دراسة التوزيع المكاني لمرضى الربو في دولة الكويت باستخدام نظم المعلومات الجغرافية

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ملخص: هدفت هذه الدراسة إلى تقديم منهجية واضحة محكمة لتصميم قواعد بيانات مكانية طبية لمرضى داء الرَّبو في دولة الكويت، فضلاً عن تقديم منهج لتحليل التوزيع الجغرافي وأنماطه لمرضى الربو من خلال أدوات التحليل المكاني المتاحة في نظم المعلومات الجغرافية. مرت عملية تصميم قواعد البيانات الطبية لمرضى الربو في ثلاث مراحل، مرحلة جمع البيانات ومرحلة إعدادها ومرحلة دمج البيانات المكانية مع البيانات الوصفية للمرضى والسكان. تم تحليل هذه البيانات باستخدام الاختبارات الإحصائية واختبارات التحليل المكاني وفق جنس المريض وجنسيته. وقد اعتمدت دراسة العلاقة الإحصائية ما بين المرضى وفق هاتين الصفتين، على تحليل معادلة الانحدار واختبار كاي. أما دراسة التوزيع المكاني للمرضى فكانت باستخدام خرائط التوزيعات وحساب مراكز الوسط للمرضى ومؤشر مورين الشامل والمحلي. وقد تبين من الاختبارات الإحصائية أن المرضى الإناث أكثر تردداً على عيادات الربو من المرضى الذكور. كما اتضح أن التوزيع الجغرافي للمرضى يتفاوت من محافظة إلى أخرى، وأن هذا التفاوت لا يتفق مع التوزيع الجغرافي العام للسكان.

المصطلحات الأساسية: داء الربو، نظم المعلومات الجغرافية، التحليل المكاني، التوزيع المكاني، الأمراض الوبائية، الجغرافيا.

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Studying the Spatial Distribution of Asthma Patients in the State of Kuwait Using GIS

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Abstract: This study aimed at designing a systematic framework for establishing a healthcare geodatabase as well as studying the geographic distribution of asthma patients in the State of Kuwait by using the spatial analysis tools available in the Geographic Information Systems (GIS). The establishment of this geodatabase followed three main steps: data collection, data preparation, and incorporation of the spatial and non-spatial data. The data were analyzed both statistically and spatially according to the gender and citizenship of patients. Regression and chi-squared analyses were used to study the relationships among patients. The geographic distributions of patients were investigated by using distribution maps and by calculating the mean centers of patients as well as Moran's indices. The statistical analysis revealed that female patients were more likely to visit asthma clinicsthan male patients. The distribution of patient visits varied in the various governorates of Kuwait, but this spatial variation did not agree with the total population distribution.

Keywords: Asthma, GIS, Spatial Analysis, Spatial Distribution, Epidemiological Diseases, Geography.

Introduction

Asthma is a serious chronic epidemiological disease that degrades the general health of those suffering from it and even threatens their lives, especially in the absence of appropriate healthcare. The World Health Organization (WHO) estimates that 235 million people worldwide suffer from asthma (WHO, 2013). As the number of asthma patients rises, not

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only will pressure on healthcare facilities increase, but also various negative consequences will emerge, including increased mortality. Numerous studies have shown that asthma significantly varies according to its location, and asthma patients are likely to be affected by the ambient factors of place (Babin et al., 2007; English et al., 1999; Esposito et al., 2014). Thus, one of the key factors for improving the healthcare available to asthma patients is to establish an efficient system in which changes in the geographic location of patients can be monitored and investigated. Establishing this system is fundamental for improving healthcare facilities and expanding coverage of the growing number of asthma patients.

Efficient medical information systems can be established by applying information science concepts. Information science provides a conceptual framework for efficiently storing, categorizing, and retrieving medical data. This conceptual framework would also facilitate information system maintenance and contribute to building a powerful data structure that could be integrated with a geographic information system (GIS), where the spatial data of patients are investigated and analyzed. GIS allows spatial data to be easily stored, managed, analyzed and displayed.

This integrated system has been used by geographers and other scientists in medical geography and epidemiological fields (Albert, Gesler, & Levergood, 2003; Souris & Bichaud, 2011) to investigate geographic distributions and patterns of asthma using GIS software extensions called spatial analysis tools (e.g., Brabin, Pearson, Heaf, & Reid, 1998; Oyana & Lwebuga-Mukasa, 2004; Rob, 2003). These spatial tools offer a very powerful means of studying the role of location on the spread of asthma by using various spatial measurements, such as geographic distribution measurements and Morin's Index, which would improve healthcare services provided to asthma patients (Oyana & Lwebuga-Mukasa, 2004). Thus, using GIS and its spatial tools to understand geographic distributions and patterns of asthma is a fundamental step for an effective healthcare system.

Providing appropriate healthcare to asthma patients requires an effective medical monitoring system in which the data of patients are gathered and analyzed periodically. This task can be very challenging, especially for countries which experience various logistic issues that accompany growth in the number of asthma patients. Kuwait is one of those countries suffering from the spread of asthma symptoms among its population, especially among children. Kuwait annually dedicates a sizeable amount of its financial resources to fulfill the needs of asthma patients (Khadadah, 2013). Yet, the country is still lacking efficient medical information systems where detailed patients' data are periodically updated and analyzed.

Study Objectives

GIS and its spatial analysis tools can be used in medical monitoring systems to study spatial distributions and patterns of asthma patients and to investigate the effects of location on asthma sufferers in Kuwait. Such an investigation would contribute significantly to improving the efficiency of healthcare services (Kethireddy, Tchounwou, Young, Luvall, & Alhamdan, 2013). To our knowledge, studies using GIS and spatial analysis to investigate the spatial distributions of asthma patients in Kuwait have not yet been established. Thus, by using GIS and spatial analysis tools, we aimedto design a systematic framework for establishing a healthcare geodatabase and studying the geographic distribution of asthma patients in Kuwait. This has been done through addressing the following questions:

1 - What is the spatial arrangement of asthma patients in the urban areas of Kuwait?
2 - Does the spatial distribution of asthma patients vary with respect to gender and citizenship of patients?
3 - What is the spatial pattern of the categories of these patients in the urban areas of Kuwait?
4 - Does the spatial pattern of the categories of these patients have significant local exceptions?

This study provided an initial spatial investigation of asthma patients living within Kuwait urban areas. The framework presented here can be applied to different diseases that might vary spatially.

GIS forAsthma Research

Asthma is believed to vary by location: this spatial variation is frequently linked with the ambient factors of place, such as concentrations of air pollutants, land use, and vegetation cover. Spatial arrangements of asthma patients and the relationship of asthma and the ambient factors within specific locations can be quantitatively studied using GIS (Crespo et al., 2009). Numerous studies have assessed the association between air pollution and asthma by using GIS. For instance, Chan et al. (2009) used GIS spatial interpolation models to investigate the spatiotemporal relationship between air pollutants and asthma-patients visits in Taipei, Taiwan. They concluded that asthma patients might be vulnerable to the exposure of certain air pollutants, such asnitrogen dioxide (NO_2). Gorai, Tuluri, and Tchounwou (2014) studied the association between air pollution and asthma in New York State. Their results demonstrated a better understanding of the correlation between air pollution and asthma, concluding that certain pollutants might explain the variations in asthma emergency visits and the discharge rate. Kethireddy et al. (2013) found that asthma is widely spread in the urban population of Mississippi, USA, where air pollutants are relatively elevated.

Studying the relationship between land use and asthma prevalence might also explain the spatial distribution of asthma patients. Maantay (2007) revealed that people living near noxious land uses in the Bronx area of New York were up to 66% more likely to be hospitalized for asthma, 30% more likely to be poor, and 13% more likely to belong to an ethnic minority than those outside that zone. Rob (2003) found that asthma patients were concentrated in inner-city areas of New York City, whereas this spatial pattern could not be observed in the New York suburbs.

Asthma can also be associated with vegetation cover distributions and types (Chen, Chen, & Albright, 2007). Khan, Arsalan, Siddiqui, Zeeshan, and Shaukat (2010) found that asthma patients in Karachi, Pakistan were allergic to pollen released by some plant species: mapping the spatial distribution of these plants by using GIS provided a better understanding of the spatial arrangement of asthma patients in Karachi. Also, Skarková et al. (2015) used GIS to map the spatial distribution of asthma prevalence by relying on survey data collected and reported annually. They found a positive association between asthma prevalence in children in the Czech Republic and air pollution and the rate of agricultural land use. They also showed a negative association with the presence of natural forests.

Epidemiological studies in the Arabian Gulf countries using GIS are very scarce.Lange, Schwartz, Doebbeling, Heller, and Thorne (2002) examined the association between the smoke from Kuwaiti oil fires and symptoms of respiratory illness in Gulf War veterans presented five years after the war. They used GIS to integrate the spatial and temporal records of smoke concentration with troop movements ascertained from global positioning systems records. Their conclusions, however, did not support the assumption that exposure to oil-fire smoke caused respiratory symptoms in the veterans.

Materials and Methods

Study Area

The study focused on patients living in the urban districts of Kuwait, which are divided administratively into six governorates (i.e. the Capital, Al-Jahara, Hawalli, Al-Farwaniyah, Mubarak Al-Kabeer, and Al-Ahmadi). Most urban districts extend along the coastal zone, from western and southern Kuwait Bay to the southern area of Kuwait, and are home to most of the Kuwaiti population, which in 2011 reached three million people, about two-thirds of whom are non-citizens (Figure 1). The male non-citizen population is much higher than the female non-citizen population (Table 1). The majority of Kuwaiti citizens (about 55%) are young, ranging in age from one to 24 years (Annual Statistical Abstract [ASA], 2011).

Table 1: Citizen and Non-citizen Population of Kuwait Governorates
Male and female citizens are almost equally distributed in the governorates, whereas the distribution of non-citizen males and females in the governorates is different

Governorate	Citizens			Non-citizen			Grand Total
	Male	Female	Total	Male	Female	Total	
The Capital	71468	75477	146945	99195	80373	179568	326513
Hawalli	95873	96905	192778	250382	229750	480132	672910
Al Ahmadi	114621	114701	229322	242342	116404	358746	588068
Al Jahra	75163	77379	152542	140008	108425	248433	400975
Al Farwaniyah	107261	108964	216225	420076	182270	602346	818571
Mubarak Al-Kabeer	76574	75583	152157	45409	61247	106656	258813
Grand Total	**540960**	**549009**	**1089969**	**1197412**	**778469**	**1975881**	**3065850**

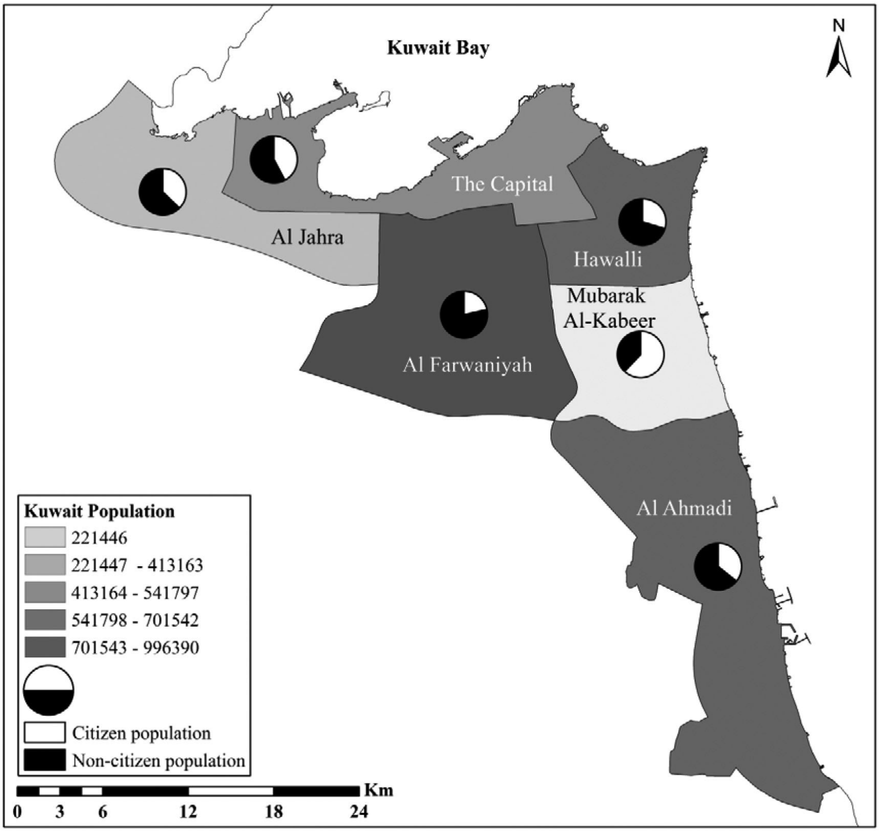


Figure 1: Population Distribution in Kuwait Governorates
The pie symbols illustrate the population proportion of citizens and non-citizens in each governorate

The population of Kuwait has increased sharply since the 1960s, from about 0.5 million in 1965 to about 1.5 million in 1995, due to the income from oil and mostly attributed to migration (Kuwait Central Statistical Bureau, 2013). This population growth has been accompanied by a rapid urban expansion: many public hospitals, health centers, and clinics were established during this time to fulfill the increasing demand for public health services. The population also increased greatly during the last two decades. During this period, however, urban development was relatively slow, and thus the country's infrastructure faced increasing pressure, including public health services.

The population of Kuwait varies across the six governorates. Mubarak Al-Kabeer Governorate has the lowest population and population density, whereas Al-Farwaniyah and Hawalli Governorates have the highest population and population density (Figure 1). Among Kuwait's urban districts, Jleeb Al-Shuyoukh (in Al-Farwaniyah Governorate), and Al-Salmiya (in Hawalli Governorate) have the highest male and female non-citizen populations, respectively. Sabah Al-Salem area (in Mubarak Al-KabeerGovernorate) has the highest population of citizens.

Asthma Patient Data

The data of Asthma patients were collected from outpatients in the AbdulazizAl-Rashed Allergy Center from 1 April to 31 August 2013. This is a specialist center that provides medical care to patients suffering from all kinds of allergies and respiratory infections, of which asthma is the most common. In 2011, 36,000 patients were referred to the center, 14% of whom had asthma. These asthma clinics receive patients from the urban areas of Kuwait. A checklist was provided to all nurses (volunteers) who worked in the center's outpatient clinics to collect data on patients' needs. The checklist covered the patients' gender, area of domicile, and diagnosis; the nurses filled in this information for each patient who saw a doctor in the outpatient clinic during that period. The patients' data were collected from 11 outpatient clinics during the morning and afternoon shifts. Each patient signed a consent form to participate in the study. The number of patients' visits to clinics was used as an indicator of asthma patients. Thereafter, we used the two variables interchangeably for brevity purposes.

Spatial Data

The spatial data used in this study consisted of two vector GIS layers: governorate, which indicates the urban areas in the six governorates, and urban district, which covers the urban administrative districts of Kuwait. The governorate and district layers were originally created by the Kuwait Municipality, which mapped the urban areas of Kuwait developed before 2008 (Kuwait Municipality, 2008a, 2008b). These two layers were updated for the urban areas developed up to 2012 by the GIS and Remote SensingConsultation Unit (Alsahli, 2012).

Establishment of Healthcare Geodatabase

The establishment of the healthcare geodatabase involved three main steps: data collection, data preparation, and incorporation of the spatial and non-spatial data. Data collection included obtaining patient data from the asthma clinics and extracting demographic data from the latest Kuwait census (ASA, 2011) based on gender and citizenship (citizen and non-citizen). Asthma patient and Kuwaiti demographic tabular data were coded according to the feature identification (IFD) of Kuwait's governorates and urban districts. The tabular data were then imported to governorate and urban district layers. The geospatial data (i.e. governorate and urban district layers) and their associated attribute data (i.e. asthma patient and Kuwait demographic data) were stored in the geodatabase using ArcGIS 10.2.

Data Analysis

The asthma patient data were statistically and spatially analyzed based on two categories: gender and citizenship. Gender was selected because men and women might respond differently to epidemiological diseases (Chan et al., 2009; Sahsuvaroglu et al., 2009), and citizenship was observed because the geographic distributions of citizens and non-citizens are significantly different; a large number of non-citizens are individual workers who dwell in areas different from those settled by Kuwaiti families.

The asthma patient data were statistically summarized to illustrate and understand the proportions of patients according to gender and citizenship, as indicated by their clinic visits. The statistical significance of these proportions was investigated using chi-squared statistics. This reveals how observed visits differ from expected visits by testing the hypothesis that the proportion of patient visits is equal to their proportion of the population (Samuels, Witmer, & Schaffner, 2012). The chi-squared statistic provides valuable information on how patients in different categories might respond to having asthma. The relationships of patients based on gender and citizenship were also investigated using regression analysis.

The patient data were spatially analyzed in GIS to study the geographic distribution of patients and their geographic patterns. The geographic distributions of patients were studied by calculating the mean centers of patient categories to detect spatial variability among patients. The number of patient visits was standardized based on the corresponding population category (e.g. visits of citizen patients divided by citizen population and then multiplied by 100) to eliminate the impact of population size differences and minimize the influence of outliers (Burt, Barber, & Rigby, 2009; Slocum, McMaster, Kessler, & Howard, 2009). Geographic distribution maps were created using the standardized data to illustrate the geographic distribution of patients in the governorates and urban districts.

The spatial patterns of asthma patients in Kuwait urban areas were investigated using global and local Moran's indices based on the standardized patient data. The global Moran's index is a useful indicator for general spatial patterns of studied variables (i.e. asthma patient visits), and it was computed using the following equation (Rogerson, 2014):

$$I = \frac{n \sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij}(X_i - \bar{X})(X_j - \bar{X})}{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij} \sum_{i=1}^{n} (X_i - \bar{X})^2} \qquad Eq.1$$

where I is the global Moran's index, n is the number of districts, X_i is the standardized number of asthma patient visits in the examined district, $\bar{X}$ is the standardized mean of asthma patient visits in all districts, X_j is the standardized number of asthma patient visits in the adjacent district, and w_{ij} is the spatial weight between the district i and j calculated using inverse weighted distance.

The local Moran's index compares the value of the feature (i.e. asthma patient visits) to the adjacent features to identify areas where a group of features tend to have similar values. Using local Moran's index as well as the global Moran's index provides a more reliable and accurate estimate of the geographic pattern of asthma patients. The local Moran's index was computed using the following equation (Rogerson, 2014):

$$I_i = \frac{(x_i - \bar{x})}{S^2} \sum_{j=1, j \neq i}^{n} \omega_{ij}(x_j - \bar{x}) \qquad Eq.2$$

where I_i is the local Moran's index, x_i is the standardized asthma patient visits in the target district i,x_j is the standardized number of asthma patient visits in the adjacent district, $\bar{x}$ is the standardized mean of asthma patient visits n all districts, ω_{ij} is the spatial weight between the district i and j calculated using inverese weighted distance, and S^2 is the variance of the adjacent features.

Result

Statistical Analysis

Asthma patient visits were recorded from 1st April to 31st August 2013 at clinics that cover all areas of Kuwait.The total number of recorded visits during this period was 4,800 (Table 2). Great variation in the total visits from month to month was observed due to some gaps in the data in June and July. The total number of citizen patients' visits was higher than those of non-citizen patients. Also, male patients visited asthma clinics more often than female patients (Figure 2).

Table 2: The Number of Asthma Patient Visits to the Clinics from April to August, 2013

M stands for male, and F stands for female

		Citizen		Non-citizen		Total				Grand Total
Year	Month	M.	F.	M.	F.	Citizen	Non-citizen	M.	F.	
2013	April	574	734	274	105	1308	379	848	839	1687
2013	May	738	948	397	207	1686	604	1135	1155	2290
2013	June	25	18	24	8	43	32	49	26	75
2013	July	236	249	180	83	485	263	416	332	748
	Mean	393	487	219	101	881	320	612	588	1200
	Total	1573	1949	875	403	3522	1278	2448	2352	4800

The statistical significance of these observations was investigated using chi-squared statistics, and the number of patients, indicated by their visits to clinics, was compared to their proportion of the population in order to calculate the difference between observed and expected visits. The chi-squared statistic revealed that citizens were more likely to visits asthma clinics than non-citizens (P = 0.000). Female citizens were also more likely to visits asthma clinics than male citizens (P = 0.000), whereas female non-citizens were less likely to visits asthma clinics than male non-citizens (P = 0.000). These differences between male and female non-citizens were expected, as a large number of male non-citizens are individual workers who spend most of their time outdoors exposed to extreme weather conditions, such as dust storms and air pollutants, whereas female non-citizens are most likely involved in indoor activities. The overall comparison between male and female patients, however, indicated that female patients were more likely to visit asthma clinics than male patients (P = 0.000).

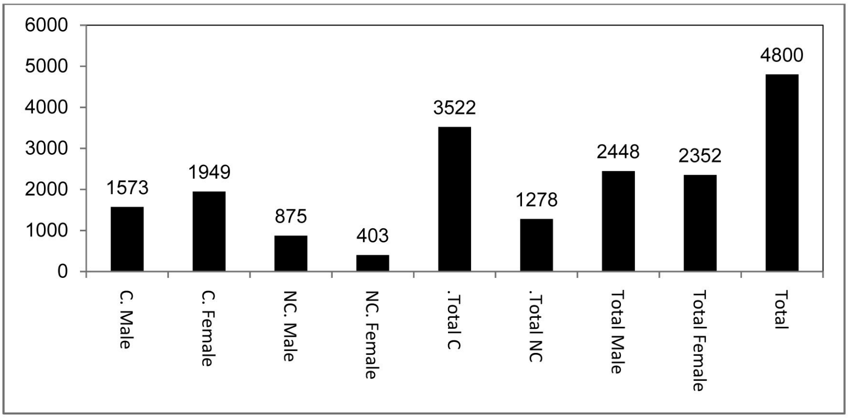


Figure 2: The Total Number of Patient Visits in Each Category
C stands for citizen, and NC stands for non-citizen.

The relationship between patients living in the same districts, based on gender and citizenship (i.e. male citizen vs. female citizen, and male non-citizen vs. female non-citizen), was statistically significant (r^2 = 0.97 and 0.86, respectively). The relationship between male non-citizens and female non-citizens was less significant than that between citizen patients. This difference was expected because of the differences in the populations of male and female non-citizens and their geographic distribution. The relationship between citizen and non-citizen patients was statistically insignificant (r^2 = 0.20) due to the significant differences in their respective populations and geographic distribution. Tables 3 and 4 show the correlation among patients.

Table 3: The Correlation between Males and Females Based on Their Citizenship

The correlation between citizens (C) and non-citizens (NC) was non-significant

	C. Males	C. Females	NC. Males
C. Females	0.983		
NC. Males	0.373	0.389	
NC. Females	0.488	0.51	0.925

Spatial Analysis

The geographic distribution of asthma patients in Kuwaiti governorates and districts was investigated using a standardized number of clinic visits. The geographic distribution of patient visits varied between the various governorates (Figure 3): This spatial variation was not compatible with the total population distribution. Al-Ahmadi and Al-Farwaniyah (the most highly populated governorates) had the lowest and highest number of visits, respectively, in all studied categories (Figures 4 and 5). Male and female citizen patients had almost similar geographic distributions like the male and female non-citizen patients, but the total male patients and total female patients had different geographic distributions. The difference between the geographic distribution of male and female patients was perhaps due to the significant differences in population and geographic distribution between male and female non-citizen patients.

The geographic distribution of asthma patients in Kuwait districts was also different from that of the Kuwait population: Al-Jahra, Al-Shuwaikh, Al-Doha, Al-Sulibikhat, and Al-Andalous had the highest number of asthma patient visits. Note that Al-Doha, Al-Sulibikhat, and Al-Andalous are close to each other. Al-Naseem, Al-Zahra, Abu Halifa, Al-Oyoun, and Bnaid Al-Qar had the lowest number of asthma patient visits. With the exception of Al-Naseem and Al-Oyoun, all these districts are far from each other (Figure 6). The geographic distribution of asthma patients based on gender and citizenship was slightly different from the general distribution of asthma patients; districts with the highest number of asthma patient visits in each category, however, were almost the same (Figures 7 and 8).

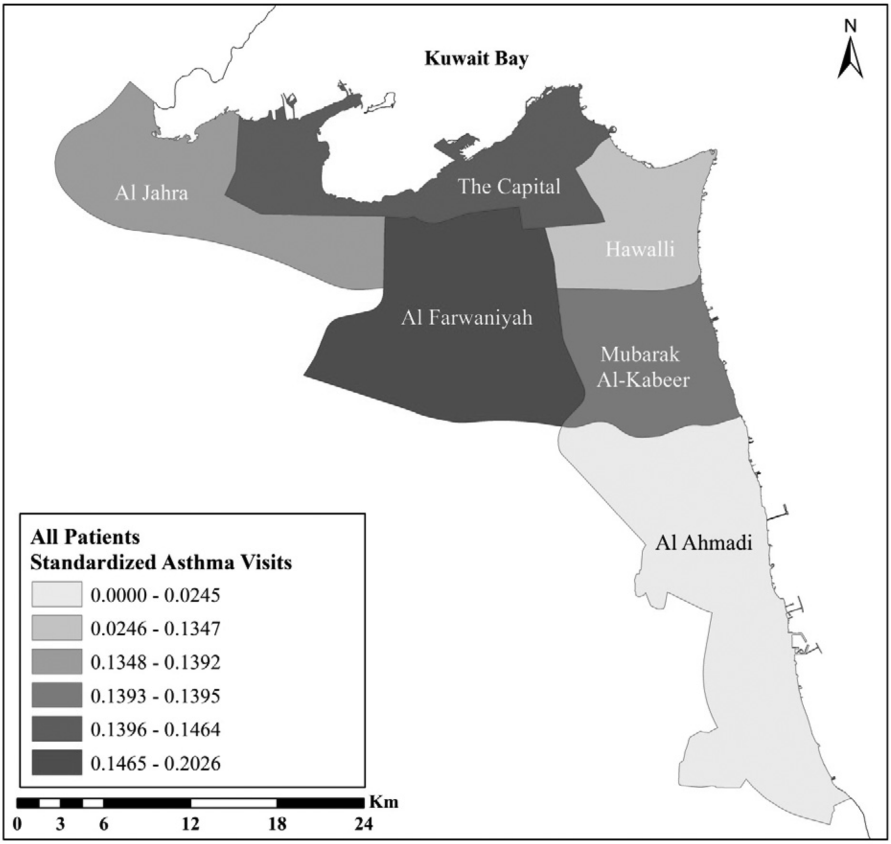


Figure 3: The Geographic Distribution of Asthma Patients in Kuwait Governorates
The color gradient illustrates the governorate rank based on the standardized number of patient visits, the percentage of patients to the population

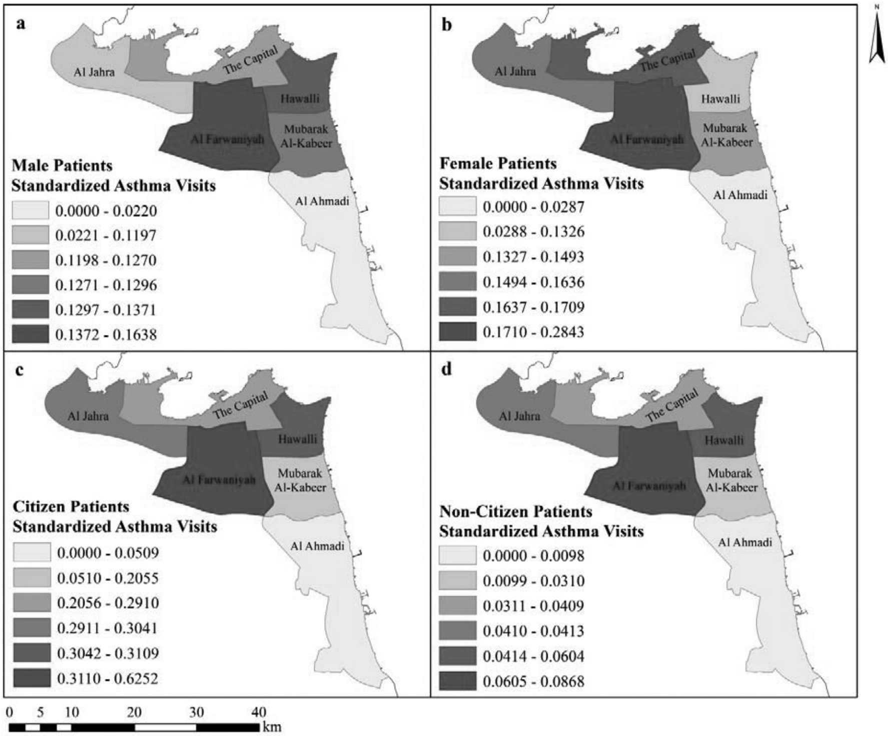


Figure 4:The Geographic Distribution of Asthma Patients in Kuwait Governorates Based on Their Gender and Citizenship

The distribution of male and female patients was different (a and b), whereas citizen patients and non-citizen patients exhibited the same pattern of distribution (c and d)

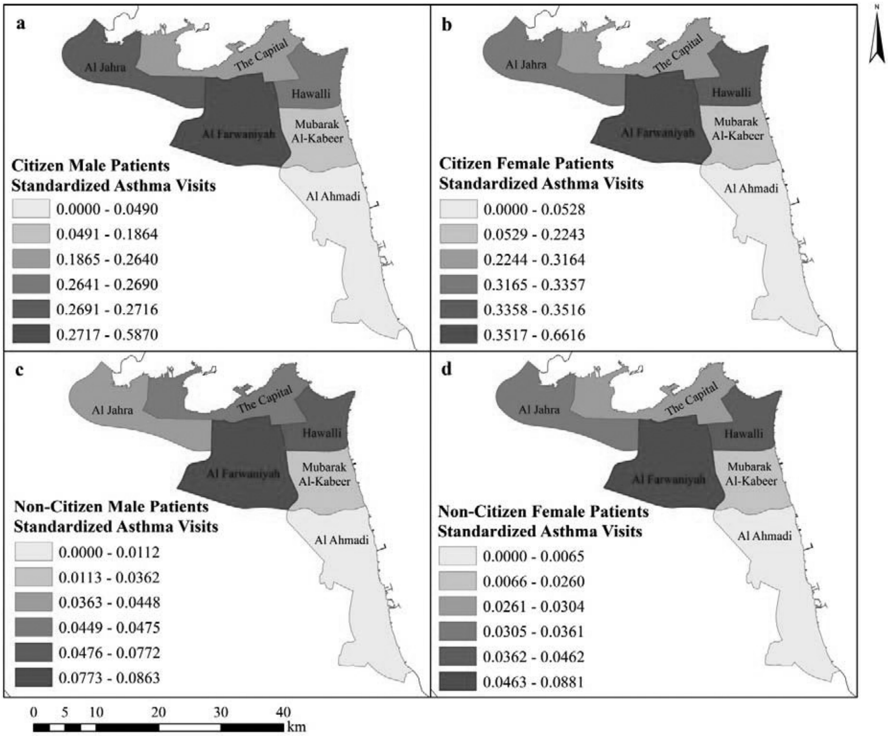


Figure 5: The Geographic Distribution of Asthma Patients in Kuwait Governorates Based on Their Gender and Citizenship

Citizen and non-citizen male patients had distinct distribution (a and c), whereas the distribution of citizen and non-citizen female patients was similar (b and d)

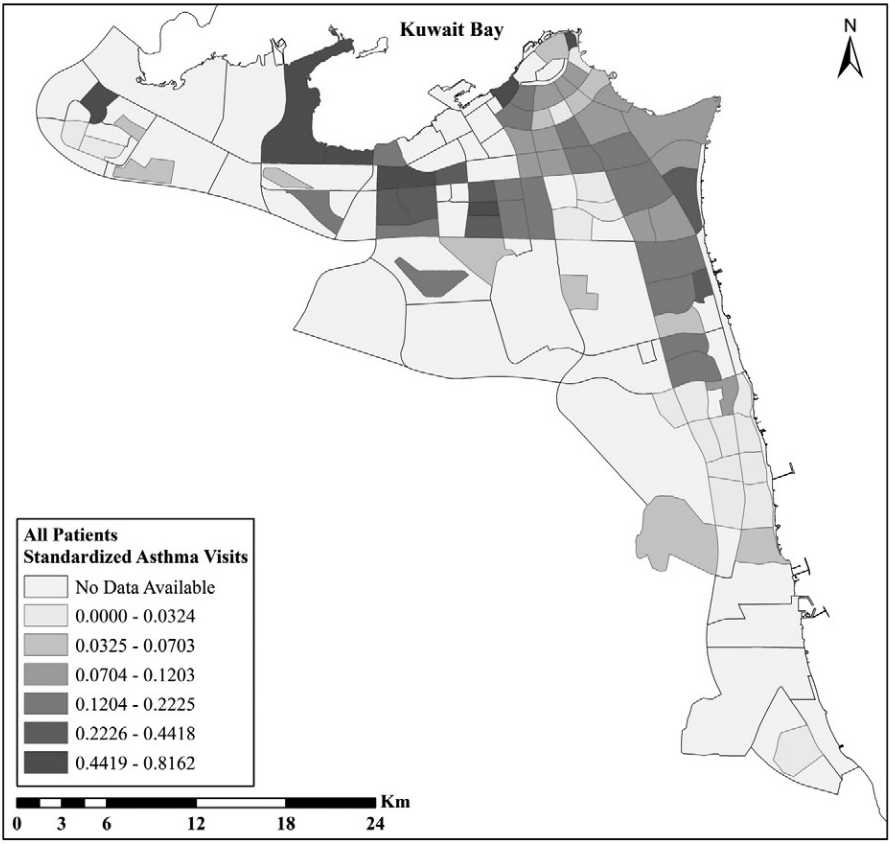


Figure 6: The Geographic Distribution of Asthma Patients in the Urban Districts of Kuwait

The area shaded in grey indicates either residential areas with no patients data recorded during the study period or non-residential areas

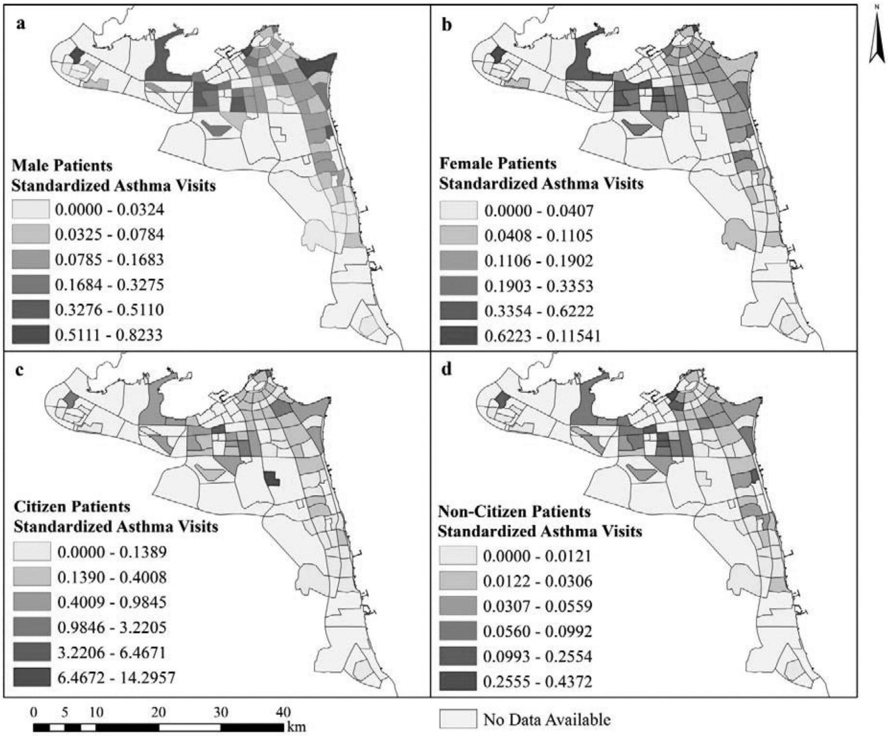


Figure 7: The Geographic Distribution of Asthma Patients in the Urban Districts of Kuwait Based on Gender and Citizenship

Citizen asthma patients exhibited the highest rate (c) among the other categories (a, b and d)

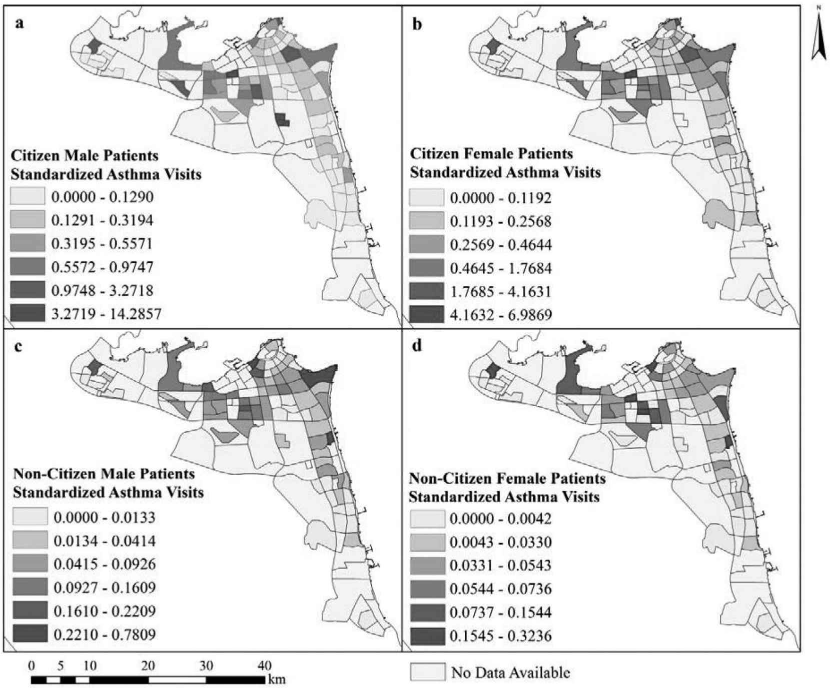


Figure 8: The Geographic Distribution of Asthma Patients in the Urban Districts of Kuwait Based on Their Gender and Citizenship
Citizen male patients exhibited the highest rate (a) among the other categories (b, c and d)

Table 4:The Correlation of the Total Visits of the Patients Based on Gender and Citizenship
The correlation between the total visits of both citizens and non-citizens was non-significant
C stands for citizen, and NC stands for non-citizen

	C. Total	**NC. Total**	**Total Males**
NC. Total	0.441		
Total Males	0.834	0.855	
Total Females	0.964	0.636	0.925

The mean center is an effective indicator to detect the general spatial variability among the studied categories. The mean centers of asthma patient visits in all categories had a general northwesterly shift compared to the mean centers of the corresponding population (Figure 9). The mean center location of male non-citizen patient visits was shifted slightly from the other asthma centers towards the east. Also, it was noted that male and female citizens shared the same mean center location, whereas the mean center location of male and female citizen asthma patients was different. Investigating factors contributing to these observations is very important in order to understand how asthma patients respond to ambient factors. Such investigation, however, was very difficult to conduct in this study due to the lack of data.

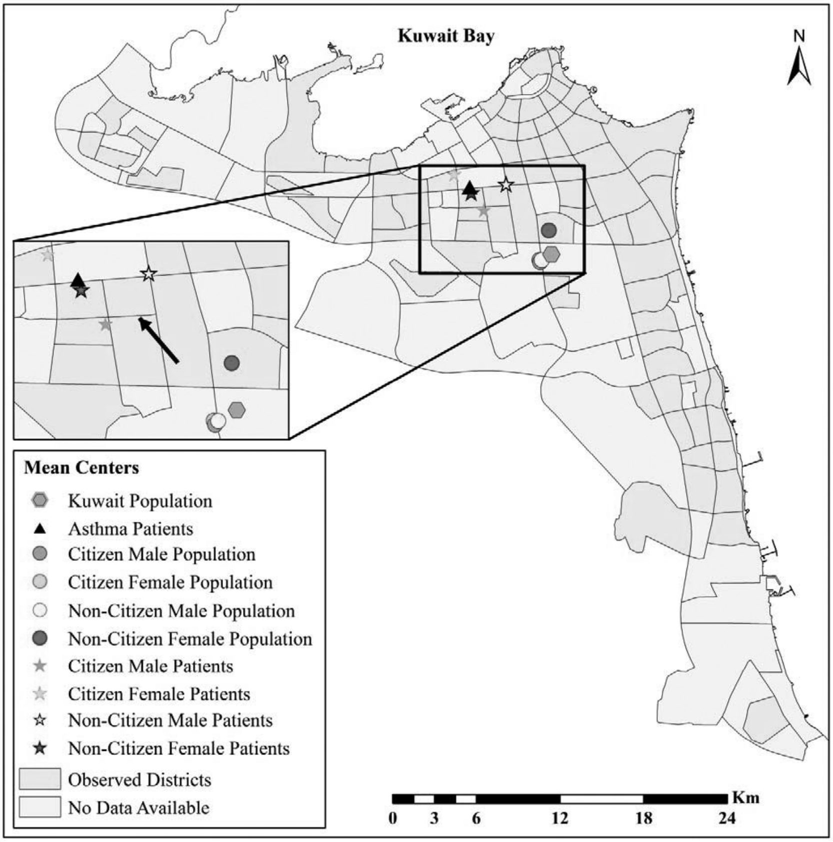


Figure 9: The Mean Centers of Asthma Patient Categories and Their Corresponding Population

The mean center locations of asthma patients exhibited a general northwesterly shift compared to the mean center locations of their corresponding populations.

The spatial patterns of asthma patients varied within patient categories. The global Moran's index indicated that male and female citizen patients were randomly distributed (P = 0.154, and 0.168, respectively), whereas the distributions of male, female, and total non-citizen patients were clustered (P = 0.050, 0.000, and 0.000; Z-score = 1.957, 4.285, and 5.442 respectively) (Table 5). The P-value of male non-citizen patient distribution was marginal at a 95% confidence level (CI) of 0.05, which meant that the result derived from the global Moran's index might not accurately represent the distribution of patients within the districts. Such cases need further investigation using the local Moran's index.

Table 5:The Global Morans Index of Each Category

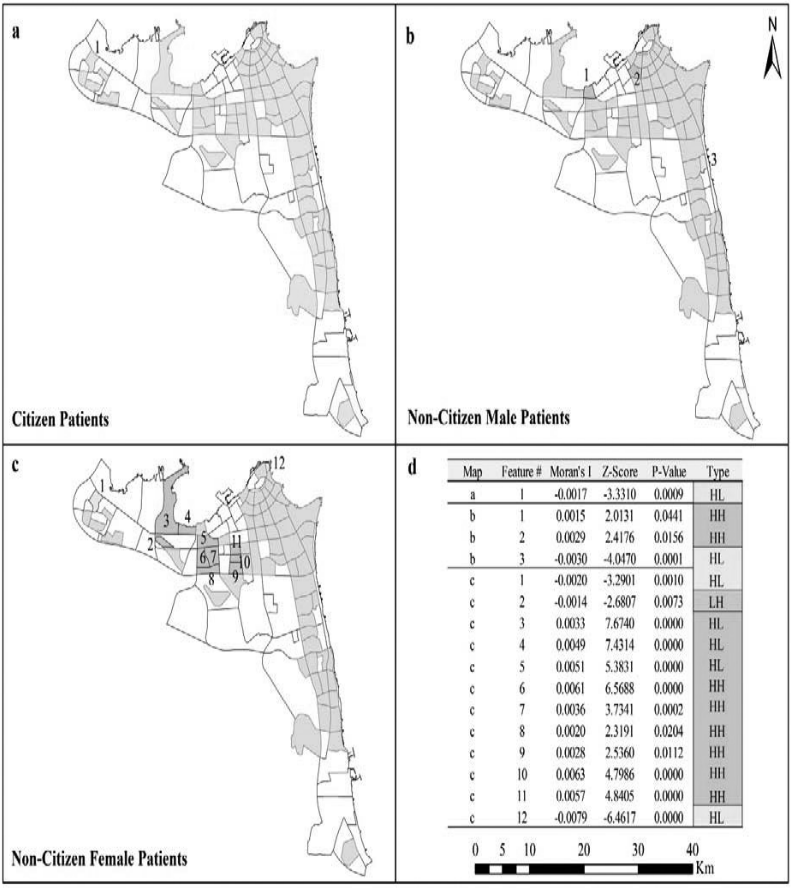
Male and female citizen patients had a random geographic distribution across the urban areas of Kuwait

	Citizen		Non-citizen		Total				Grand Total
	M.	F.	M.	F.	C.	Non-citizen	M.	F.	
I	0.016	0.019	0.034	0.099	0.018	0.055	0.112	0.067	0.13
Pattern	R*.	R.	Cl**.	Cl.	R.	Cl.	Cl.	Cl.	Cl.
Z-Score	1.424	1.378	1.957	4.285	1.428	2.847	4.81	3.142	5.442
P-Value	0.154	0.168	0.05	0	0.153	0.004	0	0.002	0

*Random

**Cluster

Overall, the local Moran's index result mostly confirmed the general spatial patterns of asthma patients in each category, as indicated by the global test (Figure 10). Citizen patients were randomly distributed over Kuwait's urban areas, with the exception of Al-Jahrawhich had a higher number of patients than the surrounding areas. Male and female citizen patients also exhibited the same spatial pattern. The spatial distribution of female non-citizen patients showed that some areas had higher values surrounded by areas with similar high values (Figure 10c). These areas seemed to be clustered. Non-citizen male patients, however, were randomly distributed over the urban area, except for two areas surrounded by areas with similar high numbers of patient visits, and one area with fewer patient visits than surrounding areas (Figure 10b). These three areas were outliers that affected the results of the global Moran's index.



Map	Feature #	Moran's I	Z-Score	P-Value	Type
a	1	-0.0017	-3.3310	0.0009	HL
b	1	0.0015	2.0131	0.0441	HH
b	2	0.0029	2.4176	0.0156	HH
b	3	-0.0030	-4.0470	0.0001	HL
c	1	-0.0020	-3.2901	0.0010	HL
c	2	-0.0014	-2.6807	0.0073	LH
c	3	0.0033	7.6740	0.0000	HL
c	4	0.0049	7.4314	0.0000	HL
c	5	0.0051	5.3831	0.0000	HL
c	6	0.0061	6.5688	0.0000	HH
c	7	0.0036	3.7341	0.0002	HH
c	8	0.0020	2.3191	0.0204	HH
c	9	0.0028	2.5360	0.0112	HH
c	10	0.0063	4.7986	0.0000	HH
c	11	0.0057	4.8405	0.0000	HH
c	12	-0.0079	-6.4617	0.0000	HL

Figure 10: Map of Local Morans Index Results

a) **The geographic distribution of citizen patients was random within the urban area**
Male and female citizen patients also exhibited the same spatial pattern: maps of male and female citizen patients showing their geographic distribution were not presented for the sake of brevity.

b) **Two areas with higher numbers of non-citizen patient visits were surrounded by areas with high numbers of visits**

c) **Female non-citizen patients map showing a cluster of areas with high numbers of visits**
Grey areas exhibited insignificant spatial relationship. Empty districts indicate either residential areas with no patients data recorded during the study period or non-residential areas.

d) **Most of P-values were far away from the smallest level of confidence revealing that the patient number in these districts was clearly distinct from the surrounding districts**

Discussion

The geographic distribution of asthma patients in the urban areas of Kuwait was investigated using the spatial analysis tools in GIS that allow healthcare data to be stored in geodatabases, powerful digital environments where spatial and non-spatial data can be effectively analyzed. The establishment of a healthcare geodatabase involved three main steps: data collection, data preparation, and spatial and non-spatial dataincorporation. The asthma data were statistically and spatially analyzed based on the gender and citizenship of patients. Correlation, regression, and chi-squared analyses were used to study the relationships among patients. The geographic distributions of patients were investigated spatially by using distribution maps,by calculating the mean centers of asthma patients, and by Moran's indices. The chi-squared statistic revealed that citizens were more likely to visit asthma clinics than non-citizens. The relationship between patients living in the same districts, based on their gender and citizenship, was statistically significant.

The geographic distribution of asthma patients in Kuwaiti governorates and districts was investigated using a standardized number of asthma patient visits. This spatial variation was not compatible with the total population distribution. The geographic distribution of asthma patients in Kuwait districts was also different from the geographic distribution of the Kuwaiti population. The spatial patterns of asthma patients varied within the patient categories. The global Moran's index indicated that male and female citizen patients were randomly distributed, whereas the distribution of non-citizen male, female, and total patients was clustered.

We could not investigate the reasons behind the spatial arrangements of asthma patients in Kuwait due to three main factors: the duration of the study, lack of detailed data about the ambient factors, and spatial resolution of asthma data. The study was conducted during the duration from 1stApril to 31stAugust 2013, which was relatively short to observe the spatiotemporal variation of asthma patients that could explain how patients might interact with the ambient factors of place, such as land use. A number of studies have linked air pollutants with spatial distributions of asthma patients (e.g. Ferguson, Maheswaran, & Daly, 2004; Gehring et al., 2010; Zhu, Wang, Zhang, & Sun, 2012). These studies relied on a number of air monitoring stations widely distributed in the target area. Such investigation could not be undertaken in this study due to the limited number of air monitoring stations (13 stations) operated by the Environmental Public Authority of Kuwait (Beatoba, 2016). Also, investigating the relationship between air pollutants and spatial distributions of asthma patients requires detailed spatial data of patients (i.e. parcel-based resolution). Currently, the Health Ministry of Kuwait collects patients' data by governorate: this spatial resolution is too coarse to detect the spatial relationship between asthma patients and the ambient factors.

Conclusion

This study provides an understanding of a method by which the geographic distributions and patterns of epidemiological diseases in Kuwait, such as asthma, can be measured. This is a critical step needed to improve related healthcare services and reduce the impacts of the disease on the community. The geographic distributions of epidemiological diseases can be effectively studied using spatial analysis tools available in GIS. This study provides a systematic approach to GIS applied in the field of healthcare to provide an extended view for future planning and helping in decision making. We presented a method to spatially investigate the geographic distributions of asthma patients in Kuwaiti governorates and districts using GIS and spatial analysis tools. Further investigation is required to understand the factors contributing to these geographic patterns.

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