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Google Trends as a Surveillance Tool for Dermatophytoses and Dermatomycoses in Indonesia

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Abstract: Background The global review of invasive fungal infections (IFI) in recent years did not include data from Indonesia bacause lack of pravalence data and its change over time. This paper aims to study the possibility of Google Trends as a tool to estimate the regional differences in the relative prevalence of IFI in Indonesia and its change over time. The research was conducted by searching for keywords related to tinea corporis and pityriasis versicolor in Indonesian on Google Trends using the 2016-2021 annual data. Data is restricted to the health category. The outputs in search interest and related queries are analyzed to see the ongoing trend. The results show that data from Google Trends shows a pattern that indicates the existence of specific areas that always have a high search interest for dermatomycoses. This article demonstrates that it is possible to use Google Trends to estimate which province has a higher or lower prevalence of invasive fungal infections than others and to see the changing over time. This paper provides new evidence of the capabilities of Google Trends in disease surveillance, particularly in developing countries.

Keyword: Google Trends, dermatophytoses, infodemiology, pityriasis, Indonesia, surveillance.

INTRODUCTION

Invasive fungal infections (IFI) are a public health problem that reaches 20-25% of the world's population [1,2]. Dermatophytoses are IFI diseases caused by a group of fungi in the Onygenales order of the family Arthrodermataceae [3]. Meanwhile, dermatomycoses are all fungal infections that are not derived from dermatophytes. One of the most prevalent dermatomycoses are pityriasis versicolor. It is a skin infection caused by yeasts of the genus Malassezia. Dermatophytes and dermatomycoses can take the form of skin, scalp, and nail infections. In immunosuppressed patients, IFI spreads on the skin and can reach organs. High morbidity and mortality due to deep infection caused by IFI have been reported in patients with hepatitis C, liver cirrhosis, subcutaneous nodules, human immunodeficiency virus (HIV), transplant recipients, patients undergoing chemotherapy, and patients with a history of diabetes mellitus [4–9]. In particular, infection in patients with CARD9 mutations can cause death with a mortality rate of 23.5% [10]. Improper handling of IFI can lead to more severe effects [11]. Some IFI, such as pityriasis versicolor, does not provide more fatal health problems but still has an

aesthetic impact and therefore, impacts psychological and social welfare for sufferers such as anxiety, stress, or depression [12]. Hypopigmented macules due to IFI amplify the harmful effects of ultraviolet radiation, making sufferers more susceptible to skin cancer than the general population [12]. A report states that pityriasis versicolor contributes to refractory dermatitis in patients receiving immune checkpoint inhibitor therapy [13]. Despite the availability of antifungal agents such as terbinafine and Itraconazole, IFI has begun to develop resistance [14,15], decreasing the effectiveness of these antifungals and finding new antifungal agents and formulations is a challenge [16].

Dermatophytoses and dermatomycoses in developing countries such as Indonesia need attention, since invasive fungal infections are endemic in this area [2]. In addition, many developing countries are located in the tropics where the infection is more likely [3]. Indonesia, in particular, is a country with a unique geographical area with an archipelagic shape so that the available health services are not evenly distributed. Moreover, Indonesia is a country with a high frequency of hydrometeorological disasters, which is one of the conditions for the spread of IFI [17]. Climate change exacerbates this condition, increasingly impacting developing countries [18]. In this case, skin-related diseases can become a plague threatening society's welfare. However, data on the prevalence of IFI in Indonesia are still very minimal. The annual national health report from the Government does not provide data on the prevalencenationally or provincially [19]. The Government's five-year survey also did not ask about the problem of IFI [20]. As a result, researchers who focus on IFI have difficulty obtaining epidemiological data and rely only on small studies conducted in minimal and incomplete geographic areas [21]. The global review of IFI in recent years did not include data from Indonesia [1,22].

Data on the relative prevalence of IFI in Indonesia and its change over time is needed by policymakers in the health sector to promote knowledge and provide adequate health policies to manage IFI, especially in geographic areas with a consistently high search vol me. Recently there has been a way to estimate the relative prevalence of the disease by utilizing Google Trends [23]. The power of Google Trends can be illustrated by recent research that studied dermatological conditions during the Covid-19 period in Turkey and Italy [24]. The research found an increase in the keyword "acne" correlated with the number of Covid-19 cases. The same trend can also be seen in Indonesia (Fig 1), where there was a spike in the keyword "acne" (in Indonesian and English) when the pandemic started. The studies above show that Google Trends can be an essential tool to fill gaps in disease surveillance data.

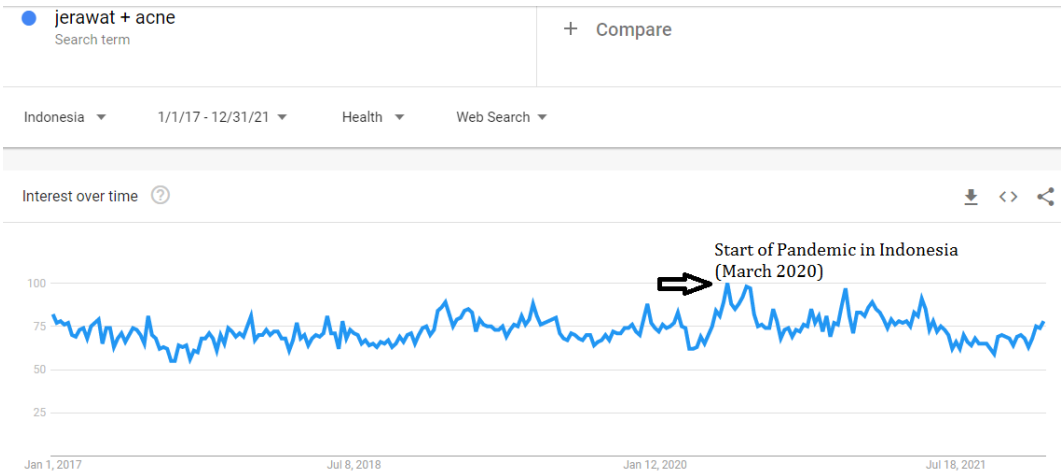


Figure 1. The surge in searches for the keywords "acne" (in English) and "jerawat" (in Indonesian) during the Covid-19 pandemic.

The present study investigates the possibility of Google Trends as a tool for estimating regional differences in the relative prevalence of IFI in Indonesia and its change over time. By

relative prevalence, we mean that the figure does not precisely show the prevalence number but whether one province has a higher search volume than another. This paper contributes to the literature by considering the use of Google Trends as an effective tool in conducting surveillance of IFI in Indonesia in the absence of usable primary data. Of course, if primary data from national surveys are available, the actual data need to be prioritized [25].

METHOD

Time range of the data

This study uses Google Trends as a data collection tool. We use a checklist from Nuti et al. [26] as the reporting guideline for Google Trends studies in a healthcare setting. This research uses the 2016-2021 annual time range. We start from 2016 because data for several provinces in 2015 did not appear in Google Trends searches due to too few searchers. The year 2022 itself is not included because it is still running, so the data obtained will only represent part of the current year. The data was downloaded on May 12, 2022.

Search strategy

One consideration that needs to be considered when using Google Trends is that it is not entirely clear what search terms should be used when exploring certain health behaviors 27. However, in our case, the keywords to search for are pretty self-explanatory. In Indonesian, three words can represent pityriasis versicolor and tinea corporis, namely “kurap”, “panu”, and “kadas”. “Panu” is a term in Indonesian to describe a pityriasis versicolor infection, while “kurap” is an infection of tinea corporis. "Kadas" is another name for "kurap". Other infections of the genus tinea have no equivalent in Indonesian and are generally referred to as “panu” or “kurap/kadas”. We have included the word “ringworm” to facilitate users’ searching in English. So the overall keywords used in this research are “panu+kurap+kadas+ringworm”. To ensure that the searched keywords are health-related, we limit them to the Health category.

Search interest is the percentage of the number of keywords searched for to the total of all keywords searched by users. Google standardizes the search interest value based on the largest percentage of the areas or time unit examined. The region/time with the largest percentage gets a score of 100 while the other regions/time get a score adjusted for the percentages that make up that maximum score. As a result, search interest reflects one area's or time’s attention to a keyword, relative to other areas or times. The higher the search interest score, the more attention people in the area pay to the keyword. The search interest data itself cannot reveal the user's intentions in searching for these keywords on Google, but this can be approached by looking at related queries, which are also standard output from Google Trends. For this reason, we also examine the related queries that arise to see users’ possible intentions in searching for keywords.

Data analysis

We use descriptive statistics to describe the data. We also perform some inferential statistics. Yearly data were compared for each province using paired t-test. We also used ANOVA tests to measure the relationships between seasonality and pandemic months with search volume.

RESULTS AND DISCUSSION

Fig 2 shows the interest over time in tinea corporis and pityriasis versicolor in Indonesia. There was a spike at the start of the Covid-19 pandemic in this keyword search. However, this spike may be superficial because there is no medical justification for the link between Covid-19 and dermatophytoses, in contrast to acne. As a result, this spike can be caused by intense internet access and use during the Covid-19 pandemic where people are mostly at home and lack of access to clinicians due to mobility limitation policy.

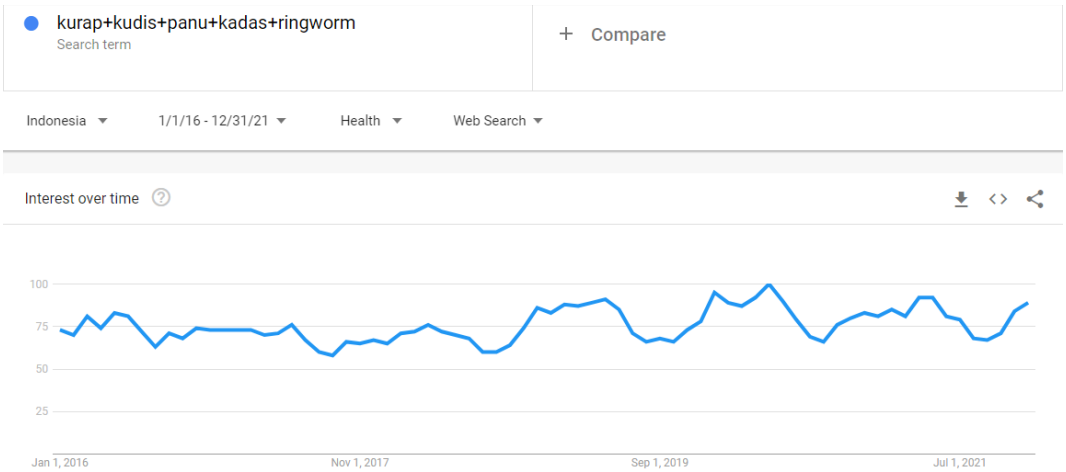


Figure 2. The spike in keyword searches during the early days of the Covid-19 pandemic.

What interests us more is how invasive fungal infections develop over time by geographic area. There are 34 provinces in Indonesia, part of which is part of a large island and part of an archipelago. Table 1 compares search interest by year and province in Indonesia from 2016 to 2021.

Table 1. Comparison of search interests by year and province in Indonesia in 2016-2021, from west to east, and south to north

Province	2016	2017	2018	2019	2020	2021
Aceh	41	60	62	73	80	91
North Sumatra	65	71	64	58	53	60
West Sumatra	35	64	53	62	61	69
Riau	53	73	69	73	66	77
Riau Islands	46	49	61	54	53	69
Jambi	73	100	71	77	78	96
Bengkulu	100	98	100	65	77	98
South Sumatra	69	84	84	69	67	79
Bangka Belitung Islands	60	87	57	100	100	67
Lampung	40	60	72	71	90	92
Banten	28	38	44	43	44	52
Jakarta	47	45	36	33	33	37
West Java	35	44	37	35	41	49
Central Java	40	48	47	46	55	59
Special Region of Yogyakarta	40	43	45	49	56	67
East Java	53	55	45	40	49	66
Bali	31	40	41	39	48	60
West Nusa Tenggara	36	56	48	64	60	82
East Nusa Tenggara	48	69	45	58	61	75
West Kalimantan	66	80	74	83	81	85
Central Kalimantan	36	38	47	58	49	66
South Kalimantan	56	54	51	52	46	59
East Kalimantan	48	65	58	70	62	71
North Kalimantan	36	56	67	45	54	88

North Sulawesi	27	48	37	34	50	64
Gorontalo	55	64	77	54	77	82
Central Sulawesi	29	43	49	45	59	77
West Sulawesi	26	63	98	72	76	100
South Sulawesi	51	69	59	56	51	65
South East Sulawesi	60	74	66	77	70	94
North Maluku	51	71	63	57	59	58
Maluku	34	68	61	77	47	65
West Papua	86	71	67	40	64	68
Papua	41	53	57	58	52	73
Mean	48.29	61.79	59.17	58.44	60.85	72.35
Standard deviation	16.99	16.18	15.84	15.81	14.77	14.88

Note: bold blue = ten highest search interests, bold green = ten lowest interests

By looking at Table 1, some patterns emerge immediately. First, the provinces in the Sumatra Island region (numbers 1 to 10) almost always have the highest ranking in search interests. Second, the provinces in Java Island (numbers 11 to 16) almost always rank the lowest in the search interests ranking. Third, provinces in eastern Indonesia (numbers 25-34) tend to get high rankings more often. Fourth, Bali is the province with the lowest search interest in six consecutive years, followed by Banten and West Java. Fifth, Bengkulu is the province with the highest search interest in five out of six years, followed by Jambi and Bangka Belitung Islands. Note that numbers 6 to 10 are neighboring provinces, so as 11 to 13.

The pattern above leads to the initial conclusion that public interest in solving IFI in the southern part of Sumatra Island is always high. In contrast,it is always low in the western part of Java. The finding is surprising, especially since Java and Sumatra are two neighboring islands. However, health facilities and population density in Java are much higher than in Sumatra.

Several provinces are in an improving situation, in terms of lower rankings. These provinces include South Sumatra, North Maluku, and West Papua. Provinces that are in deteriorating condition are Lampung, West Sulawesi, Central Sulawesi, and Southeast Sulawesi. The provinces on the island of Sulawesi are in a deteriorating situation with increasing interest in finding solutions for invasive fungal infections.

Fifteen paired samples t-test was used to discover is there was a significant difference between years (Table 2). The test compared every combination of years. The tests found statistically significant differences ($p < 0.005$) for nine of 15 pairs: 2016 with every other year and 2021 with every other year. The findings mean that the highest difference will be between 2016 and 2 21. The t-value of the difference is -7.237 ($p < 0.001$), with the year 2016 having a mean value of 48.29 and the year 2021 having a mean value of 72.35. Note that the search volume data for each year measure the volume relative to the highest volume search in that year. Hence, the significant difference between 2016 and 2021, or every other year, means a difference in the relative search volume distribution. In the case of 2016 vs. 2021, the search volume of 2021 is more evenly distributed than in 2016.

Table 2. Paired Samples t-test (N = 34)

Pair	*t*	*p*
2016 vs. 2017	-7.02	0.000
2016 vs. 2018	-4.01	0.000

2016 vs. 2019	-3.03	0.005
2016 vs. 2020	-4.16	0.000
2016 vs. 2021	-7.24	0.000
2017 vs. 2018	1.23	0.226
2017 vs. 2019	1.56	0.129
2017 vs. 2020	0.43	0.671
2017 vs. 2021	-4.11	0.000
2018 vs. 2019	0.29	0.775
2018 vs. 2020	-0.75	0.456
2018 vs. 2021	-6.98	0.000
2019 vs. 2020	-1.34	0.190
2019 vs. 2021	-5.73	0.000
2020 vs. 2021	-6.17	0.000

Table 3 shows the top five rated queries from all years. Over the years, the word "medicine" has always been the top-rated query, and the search interest rate for this word is much higher than any other phrase. This finding indicates the need for public information about drugs that can cure IFI. The finding also reflects the high level of these problems in society. Some queries contain the word "potent," indicating a drug that is considered ineffective because it does not solve the problems faced by the community.

Table 3. Five Highest Queries

Year	Queries	Search Interest
2016	Obat panu (pytiriasis versicolor medicine)	100
	Obat kurap (ringworm medicine)	55
	Obat kadas (ringworm medicine)	14
	Penyakit kurap (ringworm disease)	13
	Penyakit kulit (skin diseases)	9
2017	Obat panu (pytiriasis versicolor medicine)	100
	Obat kurap (ringworm medicine)	58
	Obat kadas (ringworm medicine)	15
	Penyakit kurap (ringworm disease)	12
	Kadas kurap (ringworm)	8
2018	Obat panu (pytiriasis versicolor medicine)	100
	Obat kurap (ringworm medicine)	63
	Obat kadas (ringworm medicine)	16
	Obat panu ampuh (powerful pityriasis versicolor medicine)	12
	Penyakit kurap (ringworm disease)	10
2019	Obat panu (pytiriasis versicolor medicine)	100
	Obat kurap (ringworm medicine)	62
	Obat panu ampuh (powerful pityriasis versicolor medicine)	15
	Obat kadas (ringworm medicine)	15
	Kadas kurap (ringworm)	11
2020	Obat panu (pytiriasis versicolor medicine)	100
	Obat kurap (ringworm medicine)	64
	Obat panu ampuh (powerful pityriasis versicolor medicine)	22
	Obat kadas (ringworm medicine)	17
	Kadas kurap (ringworm)	14
2021	Obat panu (pytiriasis versicolor medicine)	100

	Obat kurap (ringworm medicine)	60
	Obat panu ampuh (powerful pityriasis versicolor medicine)	28
	Obat panu paling ampuh (most powerful pityriasis versicolor medicine)	22
	Obat kadas (ringworm medicine)	16

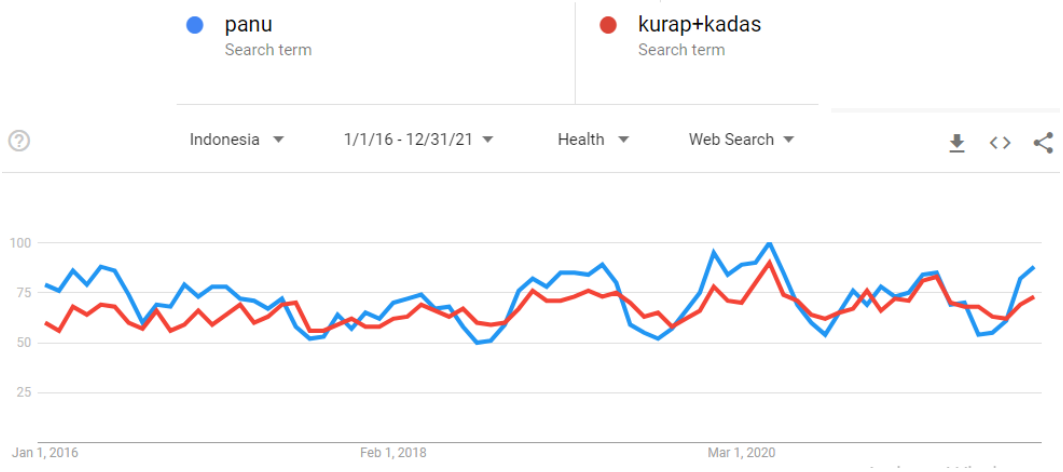
Table 4 shows the top 10 rising queries related to pityriasis versicolor and tinea corporis. Here “rising” means an increase relative to the previous year in that essential phrase. The concept of "breakout" in rising queries indicates that the keyword has experienced a tremendous increase from the previous year, indicating that this phrase is relatively new that year.

Table 4. Top Ten Rising queries

No	Queries	Period	The rising percentage from last year
1	Ways to treat tinea versicolor with turmeric	2019	Breakout
2	Ways to get rid of ringworm fast in 1 day	2021	Breakout
3	Number one most potent pityriasis versicolor medicine	2017	1500%
4	Pityriasis versicolor can be transmitted through	2020	1550%
5	Natural pityriasis versicolor drugs to be taken at pharmacies	2021	1500%
6	The most effective and quick cure for pityriasis versicolor	2021	1000%
7	Remedies for stubborn ringworm	2018	900%
8	Ways to treat ringworm with salt	2020	900%
9	The most effective cure for pityriasis versicolor and the price	2019	650%
10	Ways to treat ringworm that is already wide	2020	600%

Table 4 shows the possibility of new findings in the community regarding the role of turmeric in curing dermatomycoses in 2019, so there was a very high increase in these keywords in search engines. Meanwhile, in 2020 there is a new trend to treat ringworm with salt. People also want to know about scabies in 2021, indicating a possible outbreak. The rest of the keywords are variations of the keywords that have been used previously and are general. Finally, we separate specifically between “panu” (pityriasis versicolor) and “kurap/kadas” (tinea corporis). The results obtained show interesting findings. Fig 3 shows the relative keyword volume between the two keywords. This is in line with the findings in Palembang, South Sumatra, where the prevalence of pityriasis versicolor was around 34.6% while tinea corporis was 38.3% in the 2014-2018 range [28].

Figure 3. Search volume of "panu" and "kurap/kadas" between 2016 and 2021



A paired-samples *t*-test was calculated to compare the search volume of "panu" and "kurap/kadas." A statistically significant difference ($t(71) = 4.761$, $p < 0.001$) between the higher volume of "panu" ($m = 71.78$, $sd = 11.97$) over "kurap/kadas" ($m = 66.68$, $sd = 6.99$) was found. This finding shows that the population is more interested in pityriasis versicolor infection than tinea corporis.

We also aimed to find if there were significant differences between season and pandemic on search volume (utilizing binary value 1 for wet season/pre-pandemic and 2 for dry season/pandemic) (Tables 5 and 6). Four One Way ANOVA was used to test this. The significance level for "panu" was deemed insignificant as both were above the significance level of 0 05. Therefore, no significant differences between seasons and pandemics in the search volume of "panu." However, ANOVA of the "kurap/kadas" search volume confirmed the statistical significance of the difference in seasons and pandemic (dry season: $F(1,70) = 3.19$, $p < 0.010$; pandemic: $F(1,70) = 15.52$, $p < 0.001$). These results show that the dry season and pandemic situation positively affected the search volume for "kudis/kurap" but not for "panu."

Table 5. Mean values (standard deviation) for keywords based on seasonality

Keyword	Wet season	Dry season	ANOVA
"Panu"	73.27(9.50)	70.71(13.48)	$F(1,70) = 0.79$, $p > 0.005$
"Kadas/Kurap"	64.97(6.33)	67.90(7.24)	$F(1,70)=3.19$, $p < 0.100$

Table 6. Mean values (standard deviation) for keywords based on pandemic situation

Keyword	Pre-pandemic	Pandemic	ANOVA
"Panu"	70.74(11.54)	74.14(12.87)	$F(1,70) = 1.23$, $p > 0.005$
"Kadas/Kurap"	64.72(5.95)	71.14(7.24)	$F(1,70)=15.52$, $p < 0.001$

Table 7 reveals that "kurap/kadas" is the dominant keyword used in Sumatra, northern Kalimantan, southern Sulawesi, and southern Maluku while "panu" is the most dominant in Java, Lesser Sunda islands, southern Kalimantan, northern Sulawesi, northern Maluku, and Papua.

Table 7. The most dominant keywords by geographic area

Islands Group	Region	Panu	Kurap + Kadas
Sumatra	Aceh	39%	61%
Sumatra	North Sumatra	31%	69%
Sumatra	West Sumatra	41%	59%

Sumatra	Riau	33%	67%
Sumatra	Riau Islands	39%	61%
Sumatra	Jambi	34%	66%
Sumatra	Bengkulu	39%	61%
Sumatra	South Sumatra	39%	61%
Sumatra	Bangka Belitung Islands	37%	63%
Sumatra	Lampung	47%	53%
Java	Banten	50%	50%
Java	Jakarta	51%	49%
Java	West Java	52%	48%
Java	Central Java	62%	38%
Java	Special Region of Yogyakarta	61%	39%
Java	East Java	63%	37%
Lesser Sunda	Bali	62%	38%
Lesser Sunda	West Nusa Tenggara	65%	35%
Lesser Sunda	East Nusa Tenggara	57%	43%
Kalimantan	West Kalimantan	33%	67%
Kalimantan	Central Kalimantan	56%	44%
Kalimantan	South Kalimantan	54%	46%
Kalimantan	East Kalimantan	48%	52%
Kalimantan	North Kalimantan	39%	61%
Sulawesi	North Sulawesi	65%	35%
Sulawesi	Gorontalo	59%	41%
Sulawesi	Central Sulawesi	59%	41%
Sulawesi	West Sulawesi	57%	43%
Sulawesi	South Sulawesi	48%	52%
Sulawesi	South East Sulawesi	48%	52%
Maluku	North Maluku	100%	0%
Maluku	Maluku	40%	60%
Papua	West Papua	100%	0%
Papua	Papua	53%	47%

Google Trends in the medical sciences has been around for a long time. Researchers argue that Google Trends can be a timely, robust, and sensitive surveillance system [29]. Some studies have shown that Google Trends search results have a strong correlation with the incidence of diseases such as influenza [23], acute diarrhea and chickenpox [30], and Lyme disease [31]. Google Trends can be used for countries with a large search users [32]. Indonesia is a country with a large population of search engine users. Studies in Indonesia have shown that Google Trends can be used to monitor dengue fever activity [33,34].

Tinea corporis and pityriasis versicolor are Indonesia's two most common invasive fungal infections [28]. Our research reveals that the frequency of keywords people use to search for the two types of disease differs sharply by island. People on Sumatra tend to search for the keyword "kurap/kadas," the local name for tinea corporis. In contrast, people on Java tend to choose "panu", the local name for pityriasis versicolor.

The finding that Bali and western Java (Banten, West Java, Jakarta) have lower search interest than eastern Java (Central Java, Special Region of Yogyakarta, and East Java) mirrors

the finding of research regarding the prevalence of tinea capitis, a type of dermatophytoses, in Indonesia [21]. Bali, the province with the lowest prevalence (0.21%) is also the province with the lowest search interest in six consecutive years. Meanwhile, East Java, which has the highest search interest in Java, also has the highest prevalence from the available data.

Many epidemiological studies have argued that the high search volume and search interests reflect the distribution of related diseases [35,36]. However, several studies suggest that data from Google Trends should be viewed as an additional method for tracking disease. The data provides an overview of what is still unknown if standard methods are used or because standard surveillance methods are still not practicable [37].

Emerging research suggests that most people use the internet for medical information on dermatological diseases [38]. Education level and incomes positively correlated to search behavior [38]. The rising level of education and economics in developing countries such as Indonesia could explain why our finding show the increase in search volume for dermatophytoses, particularly after the pandemics.

There is conflicting research on seasonality of fungal infections. Some research suggest that fungal infections occur more often in the warmer period of the year [39–41], while studies in European countries show that IFI more frequently diagnosed in the colder season [42–45]. Study on Google Search Volume show that only several fungal infection follow this pattern [46]. In Indonesia, dry season occur on March to September and search volume of "kurap/kadas" or tinea corporis significantly higher in this season. Meanwhile, the search volume of “panu” (pityriasis versicolor) did not fluctuated according to season. The findings show that we cound not generalized seasonality pattern for all invasive fungal infections, at least based on the assumption that the search volume data represented the diseases relative prevalence.

The search volume of pityriasis versicolor also showed no significant difference between pre and during pandemic-months (starting on March 2020). However, looking at the graph in Fig. 3, we found that the peak search volume happened to be in March to May 2020. This figure matched with similar pattern in acne [24]. Search volume of tinea corporis was also relatively high in May 2020, before dropped again and peaked in April and May 2021. Tinea corporis search volume during pandemic was significantly higher than pre-pandemic. The increasing search volume could be due to restricted access to dermatology professionals as the impact of Covid-19 [47–49]. However, a study in Poland also found that generally there are no difference between fungal infection search volume before and after the pandemic [46], pointing out that pandemic has different effects on IFI search volume. Generally, lack of access to medical professional has affected tinea corporis knowledge seeking than pityriasis versicolor.

Overall, this research show that much information could be gained from search engine data for informing health issues. This strengthen the usefulness of infodemiology for predicting patient needs and epidemiological events, especially in developing countries.

This study highlights the importance of studying further the distribution of dermatophytoses in Sumatra and other provinces in Indonesia, which have been identified as having a high interest in IFI searching, especially in provinces with continued high interest throughout 2016-2021. This high interest generally occurs in tinea corporis, which have a relatively more dangerous impact than pityriasis versicolor.

CONCLUSION

Dermatophytoses and dermatomycoses can provide significant morbidity and health care costs [50]. If not appropriately treated, IFI can lead to worse problems [11]. It has long been observed that the incidence of IFI in Indonesia varies geographically [51]. The results of this study confirm that several regions in Indonesia continue to have great attention to this disease, indicating the lack of efforts to provide adequate health policies to manage IFI in these geographic areas.

Although generally only affects children, the frequency of occurrence of IFI is increasingly being reported in adults [11]. As a result, the high search volume on Google reflects parental concern for their potentially infected children and the efforts of adults to understand and seek treatment for IFI. Therefore, efforts to address IFI should be directed at pediatric efforts and socializing treatment for adults.

While efforts have been made to make maximum use of Google Trends to enhance the usefulness of this research, it has several important limitations that further research should address. Due to limited sources, it is impossible to correlate Google Trends search results with the incidence of IFI in every province in Indonesia. The results of this study may change if data on the prevalence of this disease is available at the provincial level in Indonesia. Secondfurther research needs to raise several variables that have the potential to be a factor in the community's prevalence and search interests.

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