ORIGINAL ARTICLE

J Mycol Infect 2020; 25(2): 35-41
pISSN:1226-4709, eISSN:2465-8278
http://dx.doi.org/10.17966/JMI.2020.25.2.35

JMI

Association between Hospital Visits for Superficial Fungal Infections and Climatological Factor

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Background: No cohort studies exist on the effect of temperature and humidity on the number of visits to hospitals by patients with superficial fungal infections.

Objective: The aim of our study was to investigate the relationship between climatological factors and superficial fungal infection-related hospital visits.

Methods: This study was a retrospective cohort study based on the National Health Insurance Service-National Sample Cohort (NHIS-NSC) database of patients with superficial fungal infection, from 2003 to 2012. We analyzed epidemiological characteristics and types of superficial fungal infection using descriptive statistics. We extracted climatological variables including temperature, relative humidity, precipitation, wind speed, possible duration of sunshine, and duration of sunshine from the Korea Meteorological Administration.

Results: 116,903 patients presented with superficial fungal infections in the NHIS-NSC database. The most common type of superficial fungal infection-related hospital visits was tinea unguium (46.72%), followed by tinea pedis (28.38%), tinea corporis (9.19%), and tinea cruris (7.52%). Significant positive linear associations were found between mean daily superficial fungal infection-related hospital visits and daily average temperature ($p < 0.001$) and relative humidity ($p < 0.001$).

Conclusion: The data from this study indicated that high temperature and high relative humidity may exacerbate superficial fungal infections.

Key Words: Humidity, Superficial fungal infections, Temperature

INTRODUCTION

Dermatophytosis is a disease condition characterized by fungal infection of keratinized tissues such as the skin, hair, and nails. The infections are generally restricted to the non-living, superficial cornified layers of the skin. Superficial fungal infections are prevalent worldwide, affecting more than 25% of the population[1]. Hot and humid climates such as that of India makes superficial fungal infections very common, especially superficial fungal infections of the skin[2]. Other factors associated with a high prevalence of superficial fungal infections include overpopulation and poor hygienic living

Received: April 21, 2020 Revised: June 17, 2020 Accepted: June 22, 2020

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conditions[3,4]. Thus, the distribution and frequency of the organisms involved vary, depending on climate, population density, and socioeconomic conditions[5]. The Republic of Korea is located across the middle latitudes of the Northern Hemisphere (35.9078° N), between the Eurasian Continent and the Western Pacific (127.7669° E), and exhibits warm and humid summer weather. To date, no cohort survey exists on the association between climatological factors and number of hospital visits by patients with superficial fungal infections.

Therefore, the purpose of this study was to investigate the association between climatological factors and superficial fungal infection-related hospital visits from 2003 to 2012, using the database of National Health Insurance Service-National Sample Cohort database (NHIS-NSC) and The Korea Meteorological Administration (KMA).

MATERIALS AND METHODS

1. Study design and database

The Korean National Health Insurance Service (NHIS) provided a sample cohort consisting of approximately one million qualified de-identified individuals from 2002 to 2015. The cohort database included diverse variables such as sex, age, location, type of subscription, social and economic qualifications, and status on medical resource utilization. Other details were described previously[6]. In this study, age, sex, residential location (urban and rural), income, and diagnostic codes based on the International Classification of Diseases, Tenth Revision (ICD-10) were retrieved. Types of superficial fungal infections were divided into dermatophytoses, tinea versicolor, and unspecified. The dermatophytoses were subdivided according to body location by diagnostic code. The KMA enabled full access to its Weather and Climate Big Data Analysis Platform to provide weather and climate data, including temperature, precipitation, wind, atmospheric pressure, humidity, hours of bright sunlight, cloud cover, and solar radiation. Among these, we selected only the appropriate data, including temperature, relative humidity, precipitation, wind speed, possible duration of sunshine, and duration of sunshine. Weather variables that exhibited missing values or were not recorded for the full period were excluded. This platform offers climate data to government organizations, public institutions, research institutes, and universities. This study was approved by the Institutional Review Boards of Hanyang University Guri Hospital (GURI 2020-02-010) and adhered to the principles of the Declaration of Helsinki.

2. Definition of clinical outcome

Patients who presented with ICD-10 codes of B35 (Dermatophytosis) and B36 (Other superficial mycoses) were identified from the NHIS-NSC. Comorbidities such as hypertension (ICD-10 codes I10-13 and I15), diabetes mellitus (ICD-10 codes E11-14), dyslipidemia (ICD-10 codes E78),

Table 1. Demographic findings of the study population

Characteristics	Patients with superficial fungal infections (n= 116,903)
Age, n (%)	
0~19	7,273 (6.22)
20~29	13,157 (11.25)
30~39	21,574 (18.45)
40~49	28,048 (23.99)
50~59	22,580 (19.32)
60~69	15,283 (13.07)
≥70	8,988 (7.69)
Sex, n (%)	
Male	61,145 (52.30)
Female	55,758 (47.70)
Location, n (%)	
Urban	77,408 (66.22)
Rural	39,495 (33.78)
Income, n (%)	
0~20%	16,024 (13.71)
20~40%	17,089 (14.62)
40~60%	21,726 (18.28)
60~80%	27,290 (23.34)
80~100%	34,774 (29.75)
Comorbidities	
Hypertension	29,435 (25.18)
Diabetes mellitus	13,700 (11.72)
Dyslipidemia	11,790 (10.09)
Chronic obstructive pulmonary disease	13,504 (11.55)
Malignancies	6,612 (5.66)

Table 2. Clinical characteristics of the study population

Clinical characteristics	Male, n (%)	Female, n (%)	Total patients, n (%)
Tinea barbae/capitis (B35.0)	707 (57.06)	532 (42.94)	1,239 (1.06)
Tinea unguium (B35.1)	24,023 (43.98)	30,596 (56.02)	54,619 (46.72)
Tinea manuum (B35.2)	914 (50.03)	913 (49.97)	1,827 (1.56)
Tinea pedis (B35.3)	17,702 (53.36)	15,473 (46.64)	33,175 (28.38)
Tinea corporis (B35.4)	6,445 (60.00)	4,297 (40.00)	10,742 (9.19)
Tinea cruris (B35.6)	7,440 (84.64)	1,350 (15.36)	8,790 (7.52)
Tinea versicolor (B36.0)	2,328 (68.51)	1,070 (31.49)	3,398 (2.91)
Unspecified superficial mycosis	1,586 (50.95)	1,527 (49.05)	3,113 (2.66)
Total			116,903 (100)

chronic obstructive pulmonary disease (ICD-10 codes J41-44 and J47), and cancer (ICD-10 codes C00-96) were investigated. To improve the accuracy of the analysis, only the subjects who presented with at least two principal diagnostic codes for each disease were included. Also, we calculated the daily average numbers of hospital visits from 2003 to 2012 according to climatological factors including temperature, relative humidity, precipitation, wind speed, possible duration of sunshine, and duration of sunshine. Holidays and Sundays were excluded from the analyses. Patients who were treated for superficial fungal infections or comorbidities during the screening period (2002) were also excluded.

3. Statistical analyses

Pearson's correlation analysis was used to investigate the relationship between mean daily superficial fungal infection-related hospital visits and climatological factors. Associations between atmospheric variables and mean daily superficial fungal infection-related hospital visits were assessed by multiple linear regression with backward elimination. We calculated 95% confidence intervals, and a probability (p) value < 0.05 was considered statistically significant. Variables with variance inflation factor values > 5 were excluded from the analysis. Data were analyzed using SAS version 9.4 (SAS Institute, Cary, NC, USA).

RESULTS

1. Baseline characteristics of the study population

From January 2003 to December 2012, we identified a total of 116,903 patients with superficial fungal infections visiting hospitals, including 61,145 (52.30%) males and 55,758 (47.70%) females. The age group with the highest prevalence was that of the 40-49-year-olds (23.99%), followed by the 50-59-year olds (19.32%). The demographic characteristics of the study population are summarized in Table 1. Hypertension was the most prevalent comorbidity (25.18%), followed by diabetes mellitus (11.72%), chronic obstructive pulmonary disease (11.55%), dyslipidemia (10.09%), and malignancy (5.66%).

2. Clinical characteristics of patients with superficial fungal infections

Table 2 shows the frequency of the types of superficial fungal infections. Of the 116,903 patients visiting hospitals due to superficial fungal infections, the most common type was tinea unguium (46.72%), followed by tinea pedis (28.38%), tinea corporis (9.19%), and tinea cruris (7.52%).

3. Climatological factors and superficial fungal infections-related hospital visits

Table 3 shows Pearson's correlation matrix presenting the relationships between mean daily superficial fungal infection-related hospital visits and climatological factors.

In the multiple linear regression analysis, significant positive associations were observed between mean daily superficial fungal infection-related hospital visits and daily average temperature, average wind speed, average relative humidity, and duration of sunshine ($p < 0.001$, respectively) (Table 4). The

Table 3. Pearson correlation matrix showing relationships between mean daily superficial fungal infections-related hospital visits and climatological factors

	Hospital visits	Average temperature	Lowest temperature	Highest temperature	Precipitation	Maximum wind speed	Average wind speed	Relative humidity	PDS	DoS
Hospital visits										
r	1									
Sig. (2-tailed)										
N	3,010									
Average temperature										
r	0.685	1								
Sig. (2-tailed)	**<0.001**									
N	3,010	3,010								
Lowest temperature										
r	0.697	0.991	1							
Sig. (2-tailed)	**<0.001**	**<0.001**								
N	3,010	3,010	3,010							
Highest temperature										
r	0.662	0.991	0.967	1						
Sig. (2-tailed)	**<0.001**	**<0.001**	**<0.001**							
N	3,010	3,010	3,010	3,010						
Precipitation										
r	0.203	0.308	0.346	0.260	1					
Sig. (2-tailed)	**<0.001**	**<0.001**	**<0.001**	**<0.001**						
N	2,376	2,376	2,376	2,376	2,376					
Maximum wind speed										
r	-0.144	-0.215	-0.200	-0.235	0.160	1				
Sig. (2-tailed)	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**					
N	3,010	3,010	3,010	3,010	2,376	3,010				
Average wind speed										
r	-0.108	-0.222	-0.195	-0.253	0.103	0.915	1			
Sig. (2-tailed)	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**				
N	3,010	3,010	3,010	3,010	2,376	3,010	3,010			
Relative humidity										
r	0.427	0.596	0.654	0.528	0.525	-0.186	-0.210	1		
Sig. (2-tailed)	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**			
N	3,010	3,010	3,010	3,010	2,376	3,010	3,010	3,010		
PDS										
r	0.562	0.810	0.801	0.802	0.306	-0.004	-0.014	0.401	1	
Sig. (2-tailed)	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	0.842	0.459	**<0.001**		
N	3,010	3,010	3,010	3,010	2,376	3,010	3,010	3,010	3,010	
DoS										
r	-0.075	-0.124	-0.208	-0.029	-0.440	0.008	0.014	-0.667	-0.049	1
Sig. (2-tailed)	**<0.001**	**<0.001**	**<0.001**	**0.118**	**<0.001**	0.668	0.457	**<0.001**	**0.007**	
N	3,010	3,010	3,010	3,010	2,376	3,010	3,010	3,010	3,010	3,010

PDS, Possible duration of sunshine; DoS, Duration of sunshine

Table 4. Multiple linear regression with backward elimination of the association between mean daily superficial fungal infections-related hospital visits and climatological factors

Variable	B	SE	*t* value	*p* value	VIF
Constant	64.555	15.173	4.25	<.001	
Average temperature	6.938	0.200	34.78	<.001	1.967
Average wind speed	7.695	1.910	4.03	<.001	1.081
Average relative humidity	0.794	0.192	4.13	<.001	3.578
Duration of sunshine	2.298	0.633	3.63	<.001	2.320

SE, standard error; VIF, variance inflation factor

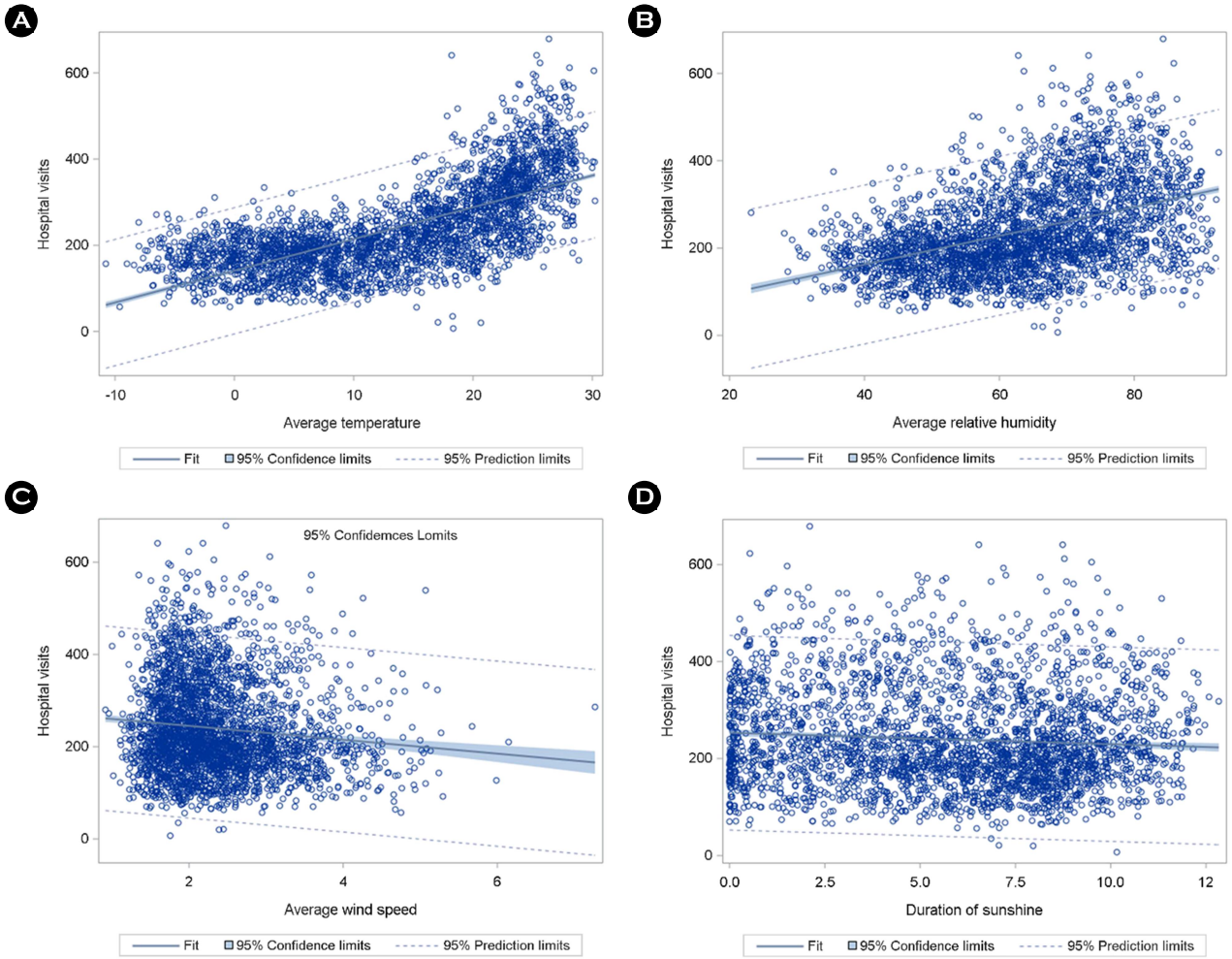

Fig. 1. The scattered plots between mean daily hospital visits and daily average temperature (A), relative humidity (B), wind speed (C), and duration of sunshine (D). Daily average temperature ($r = 0.685$, $p < 0.001$) and relative humidity ($r = 0.427$, $p < 0.001$) were significantly positively correlated with superficial fungal infection-related hospital visits, but average wind speed ($r = -0.108$, $p < 0.001$) and duration of sunshine ($r = -0.075$, $p < 0.001$) showed negative correlation with superficial fungal infection-related hospital visits.

generalized equation used to predict mean daily superficial fungal infection-related hospital visits from average temperature, wind speed, relative humidity, and duration of sunshine was as follows: mean daily superficial fungal infection-related hospital visits = 64.555 + 6.938 (temperature) + 7.695 (wind speed) + 0.794 (relative humidity) + 2.298 (duration of sunshine); these values were obtained from the coefficients table. In the scatter plot and Pearson's correlation analysis, temperature (r = 0.685, p < 0.001) and relative humidity (r = 0.427, p < 0.001) showed a consistent linear positive correlation with mean daily superficial fungal infection-related hospital visits; meanwhile, wind speed (r = -0.144, p < 0.001) and duration of sunshine (r = -0.075, p < 0.001) showed negative correlation (Fig. 1) (Table 3).

DISCUSSION

To investigate the relationship between climatological factors and superficial fungal infection-related hospital visits, we performed a retrospective cohort study of 116,903 patients with superficial fungal infections in the Korean NHIS database. We found that high temperature and relative humidity exhibited a significant linear correlation with superficial fungal infection-related hospital visits.

Humidity and temperature affect fungal penetration through the stratum corneum of the skin[7]. When the stratum corneum is overhydrated, mechanical integrity, biochemical composition and processes, and the ability to serve as an effective barrier are impaired[8]. The higher the skin temperature, the more the microbial growth is promoted and the higher the risk of infection[9]. *In vitro* studies on invasion and proliferation of *Trichophyton rubrum* and *Trichophyton mentagrophytes* showed that both fungi enter the stratum corneum with a speed that depends on humidity conditions. The invasion rate of the dermatophytes was slower at 80% humidity, but it increased proportionally with increasing humidity[10,11]. The authors also suggested that humidity was a more important environmental factor for fungal penetration than temperature and that a humidity of at least 90% is necessary for dermatophytes to penetrate into the stratum corneum within a few days[10]. Raman spectroscopy of healthy skin showed a seasonal variation in skin surface hydration with highest values observed during summer[12]. Since a rise in the external temperature leads to increased skin humidity, the belief exists that temperature also plays an important role as well as humidity. In our study, Pearson's correlation coefficient for daily average temperature (r = 0.685) was higher than that of daily average relative humidity (r = 0.427), suggesting that temperature affects the development of superficial fungal infections more than relative humidity.

As the wind blows, it sweeps away airborne water particles in the air, thereby reducing air humidity, which probably explains why the correlation between wind speed and hospital visits for superficial fungal infection showed a negative correlation (r = -0.144).

The duration of sunshine can affect both humidity and temperature. The longer the duration of sunshine, the more evaporation of moisture in the air, resulting in lower ambient humidity. Conversely, more sunshine leads to higher temperatures. Therefore, we speculated that the relatively small correlation coefficient of duration of sunshine (r = -0.075) could reflect this complex relationship.

Previous observations showed that the prevalence of superficial fungal infection is much higher in males than in females. Sundar et al. observed a 77.5%:22.5% ratio of males: females, and Debeeka et al. also identified a higher prevalence in males than in females (M:F, 3:2)[13,14]. In our study, a difference was found in the sex ratio according to the subtype of each superficial fungal infection. The largest sex ratio difference was observed for tinea cruris, with males accounting for 84.64%, followed by tinea versicolor (M:F, 68.51%:31.49%). In contrast, women comprised 56.02% of the patients with tinea unguium in our study. Collectively, superficial fungal infections are more prevalent in men, but the link to hospital visits appears to be different for each subtype of superficial fungal infection.

This study exhibits some limitations. First, patients who did not pay a visit to the hospital and were treated with over-the-counter medications may be present, so a difference will be found between the number of hospital visits and the factual prevalence. Therefore, the results of this study should be interpreted that tinea unguium is not the most common subtype, but the main reason for visiting the hospital by patients with superficial fungal infections. Second, we did not analyze the relationship between climatological factors and each type of superficial mycosis. Third, when studying associations between climatological factors and climate-affected diseases, essential climatic variables are required, including factors such as air pressure, water vapor, and cloud properties However, we did not include these weather elements in our analyses. Finally, a limitation in our analysis was the use of daily data because a lag in time was present between the climate as measured on a day-to-day basis and the time it takes to develop a fungal infection. Therefore, we also carried out analyses involving weekly and monthly average data and confirming our findings (data not shown).

In conclusion, this retrospective cohort study demonstrated

that temperature and relative humidity exhibit a large influence on hospital visits in patients with superficial fungal infections. This study was the first cohort study to report the association of superficial fungal infections and climatological factor from the population-based NHIS-NSC and KMA database.

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CONFLICT OF INTEREST

In relation to this article, we declare that there is no conflict of interest.

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