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A survey of ambulatory treated asthma and correlation with weather and air pollution conditions within Taiwan during 2001-2010

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Running head: A survey of asthma

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Declaration of Interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

Abstract

Objective: This study of asthma were performed to evaluate annual trends in emergency department (ED) for ten years. Weather and air pollution factors affecting asthma were also studied in order to identify the important factors and alert the public in advance. **Methods:** A survey of ambulatory-treated asthma patients was performed and the correlations with weather and air pollution factors examined in a cohort of one million patients in 2010. The fixed-cohort study analyzed trends, medical costs, and annual prevalence grouped by age and gender. **Results:** The number of asthma patients visiting EDs and non-emergency (non-ED) clinics significantly increased, with average annual percentage changes (AAPCs) of 2.3% and 4.6%, respectively. The average direct medical cost for EDs was increased significantly as compared with that of non-ED visits. Classification of asthma visits by hospital level indicated that local hospitals and others exhibited a significantly increasing trend (AAPC=15.3% [95% CI: 14.3–16.2]). The annual prevalence of asthma in males, females, and children was significantly increased (AAPCs of 1.5%, 1.8%, and 3.9%, respectively). Asthma patient hospitalizations were significantly correlated with temperature, humidity, and air pollution factors. **Conclusions:** The number of non-ED visits due to asthma increased, and the average direct medical cost for ED admissions also increased. Asthma patients tended to visit local hospitals primarily. Asthma visits by children increased, but a decrease was observed in adults. The number of hospitalized asthma patients was negatively correlated with temperature and humidity but positively correlated with the levels of PM_{2.5}, PM₁₀, and NO₂.

Introduction

Asthma is a disease of the respiratory system defined by the World Health Organization (WHO) as follows: asthma may occur in all age groups but often start in childhood. It is a disease characterized by recurrent attacks of breathlessness and wheezing, which vary in severity and frequency from person to person. In an individual, they may occur from hour to hour and day to day. This condition is due to inflammation of the air passages in the lungs and affects the sensitivity of the nerve endings in the airways, so they become easily irritated. In an attack, the lining of the passages swells, causing the airways to narrow and reducing the flow of air in and out of the lungs [1].

Asthma may occur in people of all ages, and often not enough care is taken with regards to the condition, which makes the disease more severe. Asthma mortality rates are relatively low [2] as compared with other chronic diseases, but the condition represents a burden for countries, especially developing and underdeveloped ones [3].

Previous studies have indicated that many factors affect asthma [4]. Among these factors, weather-related factors greatly affect the number and severity of cases of asthma [5-8]. In particular, during the process of industrialization, the building of many factories and an increasing level of traffic created a polluted environment, producing toxic gases such as $PM_{10-2.5}$, O_3 ,.... The above-mentioned issues directly affected the status of asthma in many countries [9-14].

Asthma is related to the respiratory system. When patients experience an asthma attack, they suffer dyspnea as well as oppressiveness, which is very dangerous. In severe cases, patients should be administered timely first-aid and transported to an emergency department. This is essential to avoid death [7, 15, 16]. Therefore, the objectives of this study are to understand the trends and factors affecting asthma to prevent of emergency admission and for the proper planning of resources allocation. Our hypotheses are well on the same view that air pollution and weather conditions affect asthma prevalence in Taiwan.

Methods

Data source

Taiwan launched a single-payer National Health Insurance program (NHI) on March 1, 1995. As of 2014, 99.9% population of Taiwan were enrolled [17]; foreigners in Taiwan are also eligible for this program. The database of the NHI contains registration files and original claims data for reimbursement. Large computerized databases derived from this system by the National Health Insurance Administration (the former Bureau of National Health Insurance, BNHI), Ministry of Health and Welfare (the former Department of Health, DOH), Taiwan, and maintained by the National Health Research Institutes, Taiwan, are provided to scientists in Taiwan for research purposes.

Data in the National Health Insurance Research Database (NHIRD) that could be used to identify patients or care providers, including medical institutions and physicians, is scrambled before being sent to the National Health Research Institutes for database construction and is further scrambled before being released to each researcher. Theoretically, it is impossible to query the data alone to identify individuals at any level using this database. All researchers who wish to use the NHIRD and its data subsets are required to sign a written agreement declaring that they have no intention of attempting to obtain information that could potentially violate the privacy of patients or care providers [18].

Based on the registration files and original claims data in the NHIRD, specific data subsets are constructed for research purposes. Briefly, these datasets include the Registration dataset, Systematic Sampling of CD and DD, Longitudinal Health Insurance Database (LHID), Specific subject datasets, and the Teaching demo dataset.

This study used the LHID2010, which contains all original claims data of 1,000,000 random samples from approximately 27.38 million Registry of Beneficiaries (ID) of the NHIRD in year

2010. There was no significant difference in the gender distribution between the sampling data and population data ($\chi^2=0.067$, $df=1$, $p\text{-value}=0.796$) [19-23] (data approval number: NHIRD-104-183).

These one million samples were collected retrospectively during the period of 2001-2009 to perform a fixed-cohort analysis of subjects with asthma based on ICD-9-CM code 493x. Patients were divided into two groups: 1. Patients who visited an emergency department (ED); 2. Patients who were admitted to hospital but did not visit an ED. The ED visit group was defined as patients admitted to an ED with asthma, while the non-ED visit group was defined as patients with asthma who visited a hospital only for examination and did not visit an ED. Asthma cases were analyzed and evaluated annually in terms of the number of ED visits each year, average direct medical cost per case, distribution of cases according to hospital level, seasonal distribution, annual prevalence by gender, annual prevalence by age strata, and detailed category of asthma.

Data regarding air pollutants were obtained from the Taiwanese Environmental Protection Administration (EPA) through air quality monitoring stations. There are 60 general air quality monitoring stations, 5 industrial air quality monitoring stations, 5 traffic air quality monitoring stations, 2 national park monitoring stations, 4 background air quality monitoring stations, and 2 other air quality monitoring stations (Figure 1) [24]. Air pollutant monitoring stations use Ecotech 9850, Ecotech 9841, Ecotech 9810, Model 4010, Dani 462, Metone 083C, Metone 014A, Metone 024A, Ogasawara us-760S models [25]. Then they provide daily measurements for $PM_{2.5}$, PM_{10} , NO_2 , NO , NO_x , SO_2 , O_3 . Climate data were obtained from the Taiwanese Central Weather Bureau [26, 27]. All instruments from the EPA are subject to stringent quality assurance protocols in order to maintain the accuracy and reliability of the data. After calculating the hourly mean for the day value, climate monitoring stations automatically provide data for the daily temperature, barometric pressure, humidity, rainfall... The data were collected and imported to a Cloudera Impala (Apache Hadoop) database server [28].

(Insert figure 1 here)

Ethical approval and consent for participation and publication

This study was approved by the Institutional Review Board (IRB) of Taipei Hospital, Ministry of Health & Welfare, Taiwan, certificated by the Ministry of Health & Welfare, Taiwan (IRB approval number: TH-IRB-0015-0003).

Statistical analysis

Study data were managed by Impala Hadoop big data management and retrieved via SQL. Descriptive statistics were used to present the number of cases, number of subjects, percentages, means, and standard deviation (SD). The Chi-square test was used to examine significance in gender and age groups. The Pearson correlation coefficient and Bayesian Model Averaging (BMA) [29] were used to analyze the weather and air pollution factors for asthma cases. Statistical analysis was performed using SPSS Ver. 22. The average annual percentage change (AAPC) at $\alpha = 0.05$, and 95% confidence intervals (95% CIs) were calculated using Joinpoint Regression Program Ver. 4.2.0.2 – June 2015. BMA analysis was implemented in the RStudio program Ver.1.0.136.

Results

Analysis of 1 million random samples from 2010 resulted in 34,825 subjects identified as having been treated for asthma. These subjects were classified into 2,686 ED subjects (7.71%) and 32,139 non-ED subjects (92.29%). Among the patients with asthma, there was a significantly greater proportion (38.05%) of children (41.59% ED and 37.75% non-ED). Considering asthma patients stratified by gender, male subjects made a significantly greater proportion of ED visits (55.66%), and female subjects more commonly made non-ED visits (50.44%) (Table 1).

(Insert Table 1 here)

The asthma patients in this study were analyzed annually in terms of ED and non-ED visits, annual direct medical cost per case, distribution of asthma cases according to hospital level, and distribution by season from 2001 to 2010. During this period, the number of non-ED visits was significantly greater than that of ED visits, and significantly increased with an AAPC of 4.6% (95%

CI: 2.5–6.7). Although ED visits were slightly less common than non-ED visits, the annual mean direct medical cost per ED case was significantly greater than that per non-ED case, and also exhibited a greater significant increase, with an AAPC of 7.6% (95% CI: 6.7–8.7); meanwhile, the number of non-ED cases also significantly increased, with an AAPC of 1.9% (95% CI: 0.1–3.7). Analysis of the distribution of asthma cases by hospital level according to criteria by Taiwan's Ministry of Health and Welfare [30] showed that the proportion of patients visiting medical centers was higher (60.62%) than the proportions of patients visiting hospitals of other levels in 2001; however, this was decreased to 37.77% for medical centers in 2010. The proportion of asthma patients visiting local hospitals or other hospitals significantly increased on an annual basis, with an AAPC of 15.3% (95% CI: 14.3–16.2). In contrast, the proportion of asthma patients visiting regional hospitals significantly decreased annually, with an AAPC of -2.6% (95% CI: -3.6–1.6). In addition, analyzing asthma cases by season, the results showed that the number of asthma cases in spring, summer, autumn, and winter were significantly increased, with AAPCs of 4.5%, 4.7%, 4.2%, and 4.5%, respectively (Table 2).

(Insert Table 2 here)

Furthermore, asthma patients were classified into 4 categories based on the ICD9-CM code of the first-listed diagnosis from 2001 to 2010. Most asthma cases were unspecified (accounting for 77.47% of cases, ranging from 75.57% to 80.61%). In addition, the numbers of patients in all categories (extrinsic asthma, intrinsic asthma, chronic obstructive asthma, and unspecified asthma) significantly increased, with AAPCs of 11.1% (95% CI: 6.1–16.2), 7.3% (95% CI: 4.5–10.3), 5.9% (95% CI: 4.0–7.8), and 6.2% (95% CI: 3.7–8.8), respectively (Table 2).

The annual prevalence of asthma from 2001 to 2010 was analyzed according to patient gender, age, and evaluated in terms of trend according to the AAPC at $\alpha=0.05$. For example, prevalence of asthma in male was defined by number of asthma in male subjects per 1000 male population. Table 3 shows that annual prevalence of asthma in male subjects was 29.93 per 1000 in 2001, and increased significantly to 35.38 (95% CI: 34.86–35.91) per 1000 persons in 2010, with an

AAPC of 1.5% (95% CI: 0.0–3.1); in female subjects, the annual prevalence of asthma was 28.06 per 1000 persons in 2001, and increased significantly to 34.28 (95% CI: 33.78–34.80) per 1000 persons in 2010, with an AAPC of 1.8% (95% CI: 0.6–3.0). In addition, analysis of asthma patients by age strata showed that the annual prevalence of asthma in children significantly increased, with an AAPC of 3.9% (95% CI: 2.6–5.2). In contrast, the annual prevalence of asthma in adult subjects (aged 46 to 60 years) significantly decreased, with an AAPC of -1.1% (95% CI: -1.8–0.5) (Figure 2).

(Insert Table 3 and Figure 2 here)

Many previous studies have indicated that asthma is affected by weather conditions and air pollution. This study focused on the effects of weather conditions and air pollution on the number of asthma cases day by day from 2001 to 2010. Table 4 shows descriptive statistics for daily asthma cases, including the minimum, maximum, mean, and standard deviation. Noticeably, the daily mean of ED cases at 8.58 (4.55) was lower than that of non-ED cases at 311.82 (127.07). The daily means (SD) of weather factors in Taiwan were as follows: temperature ($^{\circ}\text{C}$) 21.169 (4.404), wind (m/s) 1.843 (0.574), rain (mm) 0.293 (0.762), and humidity (%) 78.413 (6.254). In addition, the daily means (SD) of air pollution factors in Taiwan were as follows: PM_{10} ($\mu\text{g}/\text{m}^3$) 58.795 (23.635), $\text{PM}_{2.5}$ ($\mu\text{g}/\text{m}^3$) 36.903 (16.196), SO_2 (ppb) 4.400 (1.194), NO (ppb) 7.933 (3.761), NO_2 (ppb) 18.681 (5.259), and O_3 (ppb) 28.626 (8.407).

(Insert Table 4 here)

Pearson correlation was applied to analyze the relationships of daily weather conditions and air pollution factors from Jan. 1st 2001 to Dec. 31st 2010 (3,652 days) with asthma cases on the same day, as shown in table 5 and table 6. Negative associations between weather factors and asthma cases were identified in ED cases, with significant correlation coefficients for temperature $r=-0.321$ ($P<0.01$) and humidity $r=-0.101$ ($P<0.01$); in non-ED cases, significant correlation coefficients were found for temperature $r=-0.230$ ($P<0.01$) and humidity $r=-0.110$ ($P<0.01$). Air

pollution factors were significantly positively correlated with asthma cases: in ED cases, the correlation coefficients were PM_{10} $r=0.195$ ($P<0.01$), $PM_{2.5}$ $r=0.166$ ($P<0.01$), and NO_2 $r=0.100$ ($P<0.01$); in non-ED cases, the correlation coefficients were PM_{10} $r=0.236$ ($P<0.01$), $PM_{2.5}$ $r=0.162$ ($P<0.01$), and NO_2 $r=0.327$ ($P<0.01$).

(Insert Table 5 and Table 6 here)

BMA analytics for asthma visiting ED group indicated that the cumulative posterior probability of the three best models is 100% (Table 5). Temperature, wind, PM_{10} , SO_2 and NO_2 were associated with the number ED visiting due to asthma (posterior probability 100%). Regarding non-ED cases group, BMA showed that the cumulative posterior probability of the five best models is 88.41% and wind, raining $PM_{2.5}$, SO_2 , NO_2 are associated with this group (posterior probability 100%) (Table 6).

Discussion

In a study of a multicultural population of approximately 12 million people in Ontario, a province of Canada, the annual asthma prevalence, incidence (1/1,000), and all-cause mortality rates were estimated from 1996 to 2005. The prevalence of asthma increased by 70.5%, the asthma incidence rates increased in children by 30.0% and was relatively stable in adults [31]. In the present study in Taiwan from 2001 to 2010, which included 1 million random samples, the results showed that the annual prevalence of asthma in children greatly increased by 3.9%; and that in the elderly (aged over 60) increased more slowly, results that were similar trend to those of the study performed in Ontario, Canada. A cross-sectional observation analysis based on the QRESEARCH database that included 333,294 individuals from 2001 to 2005 showed that the prevalence rate of asthma per 1000 patient-years decreased from 6.9 (95% CI: 6.8–7.0) in 2001 to 5.2 (95% CI: 5.1–5.3) in 2005 ($p<0.001$), and most of asthma cases were in children under 5 years of age (-38.4%) [32]. However, the average annual percentage change of asthma prevalence in Taiwan increased from 2001 to

2010, with AAPCs of 1.5% in male subjects (95% CI: 0.0–3.1) and 1.8% in female subjects (95% CI: 0.6–3.0).

A study performed in Turkey from Dec. 2000 to Jun. 2001 that included 118 patients indicated that the mean annual direct medical costs were USD 1,465 $\pm$ 111.8 per capita, and increased with the severity of asthma [33]. A cohort of asthma patients (398,235) from British Columbia, Canada, cost \$315.9 million between 2002 and 2007. Medical cost accounted for 68.2% of the total costs, and annual increased (38.7%, $P < 0.001$) [34]. Similarly, the direct medical cost per case of asthma in Taiwan from 2001 to 2010 significantly increased, with an AAPC for ED visits of 7.6% (95% CI: 6.7–8.7) and an AAPC for non-ED visits of 1.9% (95% CI: 0.1–3.7).

In Shanghai, data of daily hospital admissions for asthma from Jan. 1st, 2005 to Dec. 31st, 2012 obtained from the Health Insurance System of Shanghai using the International Classification of Diseases Revision 10 (ICD 10) code J45 were examined. There were 15,678 hospital admissions for asthma in residents of Shanghai. Pearson correlation analysis showed a significant negative correlation ($r = -0.174$, $P < 0.001$) between asthma hospitalization and daily mean temperature, in that a lower temperature was associated with a greater risk of hospital admission for asthma [35]. Our study also showed a significant negative correlations of temperature with hospitalization for asthma following an ED visit (temperature $r = -0.321$, $P < 0.01$) and a non-ED visit (temperature $r = -0.230$, $P < 0.01$) from 2001 to 2010.

Many previous studies have indicated that air conditions affect asthma worldwide [9-11, 36]. Such a study in the Netherlands showed a significant association between PM_{2.5} level and incidence of asthma in children (aged 1 to 8 years; OR, 1.28; 95% CI: 1:10–1:49), which increased from 2000 to 2007; furthermore, the correlation of NO₂ with asthma was found to be similar [37]. A study of the effects of air pollutants on emergency room (ER) visits caused by asthma in Szeged in Southern Hungary from 1999 to 2007 showed that asthma ER visits were strongly associated with pollutant levels [7]. In Taiwan, the results of this study showed positive associations between air pollution

factors $PM_{2.5}$, PM_{10} , and NO_2 ($P < 0.01$) and asthma ED and non-ED visits in the period from 2001 to 2010. Our study showed the same result with another [6] that cold weather significantly affected exacerbation of asthma patients, especially visiting ED cases. Therefore, asthma patients need to be careful and medical facilities need to be equipped with instruments and resources during the cold weather season.

This study had several limitations, including the limitations inherent in longitudinal study. The LHID2010 data included 1 million random samples selected from the total population (27.38 million) in the year 2010 in Taiwan. Prevalence were calculated based on 1 million samples and were analyzed retrospectively to 2001, so there existed the need for caution while generalizing trends to all populations. Pearson correlation coefficients were calculated for the relationships of weather conditions and air pollution levels with asthma hospitalizations on the same day and for lags of 1, 2, and 3 days; however, no major differences in the results were observed when using different lag durations, so this study only presented the correlation coefficients of asthma cases on the same day. In the future, data will be analyzed further in terms of the associations of weather conditions and air pollution with asthma in Taiwan.

Conclusions

The present study indicated increasing numbers of asthma cases in Taiwan from 2001 to 2010. The largest proportion of asthma cases was observed in children among all age strata, and the annual prevalence of asthma in children also increased greatly. On the contrary, the annual prevalence of asthma in adults decreased. Hospitalization and ED visits were more common in male patients than in female subjects. Most patients with asthma visited non-ED clinics, but the average cost per ED visit was higher than that per non-ED visit. Patients with asthma tended to visit a local hospital. There were positive correlations between the number of asthma cases and the levels of $PM_{2.5}$, PM_{10} , and NO_2 , whereas negative correlations of the number of asthma cases with temperature and

humidity were observed. In addition, the number of asthma cases in winter and spring were higher than in summer and autumn.

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Table 1. Demographic characteristics of asthma patients in one million samples in Taiwan, 2010.

Age or Gender Category	ED ^a		Non-ED		p-value of χ^2 test	Asthma subjects in 2010		One million study subjects in LHID2010 ^b	
	N	(%)	N	(%)		N	(%)	N	%
Subjects	2,686	7.71	32,139	92.29		34,825	100	1,000,000	100
Age (years)									
0-15	1,117	41.59	12,134	37.75	0.000	13,251	38.05	167,892	16.79
16-30	239	8.90	2,934	9.13		3,173	9.11	222,844	22.28
31-45	244	9.08	4,340	13.50		4,584	13.16	248,885	24.89
46-60	339	12.62	5,297	16.48		5,636	16.18	217,534	21.75
60+	747	27.81	7,434	23.13		8,181	23.49	142,845	14.28
Gender									
Female	1,191	44.34	16,211	50.44	0.000	17,402	49.97	507,577	50.76
Male	1,495	55.66	15,928	49.56		17,423	50.03	492,423	49.24

^a Emergency Department; ^b Longitudinal health insurance dataset randomly selected in 2010.

Table 2. Annual number of asthma cases requiring medical care.

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	AAPC ^a	95% CI ^b of AAPC
ED	3,048	3,113	2,915	3,113	3,238	2,896	3,010	2,933	3,260	3,826	2.3	-0.7, 5.3
Non-ED	86,207	98,742	99,271	113,646	121,614	114,469	121,669	123,483	128,456	131,195	4.6	2.5, 6.7
Direct medical cost (US\$) per case												
ED, mean(SD)	40.15 (41.98)	41.48 (40.29)	42.72 (42.85)	47.56 (43.06)	54.94 (50.16)	57.62 (60.53)	64.08 (71.79)	64.91 (60.00)	68.98 (65.10)	74.17 (68.57)	7.6	6.7, 8.7
Non-ED, mean(SD)	25.99 (34.22)	28.10 (37.28)	30.09 (33.86)	31.97 (39.51)	31.32 (46.21)	33.28 (46.07)	30.23 (36.00)	31.52 (44.06)	31.80 (55.28)	30.47 (55.09)	1.9	0.1, 3.7
Hospital level visited by asthma patients per year, Cases No. (%)												
Medical center	54,107 (60.62)	59,878 (58.79)	52,849 (51.72)	55,020 (47.12)	49,265 (39.46)	45,722 (38.96)	48,350 (38.78)	48,674 (38.50)	50,714 (38.50)	50,998 (37.77)	-1.5	-3.2, 0.1
Regional hospital	15,949 (17.87)	16,163 (15.87)	15,682 (15.35)	16,593 (14.21)	15,093 (12.09)	14,081 (12.00)	13,439 (10.78)	14,068 (11.13)	12,974 (9.85)	13,330 (9.87)	-2.6	-3.6, -1.6
Local hospital or other	19,199 (21.51)	25,814 (25.34)	33,655 (32.94)	45,146 (38.67)	60,494 (48.45)	57,562 (49.05)	62,890 (50.44)	63,674 (50.37)	68,028 (51.65)	70,693 (52.36)	15.3	14.3, 16.2
Asthma patients by season, Cases No. (%)												
Spring	23,976 (26.86)	27,718 (27.21)	26,805 (26.23)	30,574 (26.19)	34,719 (27.81)	31,548 (26.88)	33,750 (27.07)	33,214 (26.27)	35,806 (27.18)	37,947 (28.10)	4.5	2.9, 6.1
Summer	18,326 (20.53)	22,810 (22.39)	17,952 (17.57)	25,505 (21.84)	27,040 (21.66)	25,868 (22.04)	26,428 (21.20)	25,905 (20.49)	27,737 (21.06)	29,709 (22.00)	4.7	2.0, 7.5
Autumn	22,913 (25.67)	24,462 (24.02)	26,539 (25.97)	30,210 (25.87)	29,870 (23.92)	28,529 (24.31)	30,596 (24.54)	31,217 (24.69)	32,785 (24.89)	33,375 (24.72)	4.2	2.8, 5.6
Winter	24,040 (26.93)	26,865 (26.38)	30,890 (30.23)	30,470 (26.10)	33,223 (26.61)	31,420 (26.77)	33,905 (27.19)	36,080 (28.54)	35,388 (26.87)	33,990 (25.17)	4.5	1.5, 7.7
Asthma categories ^c , Cases No. (%)												
1. Extrinsic asthma (ICD9: 493.0)	4,748 (10.13)	6,031 (11.50)	6,045 (11.11)	8,595 (12.67)	11,125 (13.81)	11,911 (15.24)	12,241 (15.07)	12,047 (14.81)	11,645 (14.16)	11,694 (14.00)	11.1	6.1, 16.2
2. Intrinsic asthma (ICD9: 493.1)	1,781 (3.80)	1,967 (3.75)	2,175 (4.00)	2,554 (3.77)	3,062 (3.80)	3,180 (4.07)	3,137 (3.86)	3,296 (4.05)	3,404 (4.14)	3,143 (3.76)	7.3	4.5, 10.3
3. Chronic obstructive asthma (ICD9: 493.2)	2,557 (5.46)	3,055 (5.83)	3,253 (5.98)	3,710 (5.47)	4,026 (5.00)	4,010 (5.13)	3,868 (4.76)	4,195 (5.16)	4,547 (5.53)	4,595 (5.50)	5.9	4.0, 7.8
4. Asthma, unspecified (ICD9: 493.9)	37,776 (80.61)	41,369 (78.92)	42,924 (78.91)	52,971 (78.09)	62,347 (77.39)	59,071 (75.57)	61,963 (76.30)	61,829 (75.99)	62,649 (76.17)	64,102 (76.74)	6.2	3.7, 8.8

^a AAPC: Average Annual Percentage Change; the AAPC is significantly different from zero at alpha = 0.05; ^b 95% CI: 95% Confidence Interval; ^c Taking into account the 1st main diagnostic code only; Currency USD: NTD = 1: 32.

Table 3. Annual prevalence of asthma from 2001 to 2010 in Taiwan.

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	AAPC	95% CI of AAPC ^a
Gender												
Female	28.06	29.34	30.56	32.55	34.50	31.64	33.65	31.30	33.70	34.28	1.8	0.6, 3.0
Male	29.93	31.63	33.04	35.09	36.91	34.66	36.03	33.15	35.45	35.38	1.5	0.0, 3.1
Age (years)												
0-15	53.63	58.61	60.88	66.06	72.09	69.22	75.39	69.51	76.12	78.93	3.9	2.6, 5.2
16-30	12.45	12.93	14.18	14.98	15.66	14.08	14.90	13.15	14.86	14.24	1.0	-0.8, 2.9
31-45	15.94	15.96	16.63	17.64	18.49	16.74	17.14	16.21	17.76	18.42	1.1	-0.2, 2.3
46-60	28.35	28.03	27.30	27.66	28.26	25.74	26.57	25.06	26.28	25.91	-1.1	-1.8, -0.5
61+	54.78	56.35	56.75	59.01	61.34	56.78	57.86	54.67	56.39	57.27	0.5	-0.6, 1.6

Prevalence: 1/1000; ^a 95% CI: 95% Confidence Interval of Average Annual Percentage Change; AAPC is significantly different from zero at alpha = 0.05.

Table 4. Descriptive statistics of daily asthma cases and daily weather/air pollution conditions from 1 Jan. 2001 to 31 Dec. 2010 (total 3,652 days).

Factors	Minimum	Maximum	Mean	Std. Deviation
ED visits (cases)	0	39	8.58	4.55
Non-ED visits (cases)	5	713	311.82	127.07
Temperature (°C)	7.701	28.445	21.169	4.404
Wind (m/s)	0.773	6.276	1.843	0.574
Rain (mm)	0	11.463	0.293	0.762
Humidity (%)	50.069	94.827	78.413	6.254
PM ₁₀ (µg/m ³)	17.928	370.034	58.795	23.635
PM _{2.5} (µg/m ³)	4.644	122.416	36.903	16.196
SO ₂ (ppb)	1.194	10.686	4.400	1.194
NO (ppb)	1.739	36.688	7.933	3.761
NO ₂ (ppb)	3.473	40.610	18.681	5.259
O ₃ (ppb)	9.584	67.264	28.626	8.407

Table 5. Weather and air pollution factors affecting asthma ED cases

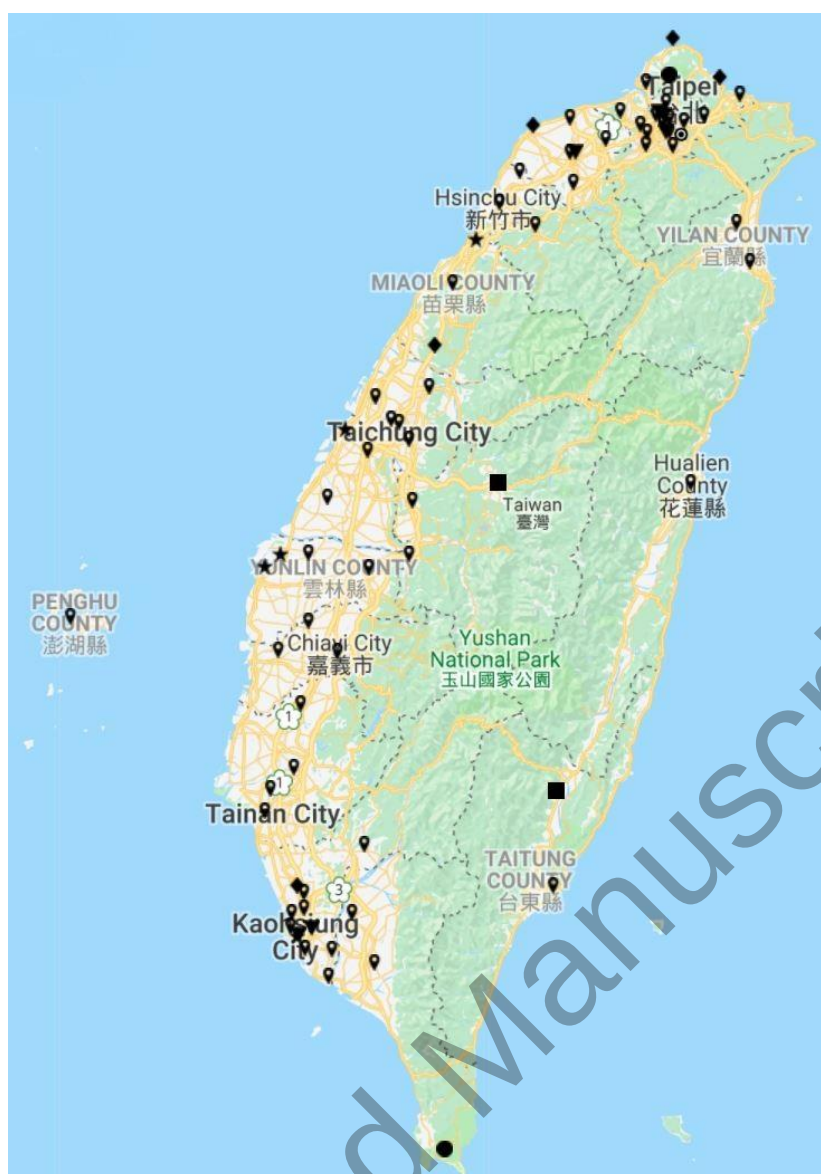
Variable	ED						
	r	P ($\beta \neq 0$)	EV	SD	B-Model 1	B-Model 2	B-Model 3
Intercept		100	28.391	1.136	28.128	28.801	28.517
Temperature	-.321**	100	-0.562	0.025	-0.564	-0.562	-0.555
Wind	.090**	100	-1.757	0.161	-1.755	-1.760	-1.762
Raining	-.096**	-	-	-	-	-	-
Humidity	-.101**	-	-	-	-	-	-
PM ₁₀	.195**	100	0.046	0.006	0.044	0.051	0.047
PM _{2.5}	.166**	0	0.000	0.000	-	-	-
SO ₂	.026	100	-0.672	0.082	-0.662	-0.691	-0.661
NO	-.055**	7.1	-0.004	0.017	-	-	-0.059
NO ₂	.100**	100	-0.261	0.025	-0.260	-0.269	-0.232
O ₃	.139**	57.9	0.017	0.016	0.029	-	-
R ²					0.172	0.170	0.171
BIC					-641.171	-640.165	-636.982
Posterior probabilities					0.579	0.350	0.071

r: Pearson correlation coefficient; **: Correlation is significant at the 0.01 level (2-tailed); P ($\beta \neq 0$): Posterior probability (non zero); EV: Expected Value; BIC: Bayesian Information Criterion

Table 6. Weather and air pollution factors affecting asthma non-ED cases

Variable	Non-ED								
	r	P ($\beta \neq 0$)	EV	SD	B-Model 1	B-Model 2	B-Model 3	B-Model 4	B-Model 5
Intercept		100	44.317	36.715	64.009	-6.836	67.953	50.110	64.336
Temperature	-.230**	26	0.475	0.885	-	1.803	-	-	-
Wind	.019	100	30.030	5.486	28.496	36.750	26.541	27.818	26.775
Raining	-.141**	100	-14.974	3.080	-14.821	-16.880	-14.024	-13.981	-13.704
Humidity	-.110**	0	0.000	0.000	-	-	-	-	-
PM ₁₀	.236**	16.1	0.059	0.149	-	-	0.370	-	-
PM _{2.5}	.162**	100	-1.750	0.222	-1.650	-1.680	-1.991	-1.802	-1.781
SO ₂	.341**	100	26.385	2.263	26.662	26.757	24.540	26.535	27.050
NO	.203**	13.5	-0.231	0.645	-	-	-	-	-1.642
NO ₂	.327**	100	8.098	0.864	7.667	8.671	7.645	7.905	8.666
O ₃	.059**	12.5	0.072	0.210	-	-	-	0.580	-
R ²					0.170	0.171	0.171	0.171	0.171
BIC					-639.725	-637.511	-637.158	-636.762	-636.453
Posterior probabilities					0.436	0.144	0.121	0.099	0.085

r: Pearson correlation coefficient; **: Correlation is significant at the 0.01 level (2-tailed); P ($\beta \neq 0$): Posterior probability (non zero); EV: Expected Value; BIC: Bayesian Information Criterion



📍: General air quality station, ★: Industry air quality station, ◆: Background air quality station, ▼: Traffic air quality station, ●: Park air quality station, ■: Other air quality station

Figure 1. The spatial distribution of air quality monitoring stations

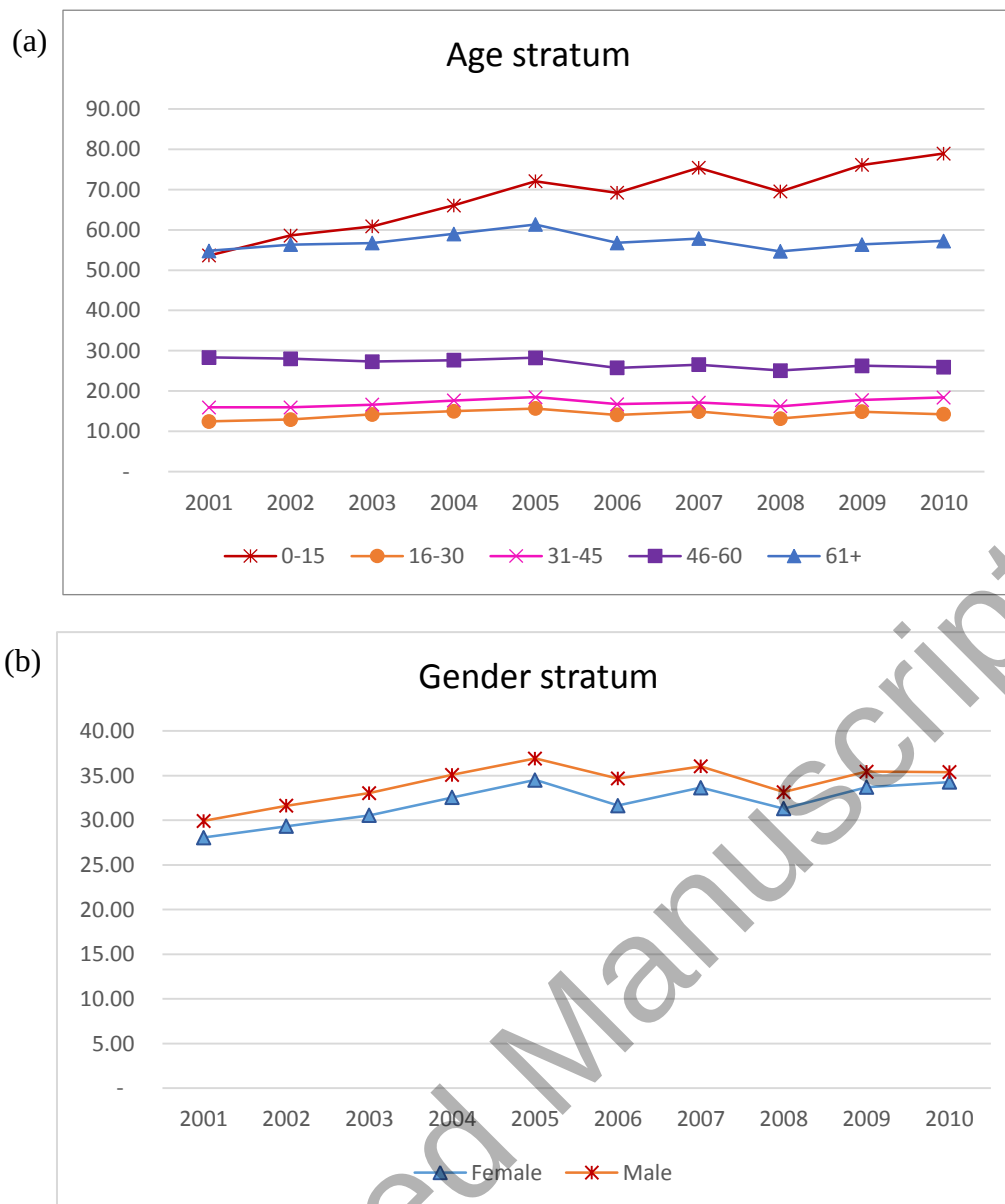


Figure 2. Trend of annual prevalence of asthma subjects (1/1000). (a) Trend of prevalence by age stratum, (b) Trend of prevalence by gender stratum.