-C, Kuo Y-K, Liu H-Y, Chien L-N. Trends in diagnosed dry eye disease incidence, 2001 to 2015: A nationwide population-based study in Taiwan. *Cornea*. 2022 Nov;41(11):1372-7. [doi: 10.1097/ICO.0000000000002892]
7. Deiner MS, Lietman TM, McLeod SD, Chodosh J, Porco TC. Surveillance tools emerging from search engines and social media data for determining eye disease patterns. *JAMA ophthalmology*. 2016 Sep;134(9):1024-30. [doi: 10.1001/jamaophthalmol.2016.2625]
8. Mavragani A. Infodemiology and infoveillance: scoping review. *Journal of medical internet*

research. 2020 Apr;22(4):e16206. [doi: 10.2196/16206]

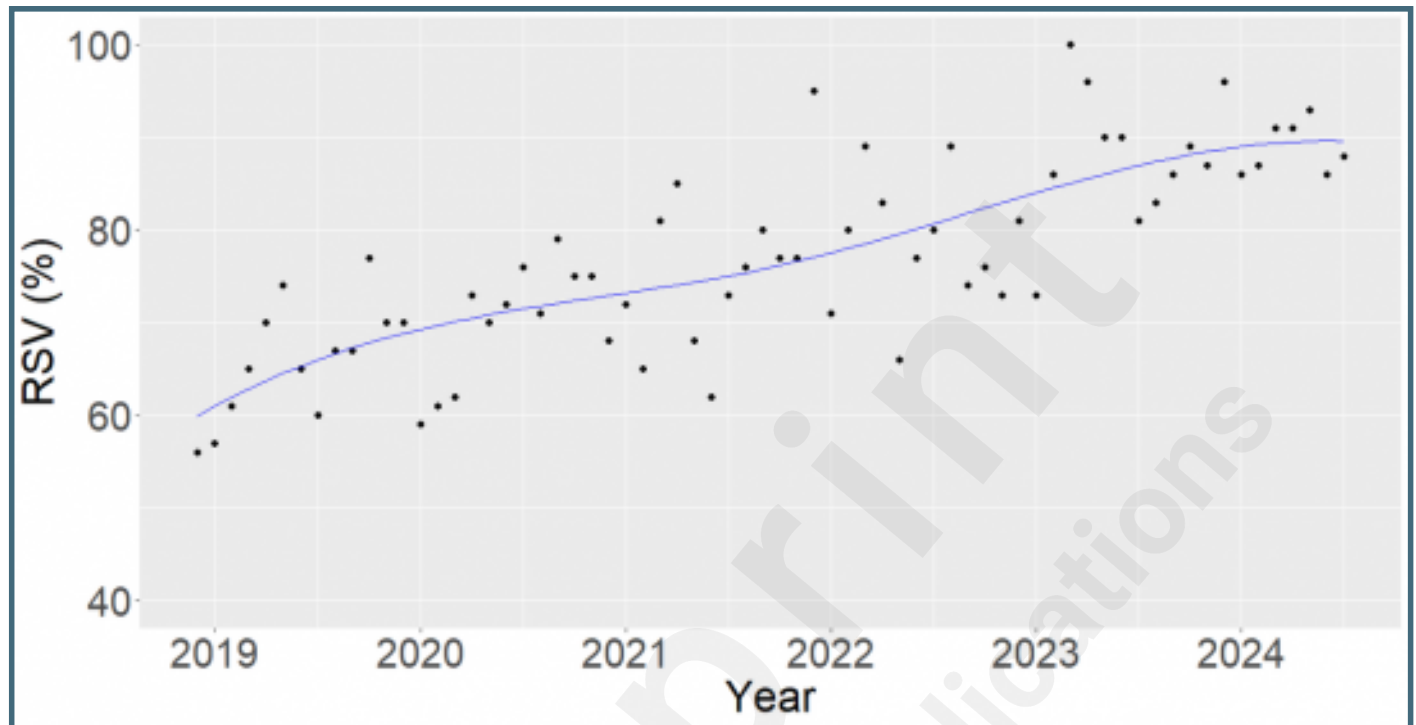
9. Nuti SV, Wayda B, Ranasinghe I, Wang S, Dreyer RP, Chen SI, et al. The use of google trends in health care research: a systematic review. *PloS one*. 2014 Oct;9(10):e109583. [doi: 10.1371/journal.pone.0109583]
10. Leffler CT, Davenport B, Chan D. Frequency and seasonal variation of ophthalmology-related internet searches. *Canadian journal of ophthalmology*. 2010 Jun;45(3):274-9. [doi: 10.3129/i09-268]
11. Azzam DB, Nag N, Tran J, Chen L, Visnagra K, Marshall K, et al. A novel epidemiological approach to geographically mapping population dry eye disease in the United States through Google Trends. *Cornea*. 2021 Mar;40(3):282-91. [doi: 10.1097/ICO.0000000000002491]
12. Prasad V, Jena AB. Prespecified falsification end points: can they validate true observational associations? *Jama*. 2013 Jan;309(3):241-2. [doi: 10.1001/jama.2012.96867]
13. Martinyan J, Starr CE. Surge in Eye Drop Safety Concerns and Interest in Alternative Dry Eye Disease Therapy Following Eye Drop Recalls: A Cross-Sectional Google Trends Analysis. *Eye & Contact Lens*. 2022 Oct;10.1097. [doi: 10.1097/ICL.0000000000000859]
14. Gayton JL. Etiology, prevalence, and treatment of dry eye disease. *Clinical ophthalmology*. 2009 Jul;405-12. [doi: 10.2147/opth.s5555]
15. Lemp MA, Foulks GN. The definition and classification of dry eye disease. *Ocul Surf*. 2007 Apr;5(2):75-92. [doi: 10.1016/s1542-0124(12)70081-2]
16. Messmer EM. The pathophysiology, diagnosis, and treatment of dry eye disease. *Deutsches Ärzteblatt International*. 2015 Jan;112(5):71. [doi: 10.3238/arztebl.2015.0071]
17. Kuo Y-K, Lin I-C, Chien L-N, Lin T-Y, How Y-T, Chen K-H, et al. Dry eye disease: a review of epidemiology in Taiwan, and its clinical treatment and merits. *Journal of Clinical Medicine*. 2019 Aug;8(8):1227. [doi: 10.3390/jcm8081227]
18. Papas EB. The global prevalence of dry eye disease: A Bayesian view. *Ophthalmic and Physiological optics*. 2021 Nov;41(6):1254-66. [doi: 10.1111/opo.12835]
19. Zhong J-Y, Lee Y-C, Hsieh C-J, Tseng C-C, Yiin L-M. Association between dry eye disease, air pollution and weather changes in Taiwan. *International journal of environmental research and public health*. 2018 Oct;15(10):2269. [doi: 10.3390/ijerph15102269]
20. Inomata T, Iwagami M, Nakamura M, Shiang T, Yoshimura Y, Fujimoto K, et al. Characteristics and risk factors associated with diagnosed and undiagnosed symptomatic dry eye using a smartphone application. *JAMA ophthalmology*. 2020 Jan;138(1):58-68. [doi: 10.1001/jamaophthalmol.2019.4223]
21. Lin P-Y, Tsai S-Y, Cheng C-Y, Liu J-H, Chou P, Hsu W-M. Prevalence of dry eye among an elderly Chinese population in Taiwan: the Shihpai Eye Study. *Ophthalmology*. 2003 Jun;110(6):1096-101. [doi: 10.1016/S0161-6420(03)00262-8]
22. Ayaki M, Kawashima M, Uchino M, Tsubota K, Negishi K. Possible association between subtypes of dry eye disease and seasonal variation. *Clinical Ophthalmology*. 2017 Jul;1769-75. [doi: 10.2147/OPHTH.S143845]
23. Kumar N, Feuer W, Lanza NL, Galor A. Seasonal variation in dry eye. *Ophthalmology*. 2015 Aug;122(8):1727-9. [doi: 10.1016/j.ophtha.2015.04.027]
24. Song P, Xia W, Wang M, Chang X, Wang J, Jin S, et al. Variations of dry eye disease prevalence by age, sex and geographic characteristics in China: a systematic review and meta-analysis. *Journal of global health*. 2018 Dec;8(2). [doi: 10.7189/jogh.08.020503]
25. Hwang SH, Choi Y-H, Paik HJ, Wee WR, Kim MK, Kim DH. Potential importance of ozone in the association between outdoor air pollution and dry eye disease in South Korea. *JAMA ophthalmology*. 2016 May;134(5):503-10. [doi: 10.1001/jamaophthalmol.2016.0139]
26. Tan G, Li J, Yang Q, Wu A, Qu D-Y, Wang Y, et al. Air pollutant particulate matter 2.5 induces

- dry eye syndrome in mice. *Scientific Reports*. 2018 Dec;8(1):17828. [doi: 10.1038/s41598-018-36185-6]
27. Chung C-J, Hsia N-Y, Wu C-D, Lai T-J, Chen J-W, Hsu H-T. Exposure to ambient NO₂ increases the risk of dry eye syndrome in females: an 11-year population-based study. *International journal of environmental research and public health*. 2021 Jul;18(13):6860. [doi: 10.3390/ijerph18136860]
28. Bai Y-C, Wang C-Y, Lin C-L, Lai J-N, Wei JC-C. Association between air pollution and the risk of uveitis: a nationwide, population-based cohort study. *Frontiers in Immunology*. 2021 Feb;12:613893. [doi: 10.3389/fimmu.2021.613893]
29. Heuss JM, Glasson WA. Hydrocarbon reactivity and eye irritation. *Environmental Science & Technology*. 1968 Dec;2(12):1109-16. [doi: 10.1021/es60022a005]
30. González N, Iloro I, Soria J, Duran JA, Santamaría A, Elortza F, et al. Human tear peptide/protein profiling study of ocular surface diseases by SPE-MALDI-TOF mass spectrometry analyses. *EuPA Open Proteomics*. 2014 Dec;3:206-15. [doi: 10.1016/j.euprot.2014.07.002]
31. Clifford D, Stone G, Montoliu I, Rezzi S, Martin F-P, Guy P, et al. Alignment using variable penalty dynamic time warping. *Analytical chemistry*. 2009 Feb;81(3):1000-7. [doi: 10.1021/ac801851d]
32. Jung SJ, Mehta JS, Tong L. Effects of environment pollution on the ocular surface. *The ocular surface*. 2018 Apr;16(2):198-205. [doi: 10.1016/j.jtos.2018.01.001]
33. Naseer S, Hasan S, Bhuiyan J, Prasad A. Current public trends in the discussion of dry eyes: a cross-sectional analysis of popular content on TikTok. *Cureus*. 2022 Feb;14(2). [doi: 10.7759/cureus.22069]
34. Yu H, Zeng W, Zhang M, Zhao G, Wu W, Feng Y. Utilizing Baidu index to investigate seasonality, spatial distribution and public attention of dry eye diseases in Chinese Mainland. *Frontiers in Public Health*. 2022 Feb;10:834926. [doi: 10.3389/fpubh.2022.834926]

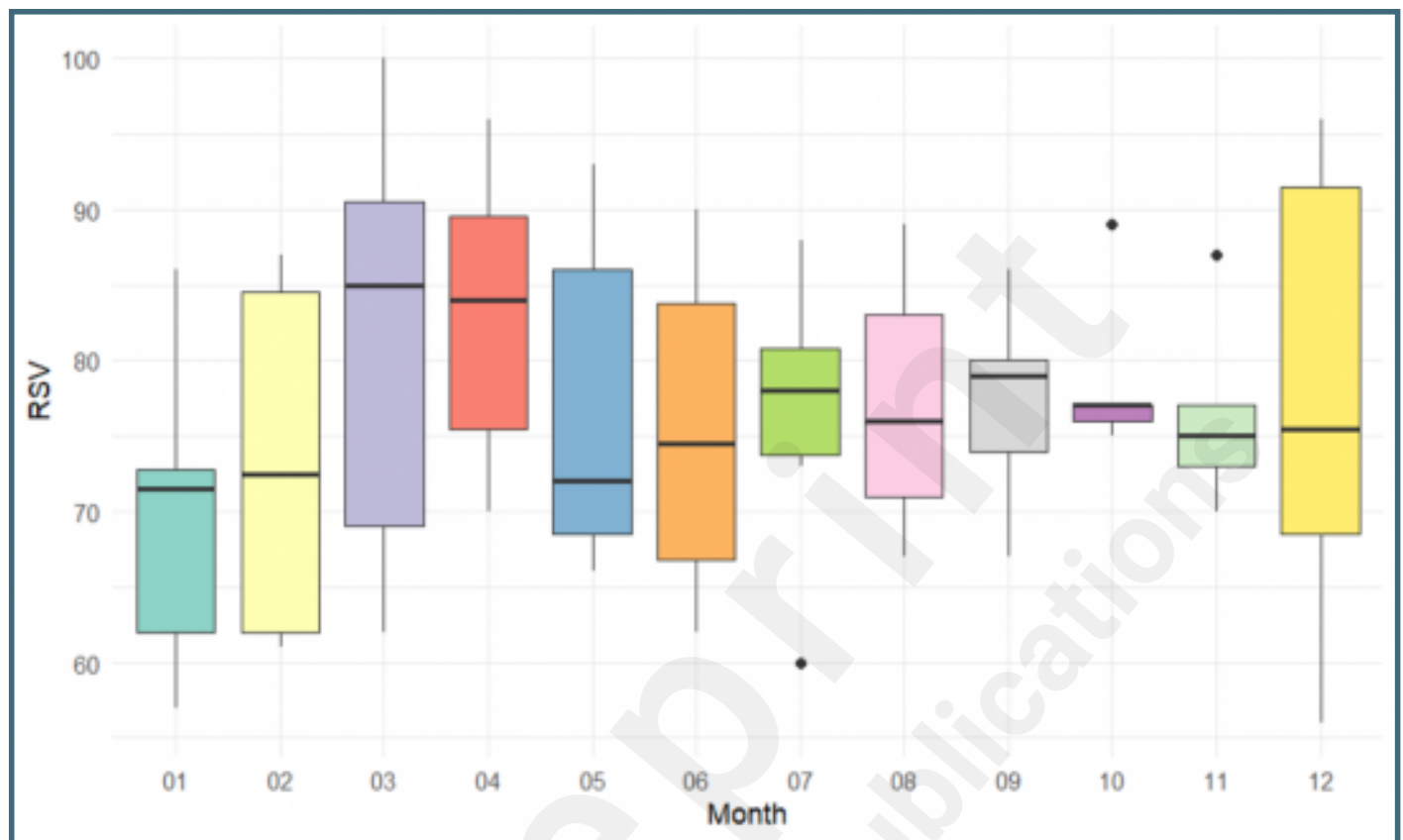
Supplementary Files

Figures

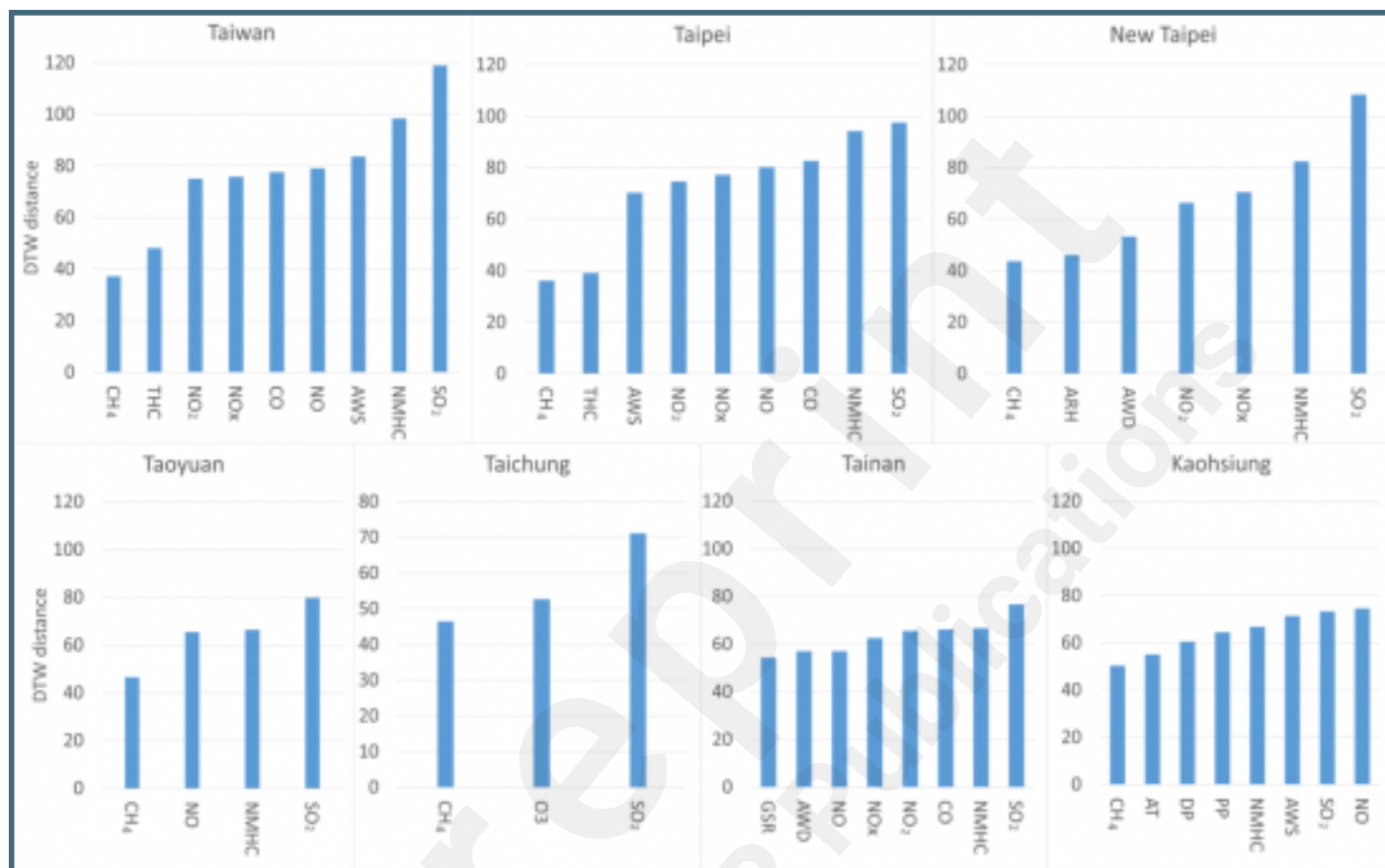
This figure illustrates trends in RSV for dry eye syndrome from December 2018 to July 2024 in Taiwan based on Google Trends data. The blue line represents overall RSV trend in Taiwan, with mean instantaneous derivative (MID) computed at 0.445 per month (95% CI: 0.308 to 0.593, $p < 0.001$), indicating a significant positive trend in public interest.



The figure is regarding monthly variations in RSV for dry eye syndrome in Taiwan from December 2018 to July 2024. Kruskal-Wallis test was performed, indicating no statistically significant monthly differences in RSV ($p = 0.850$). This suggests consistent public search interest throughout the year.



The figure illustrates the DTW distance data between RSV and statistically significant environmental parameters identified through Spearman's correlation analysis. The DTW distance are arranged in ascending order from left to right, showing the temporal correlations between RSV and various environmental parameters in Taiwan and its six special municipalities. Most of the significantly correlated parameters are air pollutants, and the visualization provides insights into the relationship between air quality and RSV over time.



Multimedia Appendixes

Supplementary tables and figures.

URL: <http://asset.jmir.pub/assets/76d65beed4ba6148dad881b1dc90e5c4.docx>

