

Modeling Incidence Rate by Region: Analysis of Asthma and Other Chronic Obstructive Lung Diseases

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Abstract

This study aimed to examine regional differences for asthma and other chronic obstructive lung diseases. The study was based on data collected from annual reports produced by the Ministry of Health over a ten-year period beginning from 2010 to 2019. Incidence rates for eleven regions in the Sultanate of Oman were analyzed using statistical tools including; analysis of variance and binary logistic regression model to determine the effect of region on asthma and other chronic obstructive lung diseases. The incident rates were found to be significantly different by region (F-value=27.07, $p=0.00$). There was no significant variation by year (F-value=1.05, $p>0.407$). Overall over the ten-year period the incidence rates stagnated between 250 and 300 per 10000 of the population, but showed a reducing trend between 2016 and 2019. The logistic regression model shows that compared to the Muscat region, all the other regions had significant increased odd ratios. There is a significant evidence of regional variation in the incidence of asthma and other chronic obstructive lung diseases. This implies probable characteristics in geographical regions that are associated with asthma and other chronic obstructive lung diseases' exacerbation. Five asthma-region classifications were identified from our analysis. Findings of this study may be used to guide decision making towards the management and control of asthma and chronic obstructive lung diseases.

Introduction

The incidence and etiology of asthma in the human populations is exacerbated by factors that may be classified as genetic and environmental. Studies have established a strong genetic and environmental linkage that interacts both in the induction and subsequent expression of the disease phenotypes (Thomsen 2015; Yang et al. 2017). In their recent study (Krautenbacher et al. 2021), have established that among farm children, asthma is more determined by genetic polymorphisms, while in non-farm children, it is mainly environmental factor-driven. Multiple genes are involved and sometimes interact, but studies to identify the exact asthma-related gene are still being developed (Altzibar et al. 2015; Lawson et al. 2017; Bayliss et al. 2017; Burnett et al. 1994). On the other hand, the epithelium, which is in contact with the environment, and the underlying cells (fibroblasts and dendritic), indicate reactivation of the unit (epithelial mesenchymal trophic) that provides a source for asthma (Holgate 2008; Hellings and Steelant 2020; Mitchell and O'Byrne 2017). Although, studies confirm the effect of environment on exacerbating asthma, not many studies have provided substantial data-centered evidence to support the hypotheses. In this study, we tested the effect of region to examine its effect on the variation in the incidence rates for asthma and other chronic obstructive lung diseases within Oman.

Asthma and other chronic obstructive lung diseases (ACOLD) within the Sultanate of Oman present a complicated scenario resulting into episodic exacerbations, caused by persistent and variable airway obstruction (Buendía et al. 2018; Tliba and Panettieri Jr 2019). In the medical field, asthma has been described as difficult due to poorly controlled chronic symptoms, or resulting from patients with refractory asthma who remain difficult to control despite an extensive re-evaluation of diagnosis, management, and following an observational period of at least six months by an asthma specialist (Ma et al. 2016; Bhan et

al. 2015; Cosio et al. 2016; Alves et al. 2019). It is known that approximately 5% of patients are not controlled even on high doses of inhaled corticosteroids (Heffler et al. 2018; Ye et al. 2017). The ACOLD are known to contribute to substantial healthcare, societal costs and general poor quality of life, mainly attributable to poor asthma control (Uphoff et al. 2015).

It is noteworthy that disease severity and poor response to treatment are mainly associated with genetic and environmental factors. A number of risk factors such as region, race, sex, body mass index (BMI), diabetes and lung function, have been investigated with differing outcomes (Moradi-Lakeh et al. 2015; Al-Busaidi et al. 2015). Our study sought to examine ACOLD incidence, distribution and determine the effect of region on incidence rates.

Methodology

Study Design

This study was based on data collected from annual reports produced by the Ministry of Health, and archived on their website. Quantitative data on asthma and other chronic obstructive lung diseases' incidence data from eleven regions (governorates) for a ten-year period from 2010 to 2019 were analyzed.

Data Analysis

We evaluated two predictors, region and year to assess the incidence rates among the population. Data analysis was performed primarily to achieve the set specific objectives mentioned above. The incidence rates were measured as a rate per 10000 of the population for the period of study.

Assessing regional differences using analysis of variance

With region and year as factors, a two-way Analysis of variance (ANOVA) main effects model was fitted to assess the main effects of the two factors (Henson 2015; Chatfield 2018; Andrusaityte et al. 2016; Duddek et al. 1995). We applied this approach to establish if there existed significant effects on incidence rates by region and year. Since we have only one observation per (region, year) category, we assume no region-year interaction to be able to assess the effects of year and region. Besides an assumption of interaction is hard to justify, since its existence implies overall regional variation in incidence rates are not meaningful unless they are examined year by year. Since the years in question have passed, a main effects model was fitted. Using the Duncan's multiple comparisons test, we identified the most significant differences. Duncan's test was used rather than least significant difference (LSD) to avoid inflating the overall probability of type I error to a level much higher than 0.05. As a follow-up, a one-way analysis of variance and a nonparametric test were also carried out.

Determinants of asthma incidence rates

Since incidence rates are proportions resulting from a binary classification of the population as diagnosed with Asthma or not, a binary logistics regression analysis is a more natural approach to study

the effects of region and year on the odds of asthma. A binary logistic model with Muscat as a reference category was fitted. Regions are compared with Muscat because unlike other regions, Muscat is the capital of the country and the most metropolitan region. Year was included in the model to provide an estimate of the annual change in the odds of incidence of asthma and other chronic obstructive lung diseases.

Estimation And Results

We present the study findings beginning with the general distribution of asthma incidence by region and year, followed by analysis of variance (ANOVA) and the logistic regression model. The analyses were aimed at determining the effect of region on the incidence of asthma and its possible distribution over the regions.

Incidence rates by region and year

Figure 1 displays the incidence rates by year and region. It shows that the incidence rates were relatively stable over the ten-year study period for most of the regions except Dhofar and Al Wusta. Whereas incidence rates for Dhofar decreased, those for Al Wusta increased between the year 2010 and 2019. The rates for Musandam were consistently higher than other regions followed by those in South Ash Sharqiyah region. The figure provides no clear evidence of region-year interaction.

Table 1, gives the mean (standard deviation) for regions and years. The standards deviations show the erratic variability of incidence rates in Dhofar and Musandam.

Table 1
Incidence rates for Asthma and other chronic obstructive lung disease by Region and Year

Parameter	Incidence Rate Per 10000 population
Region	Mean (SD)
Musandam	499.1 (73.6)
Al Wusta	434.5 (151.2)
Dhofar	394.6 (176.6)
South Ash Sharqiyah	311.5 (31.6)
North Al Batinah	220.9 (27.0)
South Al Batinah	202.6 (19.9)
Ad Dhahirah	200.5 (37.5)
Al Buraymi	196.4 (67.6)
Ad Dakhliyah	183.5 (26.5)
North Ash Sharqiyah	158.2 (27.6)
Muscat	75.1 (14.2)
Year	
2010	257.9(193.5)
2011	234.0(133.3)
2012	280.0(168.4)
2013	279.6(159.4)
2014	270.0(139.3)
2015	278.0(154.5)
2016	289.7(163.3)
2017	275.0(161.1)
2018	232.1(112.6)
2019	219.0(102.7)

Analysis of variance of incidence rates of asthma and other chronic obstructive lung disease

To test the hypothesis for existence of differences in asthma incidence among the eleven regions, and the ten years, we used analysis of variance (ANOVA) and the null hypotheses of no differences in mean incidence rates for regions or years were tested (see Table 2). There were highly significant differences in asthma incidence rates among regions ($F = 27.072$, $p = 0.001$); however, these differences were not significant among the years ($F = 1.051$, $p = 0.407$). Further our model shows that region and year explain about 75% of the variation in incidence rates ($R^2 = 0.757$). Since there is no evidence of variation among years, a one-way ANOVA was fitted using regions only, resulting to the same conclusion of highly significant differences among regions ($F = 26.948$, $p = 0.001$). Here, regions explain about 73% of the total variation in incidence rates ($R^2 = 0.73$) indicating that yearly variations account for about 3% only of the total variability in incidence rates.

Table 2
Analysis of variance for Asthma and other chronic obstructive lung disease
by region and year.

Parameter	Degrees of freedom	Sum of Squares	Mean Square	Fvalue	Pvalue
Region	10	1711748	171175	27.072	0.000
Year	9	59785	6643	1.051	0.407
Residuals	90	569061	6323	-	-

Multiple comparisons of the average incidence rates between regions using Duncan's multiple range test at the 0.05 alpha-level of significance was carried out. This comparison (from both one way and two way analysis of variance) gave the same result. Five groups were identified, where regions in different groups have significantly different incidence rates, while regions in the group are not significantly different. The groups arranged in order from lowest to highest incidence rate as follows:

1. The first group is made up of only the Muscat region with the lowest average rate of 75 per 10000. This region hosts the capital city, it is urban, metropolitan, with plenty of government and private clinics and health care facilities.
2. The second group is made up of six geographical regions, that is North As Sharqiya, Ad Dakhliya, Al Buraimi, Ad Dhahira, South Al Batina and North Al Batina with average rates ranging from 158 to 220 per 10000. They are basically located in the central and interior area of Oman.
3. The third group is made up of only the South As Sharqia region with an average rate of 312 per 10000. This region is located on the East coast.
4. The forth group is made up of two regions, Dhofar and Al Wusta with average rates of 395 and 435 per 10000. These two are located in the Central and Southern parts of the country.
5. In the fifth group is the Musandam region with average rate of about 500 per 10000. The Musandam region is located in the far north, separated from the mainland by the United Arab Emirates, it is a mountainous peninsula.

Overall, the incidence rate in Muscat region was by far the lowest in the country, followed by those regions in the Central, then the South and the far North of Oman. There was evidence of lack of homogeneity of variance (Levene's test statistic = 4.867, $p = 0.000$). Evidence of lack of homogeneity suggested performing analysis based on a nonparametric method and the Friedman's nonparametric test was used to test differences between regions. This led to the same conclusion (Friedman's Test Statistics = 37.843, $p = 0.000$).

Determinants of asthma and other chronic obstructive lung disease incidence rates

Binary logistic regression is more appropriate technique for examining the effects of a number of qualitative and quantitative explanatory variables on a binary response and hence for rates and proportions. It models the logarithm of the odds ratio as a linear function of the explanatory variables. Muscat was taken as the reference category for other regions and year was entered as a quantitative variable. Table 3 summarizes the results. The negative coefficient for year shows that overall incidence rate is decreasing over the years. The odds on incidence of asthma and other chronic obstructive lung disease decrease by about one percent per year. All the coefficients for regions are positive, confirming that they all have higher incidence rates than Muscat. The estimated odds of incidence for regions range from twice the odds for Muscat in North Sharqiya, to six fold as in Al Wusta and Musandam. We noted that the regions ordered from lowest to highest estimated odds of incidence is the same as the order of the observed raw incidence rates.

Table 3
Binary logistic Regression analysis if Incidence rates.

Variable	Coefficient (β)	SE	P-value	95% CI for β		Odds Ratio	95% CI for Odds Ratio	
				L	U		L	U
Year	-0.008	0.002	0.000	-0.012	-0.004	0.99	0.988	0.996
North Ash Sharqiyah	0.753	0.045	0.000	0.666	0.841	2.12	1.946	2.319
Muscat (<i>ref</i>)	0.000	-	-	-	-	1.00	-	-
Ad Dakhliyah	0.904	0.044	0.000	0.819	0.999	2.47	2.268	2.716
Al Buraymi	0.974	0.043	0.000	0.889	1.058	2.65	2.433	2.881
Ad Dhahirah	0.995	0.043	0.000	0.910	1.079	2.70	2.484	2.942
South Al Batinah	1.005	0.043	0.000	0.921	1.090	2.73	2.512	2.974
North Al Batinah	1.094	0.043	0.000	1.010	1.177	2.99	2.746	3.245
South Ash Sharqiyah	1.447	0.041	0.000	1.367	1.527	4.25	3.923	4.604
Dhofar	1.692	0.040	0.000	1.613	1.77	5.43	5.018	5.871
Al Wusta	1.799	0.040	0.000	1.714	1.870	6.05	5.551	6.488
Musandam	1.938	0.040	0.000	1.860	2.015	6.94	6.424	7.501

Discussion

Statistics are important, whether from administrative data, surveys or controlled studies. Asthma and other chronic obstructive lung diseases are silent killers; therefore information pertaining these diseases is important to guide decision making for quality health service provision (D'Anna et al. 2021; Shayo and Bintabara 2019; Sharma et al. 2018). In this study, we have tested for region and fitted a related prediction model for ACOLD incidence rates.

The study established five ACOLD geographical regions, which are based on the incidence rates. Generally, the incidence rates remained fairly the same over the period, but started to decrease between 2016 and 2019. The lowest incidence rate was in the year 2019, possibly influenced by demographic and other socio-economic characteristics that were outside the scope of this study.

Asthma incidence rates by geographical regions

Using the analysis of variance (ANOVA) (Andrusaityte et al. 2016) we identified five groups for asthma incidence rates by regions. The grouping of eleven geographical regions into five regions was premised on incidence rates, their standard deviations, correlations and trends of the incidence rates over the period. There was a general consensus for the regional groups for the incidence rates.

Asthma incidence using the logistic regression model

The results from the logistic model corroborate with those obtained from the Analysis of variance. The logistic regression provided an estimate of the annual decrease by about 1% of the odds of asthma and other chronic obstructive lung disease. It also readily provides a comparison of two regions using the ratio of the two odds of asthma and other chronic obstructive lung disease for the two regions. This is obtained directly by dividing the odds of the two regions relative to Muscat by each other.

The general climate in Oman is tropical desert, almost everywhere, characterized with some summer rains in the northern and southern parts, with clouds along the eastern coast brought by the Monsoon winds. These winds, though have limited effects in terms of rain, but tend to influence the climate of the country. (Mountjoy et al. 2015) At the coastal areas of the Gulf of Oman, the desert climate is predominant, sunny throughout the year, with some little winter rains in the far north encompassing the Musandam region. This area is extremely hot in summer, with an average high temperature of about 38 degrees Celsius, possibly due to the humidity from the sea. It has been noted that sometimes with the wind blowing from the inland, causes humidity to drop, resulting into very high temperatures of about 50 degrees Celsius. As to whether this would probably provide an explanation, why the incidence rates are the highest in the Musandam region is uncertain (Epton et al. 1997; Beggs and Bambrick 2005; Wang et al. 2021).

Other known clinical and gene-environmental factors associated with asthma could not be assessed in this study because of data limitation arising from the use of administrative data. However, studies show that under genetics, genome-wide linkage studies have identified 18 genome regimes and more than 100 genes associated with allergy and asthma in eleven different populations (Shrine et al. 2019; Miller et al. 2018). The prenatal risk factors may include, but not limited to prenatal tobacco smoke use, poor diet and nutrition, stress and antibiotic use (Vlaski and Lawson 2015; Andrusaityte et al. 2016). There are also childhood risk factors that include among others, phenotypes of asthma, for example early childhood wheezing and age at onset, breastfeeding, poor lung function, family structure, low socio-economic status, exposure to environmental tobacco, exposure to animals, sex and gene-environment interactions. However, our findings show that though, region was significant, its interaction with year was not significant (Akinbami et al. 2016).

Availability of time series data for a relatively longer period would possibly provide trends and seasonality of the incidence rates among all categories of, for example; age, region and gender. Nonetheless, this study highlights the significance of distributive evidence of asthma by region.

Conclusion And Policy Implications

The fact that asthma is chronic and categorized as one of the most hazardous health threats to the economic contribution by the workforce points to the urgent need for it to be prioritized among common health risks. Its association with COVID-19 severity and poor outcome is also compelling (Eger et al. 2021). Combatting this health threat primarily requires information on incidence rates; distribution and other related risk factors so as to inform decisions on human and financial resource mobilization and allocation. This study draws the conclusion that geographical region of residence has significant association with incidence rates of asthma and chronic obstructive lung diseases. As to whether, this effect may vary over time and space is yet a gap to be ascertained. The implication of our findings is that both health practitioners and policy makers should focus resources to the identified regions to abate the effect of incidence rates, since different regions have different defining characteristics, which in turn affect asthma incidences. Secondly, grouping incidence rates by region helps to focus resources and maximize reduction in the disease incidence rates because of the targeted interventions. The Ministry of Health should consider the five-asthma regions when making resources allocation decisions.

Declarations

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Conflict of interest

The authors declare no conflict of interest.

Availability of data and material

Administrative data used are extracts from reports that are publicly available online

Ethics approval

Not applicable

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Figures

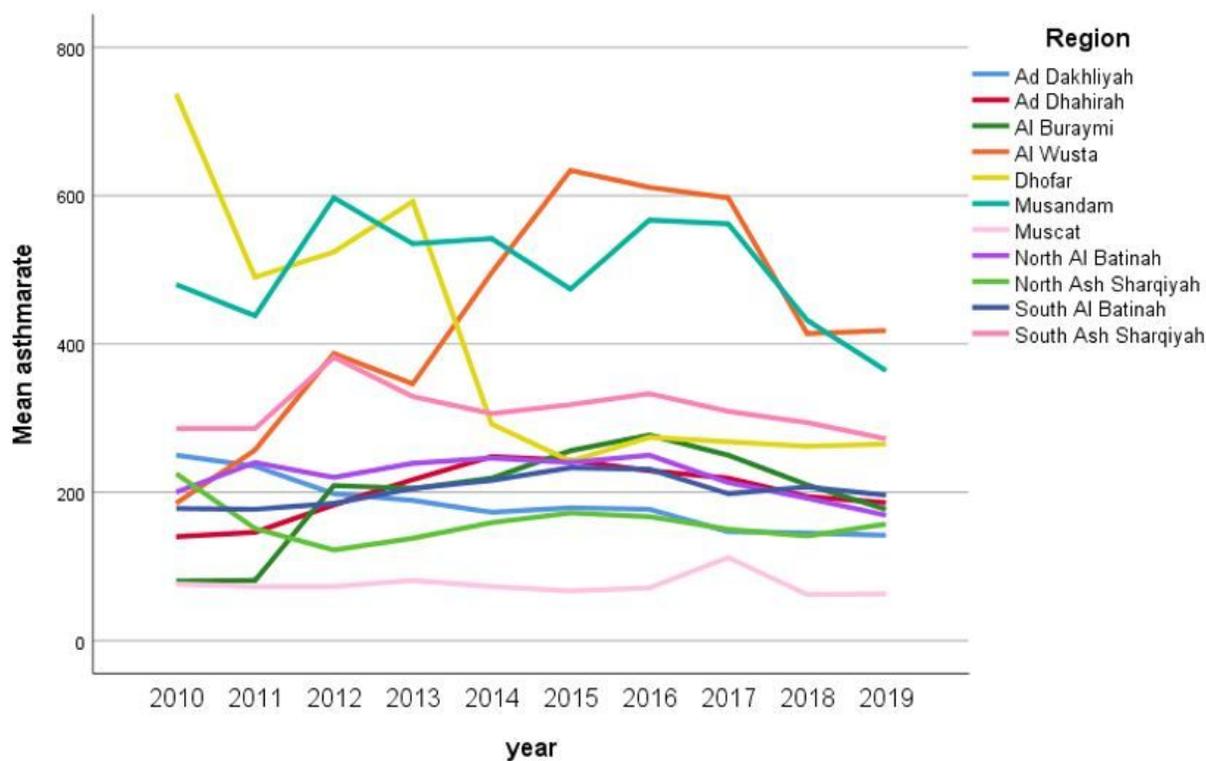


Figure 1

Incidence rates of Asthma over the eleven regions by year (2010-2019).