

Mini Review

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Potential causes of asthma in the United Arab Emirates: drawing insights from the Arabian Gulf

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Abstract: There is considerable concern on the rise in the incidence of asthma worldwide with statistics in the United Arab Emirates (UAE) indicating that at least 13% of schoolchildren, particularly of Emirati descent, suffer from asthma. With its high rates of hospital admissions, negative socioeconomic impact and significant morbidity, this is a disease that requires optimal guidelines for control and awareness. In this article, we review the current knowledge of asthma in the UAE and draw on studies, especially from the surrounding region, to identify its contributing factors within this population. The most frequently identified agents pertinent to the UAE include outdoor and indoor environmental causes exacerbated by the country's rapid urbanization, genetic factors aided in transmission by consanguineous marriage, the patient's socioeconomic status and a rise in vitamin D deficiencies. This evidence aims to inform healthcare professionals and governmental agencies in order to best create guidelines for controlling the burden of this debilitating disease.

Keywords: asthma; environmental factors; genetics; UAE; vitamin D.

Introduction

Asthma is a chronic, inflammatory, respiratory disease that has become a major health problem globally [1]. Asthma poses a formidable challenge, with its burden and duration of disease [2]. Recent evidence suggests a steady increase in the number of global asthmatic cases with a

reported estimate of 334 million individuals who suffer from asthma [2–4]. Phase III of the International Study of Asthma and Allergies in Childhood (ISAAC) found that 13.7% of 13–14-year olds in 56 countries and 11.6% of 6–7-year olds in 37 countries reported to have had asthmatic symptoms [5]. Asthma commonly presents in children aged 10–14 years and in the elderly (≥ 75 years) [2, 6]. The World Health Survey (WHS) on 178,215 adults between the ages of 18 and 45 from 70 different countries revealed the global prevalence of doctor-diagnosed asthma, clinical/treated asthma and wheezing to be 4.3%, 4.5% and 8.6% respectively, varying 21-fold across the 70 countries [7]. Although asthma is also common in middle-aged and older adults (>45 years), there is a paucity of data available [2].

There has been some focus on studying the prevalence of asthma in certain countries in the Middle East and North Africa (MENA). In Tunisia, the prevalence of asthma was measured using WHS, revealing 2.74% reported cases of doctor-diagnosed asthma, 2.79% of clinical asthma and 7.21% of wheezing, while Morocco demonstrated 2.76%, 2.84% and 11.65%, respectively [7]. Comparatively, Algerian responses to questionnaires developed by the Asthma Insight and Reality (AIR) reported a prevalence rate of 3.4% among the general population and 3.45% after adjusting for age and gender [8]. In the Levant region, there are some data available. In Lebanon, 3909 students between 5 and 12 years of age surveyed demonstrated a low number of cases of doctor-diagnosed asthma (4.8%), with incidences of asthma occurring significantly higher in urban areas (11.6% in Beirut) than in rural areas (1.8% in Bekaa) [9]. Amongst the Lebanese adolescents (ages 13–14 years; $n = 3115$), 8.3% reported to have asthma, while 24.1% admitted to have had asthmatic symptoms over the past year [10].

In the Arabian Gulf, there is also a marked shortage of regional epidemiological data on the prevalence of asthma across different populations. Oman is one of the few Gulf Cooperative Council (GCC) countries to participate in studies conducted by ISAAC, although there is virtually no data collected across the general population [11]. Through the phase III of ISAAC, 10.5% of 6–7-year olds and

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20.7% of 13–14-year olds were found to experience asthmatic symptoms [12]. Based on accumulated data, Oman ranked the highest in asthma severity within its region [11]. In Kuwait, Khadadah [13] reported that approximately 15% of adults and 18% of children had asthma. Among Kuwaiti schoolchildren, 15.6% of 13- and 14-year olds and 22% of 5–7-year olds reportedly suffer from asthma [14, 15]. A national survey in Saudi Arabia was conducted in 2013 to estimate the prevalence rates of asthma within the adult population. The responses demonstrated that 4.05% of the adult general population suffered from asthma, indicating low prevalence rates [16]. However, among 3073 Saudi 15–18-year-old adolescents who were surveyed in Riyadh, 25.3% of them exhibited a lifetime wheeze, 18.5% expressed symptoms of wheezing during the past 12 months and 19.6% had physician-diagnosed asthma [17].

There is considerable and up-to-date epidemiological data on the prevalence rates of asthma in the United Arab Emirates (UAE). A large cross-sectional study conducted by Alsowaidi et al. [18] observed that among the 6543 subjects analyzed, 4.8% and 8.5% of the subjects had asthma and a comorbidity of asthma and allergic rhinitis (AR), respectively. In their observations, immigrants had a significantly lower prevalence of asthma, as well as asthma co-occurring with AR, compared with UAE nationals. A more recent study surveyed 1220 individuals using the European Community Respiratory Health Survey (ECRHS) and found that the prevalence of asthma in the subject population was between 8 and 10%. However, participants between the ages of 22 and 44 presented lower prevalence rates, comparatively [19]. There has been much focus on the adolescent groups. According to a study conducted by Barakat-Haddad et al. [1], 776 of the 6363 adolescents aged between 13 and 20 years reported doctor-diagnosed asthma, with 740 (12.2%) reporting wheezing and 2125 (34.8%) reporting a dry cough in the past year. Ethnicity proved to be a predictor of asthma development, with 13.9% of UAE nationals, 15.7% from GCC countries, 10.9% of Arab Middle Eastern descent, 13% of Arab Africans, 7.1% of Southeast Asians and 13.6% of Western adolescents reporting asthmatic symptoms. In addition, questionnaires were distributed among 6543 individuals in Al-Ain (UAE) with the aim of studying the prevalence of asthma [20]. The overall self-reported prevalence rates were 13%. The authors recognized family history and UAE nationality as important risk factors for developing asthma. In one group of members aged 13–19 years, UAE nationals were significantly more likely to have asthma than other Arabs and non-Arabs (19%, 12% and 11%, respectively). In the second group, which comprised individuals aged >19 years, 14% of UAE nationals had asthma,

while asthma was present in 11% and 8% of other Arabs and non-Arabs, respectively. There was also a significant interaction between gender and age. The 13–19-year-old males were more likely to have asthma (17%) than females (14%); however, in the second group (>19 years), females had a significantly higher prevalence of asthma (13%) than males (11%).

This review paper aims to disseminate some of the information about asthma in the MENA region, whilst focusing on the potential causes for the prevalence of asthma cases in the UAE in particular.

Environmental factors and air quality

Epidemiological studies have reported the association between air pollutants and several health effects including the prevalence of asthma, decreased lung growth, behavioral problems, neurocognitive decrements and increased rates of respiratory tract infections. Such environmental factors can be categorized into common outdoor pollutants as well as indoor pollutants [21]. The UAE is mainly a desert environment with mostly coastal settlements, experiencing occasional sandstorms. In the summer, the temperatures can be as high as 50°C, whereas in the winter, temperatures drop significantly. Such weather variations can exacerbate chronic lung conditions. Exposure to air pollution in the UAE is mainly through industrial exposure and emissions from vehicles, the main means of transportation due to the country's arid desert environment. Another major route of exposure is through indoor air pollution which includes cultural practices such as smoking of cigarettes, water pipe (shisha), use of midwakh to smoke dokha (an alternative tobacco product) as well as the use of strong Arabian incense (bakhour).

A recent study commissioned by the UAE government revealed that outdoor air pollution was the leading contributor to mortality amongst all possible environmental exposure routes [22]. One study targeted UAE adolescents between the ages of 13 and 20 years from nine different regions within the UAE. The results revealed that geographical region and residing near an industrial plant, a gas station, a dumpsite or a construction site can be predictors of asthma [1]. Long-term and short-term exposure to particulate matter (PM) has been associated with increased mortality from respiratory and cardiovascular diseases, asthma, exacerbation of allergies and decrease in pulmonary function [21]. A cross-sectional study conducted across the UAE examined the effect of five gas pollutants: sulfur dioxide (SO₂), nitrogen dioxide (NO₂), hydrogen sulfide (H₂S), formaldehyde (HCHO) and carbon

monoxide (CO); and three size fractions of PM on the prevalence of respiratory symptoms in children and adults [23]. These pollutants are common indoor pollutants and serve as markers of infiltration from outdoor air sources and are thus related to the location of the residence and the degree of outdoor pollution, as well as proper ventilation. The results revealed a significant association between quantified household concentrations of SO_2 and H_2S and doctor-diagnosed asthma. The strongest association was with SO_2 as households with quantified SO_2 were 1.95 times more likely to report doctor-diagnosed asthma than houses with lower concentrations. Similar associations were found for NO_2 , H_2S and HCHO but not all were statistically significant. However, the study found no association between indoor PM and respiratory symptoms.

One important environmental factor that should be considered is the geographical location of the country. As the UAE has a hot desert climate, dust storms occurring throughout the year are very dominant. Several studies have been conducted in Middle Eastern countries such as Kuwait that looked into the health effects of dust storms. A study in Kuwaiti hospitals described that Middle Eastern countries impacted by dust storms have a higher chance of asthma than European countries [24]. This study was conducted for 1629 days, out of which 39 days had severe dust storms with PM_{10} levels higher than $1000 \mu\text{g}/\text{m}^3$. A total of 856,107 hospital admissions occurred over a study period of 5 years in Kuwait. Out of these admissions, 88,267 were respiratory admissions and asthma which were 10 times higher for children below the age of 15, compared to individuals of ages 65 and above. Moreover, a correlation was established between the presence of biological aeroallergens in the environment and an increase in the severity of asthma symptoms, measured through the number of asthma patient visits to emergency centers in Kuwait [25]. Environmental factors most suitable for the dispersal of fungal spores (low temperature and high relative humidity) were highly correlated with the highest reported number of asthma patient admissions and emergency visits. However, there was no significant correlation to pollen counts. These findings may also be applicable to the UAE as it shares environmental conditions similar to Kuwait. The effects of ambient air pollution in the UAE on the national burden of disease were investigated, which showed that an excess death of 545 individuals in the UAE in 2007 could be attributed to PM exposure [26]. The study also considered the effect of seasonal changes and temperature differences within a year, from 2007 to 2008, as well as differences in the concentration levels of PM across the whole UAE. Their results also suggest that higher concentrations of PM are

predicted during the summer season, when ambient temperatures are high.

Likewise many indoor pollutants have been linked to the severity of asthma symptoms. There was a strong correlation between tobacco smoking in the household and exposure to secondhand smoke and the increase in the severity of wheezing and dry cough [1]. Another possible source of indoor allergens and pollutants is incense (bakhour) burning, which is very widely practiced in the Gulf region. Arabian bakhour is made up of woodchips from agarwood (oud), flowers, musk and sandalwood along with scented oils and perfumes that undergo a slow burning process with the help of a charcoal burner. It has been reported that the slow burning of bakhour releases many toxic gases such as polycyclic aromatic hydrocarbons, CO, benzene and isoprene that might accumulate indoors especially with inadequate ventilation [27]. An analysis of 859 chemical compounds emitted in bakhour smoke revealed that at least 200 compounds are known irritants to eyes, skin, respiratory and digestive systems [28]. Many of these could be contributors to the onset and the severity of asthma in households that frequently burn incense. A study in Oman revealed that parents who reported using bakhour more than twice a week were three times more likely to report that their children were affected by bakhour smoke, and that manifested as a 2.5 times higher prevalence of children with current asthma [27]. However, there is no significant difference between bakhour users and non-users in the prevalence of any of the asthma core symptoms. Other common indoor allergens include pests (such as cockroaches and rodents) which were also associated with a dry cough [1]. One study conducted in Saudi Arabia explored the spectrum of an immunoglobulin E (IgE) skin test reactivity or sensitization to common indoor allergens among asthma patients and its correlation to the severity of the symptoms. The most common indoor allergens were shown to be: house dust mites (HDMs), cats and cockroaches. Increased levels of asthma severity were significantly correlated to patients who had positive skin test reactions to any number of indoor allergens and to the degree of reactivity to HDMs, but did not reach statistical significance in the case of cat and cockroach allergens [29].

Genetic factors

Triggering of asthma is not solely the result of environmental factors, individuals appear to have genetic tendencies to develop asthma as well. Often, allergens found in the environment interact with the genetic component

to ultimately express asthmatic symptoms [30]. A cross-sectional study in the UAE demonstrates this relationship [31]. Seven hundred and twenty-nine children aged between 6 and 14 years were provided with questionnaires pertaining to both the child and the parents' respective lifestyles and medical histories. It was apparent that parental asthma and exposure to allergens from pets, medicine, plants, dust storms and perfumes, as well as physical inactivity and humidity, were the more significant predictors of asthma, whilst foods, climate and parental smoking showed little influence. Moreover, the prevalence of asthma was significantly higher amongst siblings than parents, pointing to the role of genetic factors in the clinical onset of asthma. A limitation to this study however was that participants were recruited between October 1992 and May 1993, whereupon air quality in the UAE dwindles due to elevated respirable salt and sand particles detected between the months of May and December.

The exact mechanism for the transmission of asthma remains largely unknown. Some researchers suggest that inheritance occurs through simple Mendelian genetics [31]. However, other studies have discovered major genes that may be linked to atopy. For example, Marsh et al. [32] discovered evidence linking five markers found on chromosome 5q31.1, which included the interleukin-4 (*IL-4*) gene, with total IgE concentrations in serum. Their results revealed that there is genetic influence, from the *IL-4* gene or one close to it, on total IgE levels in a non-cognate fashion. Further studies found a C→T polymorphism on the promoter region of the *IL-4* gene [33]. Using Caucasian Americans, the authors demonstrated that total IgE levels in serum were influenced by the T allele exchange. However, when the study was replicated on Caucasian subjects in Britain and Australia [34] and in Japan [35], their data revealed no such linkage. The study was also replicated in local Kuwaitis using 184 subjects: 84 of whom were asthmatic, 53 of whom were non-asthmatic relatives and the rest, a constitution of 47, of whom were unrelated, non-asthmatic controls who have not had an incident of asthma for three generations [36]. Similar to other studies, the authors did not find an association between the C→T promoter polymorphism of the *IL-4* gene and the clinical onset of asthma, even when they clustered subjects with the TT and CT genotypes together and compared them with subjects who had the CC homozygous genotype. Nevertheless, the authors noted that control subjects from both the Kuwaiti and Japanese studies had a higher prevalence of this polymorphism compared with the Caucasian participant demographics of the USA, Britain and Australia. Their data also suggested findings similar to those of Noguchi et al. [37], who reported a high prevalence of the polymorphism among asthmatic children. This

may indicate that the T allele sensitizes individuals to the development of asthma, but does not regulate total IgE concentrations in serum. Researchers explained that the high prevalence of the T allele could be attributed to the high degree of consanguinity in the general Kuwaiti population.

As the UAE also exhibits a high degree of consanguinity [38], perhaps the local asthmatic population may need to be assessed for the possession of the C→T polymorphism. In fact, the effect of consanguinity on the development of asthma has been studied in the UAE. Two hundred and ninety-five families, as well as 1136 children between the ages of 6 and 14 of local Arab members of the UAE population, were selected to participate in the study [30]. Data demonstrated that the prevalence of childhood asthma was significantly higher in consanguineous families than in non-consanguineous families (43.3% and 22.6%, respectively). Girls in consanguineous families (42.9%) were also significantly more likely to have asthma than boys in consanguineous families (23.1%). Moreover, paternal asthma was found to be a significant predictor in both girls and boys in consanguineous families, while maternal asthma demonstrated little or no effect. Furthermore, the authors observed the potential effects that several environmental factors, such as pets, smokers in the family, practice of incense burning, diets and carpeting, may have on childhood asthma. Their results revealed that the most significant predictors of asthma in girls were paternal asthma and the degree of consanguinity, while the only significant predictor in boys was paternal asthma.

Further genome-wide association studies (GWAS) on asthma have successfully identified many loci that are potentially involved in its pathogenesis [39]. Studies involving individuals of European descent identified the *HLA-DQ* gene (a cell surface receptor protein found on immune cells) as having a strong association with asthma in adults and loci on chromosome 9 (near *IL33*), chromosome 2 (within *IL18R1*), chromosome 15 (within *SMAD3*) and chromosome 22 (within *IL2RB*) as having associations with childhood-onset asthma. Further analysis of childhood-onset asthma showed a strong link with chromosome 17q12-21, containing the *GSDMA*, *GSDMB* and Orosomucoid-like 3 (*ORMDL3*) genes. Members of the Gasdermin (*GSDM*) family have been shown to regulate expression of 5-lipoxygenase (5-LO) and transforming growth factor-β1 (TGF-β1) pathways involved in the pathogenesis of asthma and *ORMDL3* is an allergen inducible protein localized to the endoplasmic reticulum (ER) that has been implicated in increased airway remodeling in asthma. A meta-analysis performed on North American cohorts revealed additional loci of interest including the 17q12-21 locus, the *IL1RL1* gene on chromosome 2 and near the *TSLP* gene on

chromosome 5, single nucleotide polymorphisms (SNPs) within *CRCT1*, *PYHIN1*, *SRP9*, *RTP2*, *EPHA5*, *GALNT10*, *FBXO43*, *IL33*, *C11orf71*, *RASSF8*, *AURKB* and *c19orf2* as well as SNPs from the 17q12-21 locus and the *IL1RL1*, *TSLP* and *IL33* genes. Differences are evident between ethnic populations making replication of GWAS results difficult. However, the *ORMDL3/GSMDB* locus (chromosome 17q21) appears to be the most frequently described and replicated locus for asthma susceptibility [40].

These various studies provide some evidence suggesting that several significant environmental allergens may interact with genetic factors to exacerbate or increase the risk of development of asthma. Research indicates possible genes (specifically, a C→T base pair substitution in the *IL-4* promoter region), as well as a high degree of consanguinity and paternal asthma, to increase the chances for the clinical onset of asthma. Furthermore, genome-wide association research on susceptibility genes for asthma is lacking within the Arab populations and would need to be conducted to progress our understanding of the genetic components of asthma within this population.

Vitamin D deficiency

Recent evidence suggests that the increased incidences of asthmatic cases may be attributed to hypovitaminosis D. In Qatar, Bener et al. [3] measured serum vitamin D levels in 483 asthmatic children below the age of 16 and compared the results with healthy controls ($n=483$). Researchers also factored in the subjects' dietary intake, parental history, socio-demographics, socioeconomic status, parental education and occupation, consanguinity and morphometric measures. Their results revealed higher incidences of vitamin D insufficiency and deficiency among asthmatics (41.8% and 26.3%, respectively) compared with non-asthmatics (25.1% and 11%, respectively). The authors reported that vitamin D deficiency and reduced time spent outdoors were strong predictors of developing asthma. Other risk factors for the onset of asthma included familial history of vitamin D deficiency and resulting elevated serum levels, reduced physical activity, a higher body mass index (BMI) in children and consanguinity.

A study in Iran supports these results [4]. Their study recruited 200 asthmatic children aged 3–12 years and 200 healthy controls in a similar age range. They observed lower vitamin D levels in the serum of asthmatics compared with non-asthmatics (80% and 61%, respectively), whereby 56% of asthmatic patients were vitamin D deficient, 24% were vitamin D insufficient and 20% were vitamin D sufficient, compared with the healthy controls

(40%, 21% and 34%, respectively). Researchers did not find a correlation between the concentration of vitamin D and asthma severity in both groups. Moreover, they discovered significantly higher total IgE levels in the serum of asthmatic patients (121.4 ± 22.1 IU/mL) than those measured in the non-asthmatics (37.9 ± 2.1 IU/mL). Total serum IgE concentrations were highest among asthmatic patients with vitamin D deficiency (132.4 ± 20.1 IU/mL).

There are many reasons behind the widespread prevalence of vitamin D deficiency in the Gulf, with sociocultural evolution, an increase in prosperity and the time spent indoors being major causes [3]. More recently, polymorphisms within the vitamin D metabolism genes (*CYP27B1* and *CYP24A1*) [41] as well as genetic polymorphisms in the vitamin D receptor gene among Emiratis have been identified and associated with susceptibility to chronic diseases [42, 43]. A study that measured serum vitamin D concentrations in Turkish, Moroccan, Indian and Sub-Saharan immigrant European populations suggested that cultural dress codes may also limit the amount of sunlight exposure [44]. Evidence links maternal intake of vitamin D during pregnancy and the prevalence of childhood asthma and other respiratory illnesses. For instance, vitamin D deficiency was found to be significantly higher in parents of young asthmatic patients, imposing a risk factor for the development of childhood asthma [3]. Hence, pregnant or lactating mothers whose vitamin D status is poor may increase the risk for their children to have vitamin D deficiency, and therefore, increase the risk of developing childhood asthma [45, 46]. Epidemiologic data also suggest that obesity may adversely affect the status of vitamin D [47]. With the UAE experiencing an increase in the prevalence of obesity among its population as well as high levels of physical inactivity [48], these parameters may be inextricably linked to vitamin D deficiency and hence may also play important roles as contributors for the development of asthma.

Although many of these studies that link vitamin D deficiency with asthma are observational in nature, the main link between vitamin D and asthma appears to be in its immunomodulatory effects [49]. Vitamin D has been shown to target various immune cells, such as monocytes, macrophages, dendritic cells and lymphocytes, hence modulating both innate and adaptive immune responses. Moreover, vitamin D can increase the production of anti-inflammatory cytokines, while reducing the expression of pro-inflammatory cytokines in airways. These results suggest a key role for vitamin D in maintaining a healthy immune response and therefore a clear link between vitamin D deficiency and the pathogenesis of inflammatory diseases.

Socioeconomic factors

Socioeconomic status can also have a significant effect on the prevalence, diagnosis and burden of asthma on the patient and the population in general. Since the discovery of oil reserves, the UAE has undergone accelerated economic and social transformation. Such changes lead to improved living conditions, healthcare and education that introduced new risk factors due to urbanization and industrialization [1]. With the lack of proper asthma control, such conditions can lead to increased health care cost, lost disability-adjusted life years, decreased work productivity and a negative economic impact on the family [1]. A survey in the UAE revealed that of the 200 participants, 11% of children and 3% of adults were hospitalized and 16% of adults and 53% of children had to miss work or school [50]. These findings provide evidence that despite the availability of guidelines and effective medications, the burden of asthma in the UAE remains high [1]. In Oman, the level of asthma control was also assessed revealing poor levels of asthma control that can be attributed to socioeconomic factors [51]. Of the 201 participants, 38% completed primary education, 30% secondary education and 75% made less than \$1000 per year. This could have resulted in the observed burden whereby 32.6% of children reported an average of 6.1 absences from school due to asthma and 34.8% of adults reported an average of 9.9 absences from work due to asthma, in addition to 30% of hospitalizations and 58% of emergency medical visits. This clearly illustrates the strong effect that socioeconomic factors can have on asthma control and management.

However, a study in Al Ain, UAE, showed contradictory findings. More patients with higher levels of education were unaware of their condition, undiagnosed or undertreated than patients with lower levels of education [52]. Researchers attributed these unexpected findings to the reluctance of doctors to “label” higher education patients as asthmatics because they are aware that it is a chronic disease. Nevertheless, the overall global trend consistently affirms the expectation that a lower socioeconomic status increases the risks of under-diagnosis and under-treatment of asthma.

Conclusion

Asthma is a very prevalent disease with over 300 million sufferers worldwide and many known common triggers. These essentially include environmental factors such as air quality, pollution, pollen, dust, sandstorms, smoke and other airborne irritants. However, indoor conditions

may also play a role in increasing the risk of asthma as does a family history of asthma, lower socioeconomic status and stress and perhaps some unlikely contributors such as vitamin D deficiency, dietary habits and obesity. Our report suggests that the impact of rapid urbanization and customary indoor bakhour use in the UAE may have confounding roles in the prevalence of this disease amongst the UAE population. A genetic predisposition may also increase the chances for the clinical onset of asthma with some evidence of a base pair substitution in the *IL-4* promoter region potentially being a factor, exacerbated by a high degree of consanguinity. With research pointing to vital roles for vitamin D in regulating immune and inflammatory responses, deficiency appears to increase the risk of incidence of asthma. This is pertinent to the UAE with statistics indicating that Arab infants and children in the UAE have poor vitamin D values and there are also notable links between vitamin D deficiency and non-communicable diseases like cardiovascular disease, diabetes and obesity, all of which are highly prevalent in the UAE population [53]. Effective asthma control guidelines are vital in reducing the burden of the disease and its negative impacts on families and the economy.

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Author statement

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References

1. Barakat-Haddad C, Zhang S, Siddiqua A, Dghaim R. Air quality and respiratory health among adolescents from the United Arab Emirates. *J Environ Public Health* 2015;2015, Article ID 284595.
2. Global Asthma Report. 2014. Auckland, New Zealand: Global Asthma Network. Available at: http://www.globalasthmareport.org/resources/Global_Asthma_Report_2014.pdf.
3. Bener A, Ehlayel MS, Tulic MK, Hamid Q. Vitamin D deficiency as a strong predictor of asthma in children. *Int Arch Allergy Immunol* 2012;157:168–75.
4. Hatami G, Ghasemi K, Motamed N, Firoozbakht S, Movahed A, Farrokhi S. Relationship between vitamin D and childhood asthma: a case-control study. *Iran J Pediatr* 2014;24:710–4.
5. Pearce N, Ait-Khaled N, Beasley R, Mallol J, Keil U, Mitchell E, et al. Worldwide trends in the prevalence of asthma symptoms: phase III of the International Study of Asthma and Allergies in Childhood (ISAAC). *Thorax* 2007;62(9):758–66.

6. Bener A, Abdulrazzaq YM, Debusse P, Al-Mutawwa J. Prevalence of asthma among Emirates school children. *Eur J Epidemiol* 1994;10:271–8.
7. To T, Stanojevic S, Moores G, Gershon A, Bateman E, Cruz A, et al. Global asthma prevalence in adults: findings from the cross-sectional World Health Survey. *BMC Public Health* 2012;12:204.
8. Nafti S, Taright S, El Ftouh M, Yassine N, Benkheder A, Bouacha H, et al. Prevalence of asthma in North Africa: the asthma insights and reality in the Maghreb (AIRMAG) study. *Respir Med* 2009;103:S2–11.
9. Waked M, Salameh P. Asthma, allergic rhinitis and eczema in 5–12-year-old school children across Lebanon. *Public Health* 2008;122:965–73.
10. Musharrafieh U, Al-Sahab B, Zaitoun F, El-Hajj MA, Ramadan F, Tamim H. Prevalence of asthma, allergic rhinitis and eczema among Lebanese adolescents. *J Asthma* 2009;46:382–7.
11. Al-Busaidi N, Habibulla Z, Bhatnagar M, Al-Lawati N, Al-Mahrouqi Y. The burden of asthma in Oman. *Sultan Qaboos Univ Med J* 2015;15:e184–90.
12. Al-Riyami BMS, Al-Rawas OAS, Al-Riyami AA, Jasim LG, Mohammed AJ. A relatively high prevalence and severity of asthma, allergic rhinitis and atopic eczema in schoolchildren in the Sultanate of Oman. *Respirology* 2003;8:69–76.
13. Khadadah M. The cost of asthma in Kuwait. *Med Princ Pract* 2013;22:87–91.
14. Owayed A, Behbehani N, Al-Momen J. Changing prevalence of asthma and allergic diseases among Kuwaiti children. *An ISAAC Study (Phase III)*. *Med Princ Pract* 2008;17:284–9.
15. Abal AT, Ayed A, Nair P, Mosawi M, Behbehani N. Factors responsible for asthma and rhinitis among Kuwaiti schoolchildren. *Med Princ Pract* 2010;19:295–8.
16. Moradi-Lakeh M, El Bcheraoui C, Daoud F, Tuffaha M, Kravitz H, Al Saeedi M, et al. Prevalence of asthma in Saudi adults: findings from a national household survey, 2013. *BMC Pulm Med* 2015;15:77.
17. Al Ghobain M, Al-Hajjaj M, Al Moamary M. Asthma prevalence among 16- to 18-year-old adolescents in Saudi Arabia using the ISAAC questionnaire. *BMC Public Health* 2012;12:239.
18. Alsowaidi S, Abdulle A, Bernsen R, Zuberbier T. Allergic rhinitis and asthma: a large cross-sectional study in the United Arab Emirates. *Int Arch Allergy Immunol* 2010;153:274–9.
19. Mahboub B, Al-Hammadi S, Rafique M, Sulaiman N, Pawankar R, Al Redha AI, et al. Population prevalence of asthma and its determinants based on European Community Respiratory Health Survey in the United Arab Emirates. *BMC Pulm Med* 2012;12:4.
20. Alsowaidi S, Abdulle A, Bernsen R. Prevalence and risk factors of asthma among adolescents and their parents in Al-Ain (United Arab Emirates). *Respiration* 2010;79:105–11.
21. Soto-Martinez M, Sly PD. Review series: what goes around, comes around: childhood influences on later lung health? Relationship between environmental exposures in children and adult lung disease: the case for outdoor exposures. *Chron Respir Dis* 2010;7:173–86.
22. MacDonald Gibson J, Thomsen J, Launay F, Harder E, DeFelice N. Deaths and medical visits attributable to environmental pollution in the United Arab Emirates. *PLoS One* 2013;8:e57536.
23. Yeatts KB, El-Sadig M, Leith D, Kalsbeek W, Al-Maskari F, Couper D, et al. Indoor air pollutants and health in the United Arab Emirates. *Environ Health Perspect* 2012;120:687–94.
24. Thalib L, Al-Taiar A. Dust storms and the risk of asthma admissions to hospitals in Kuwait. *Sci Total Environ* 2012;433:347–51.
25. Qasem J, Nasrallah H, Al-Khalaf B, Al-Sharifi F, Al-Sherayfee A, Almathkouri S, et al. Meteorological factors, aeroallergens and asthma-related visits in Kuwait: a 12-month retrospective study. *Ann Saudi Med* 2008;28:435–41.
26. Li Y, Gibson JM, Jat P, Puggioni G, Hasan M, West J, et al. Burden of disease attributed to anthropogenic air pollution in the United Arab Emirates: estimates based on observed air quality data. *Sci Total Environ* 2010;408:5784–93.
27. Al-Rawas OA, Al-Maniri AA, Al-Riyami BM. Home exposure to Arabian incense (bakhour) and asthma symptoms in children: a community survey in two regions in Oman. *BMC Pulm Med* 2009;9:23.
28. Dalibalta S, Elsayed Y, Alqtaishat F, Gomes I, Fernandes N. A health risk assessment of arabian incense (bakhour) smoke in the United Arab Emirates. *Sci Total Environ* 2015;511:684–91.
29. Koshak EA. Skin test reactivity to indoor allergens correlates with asthma severity in Jeddah, Saudi Arabia. *Allergy, asthma, and clinical immunology. Allergy Asthma Clin Immunol* 2006;2:11–9.
30. Joseph M, Zoubeidi T, Al-Dhaheeri SM, Al-Dhaheeri AA, Al-Dhaheeri AA, Al-Kaabi FM, et al. Paternal asthma is a predictor for childhood asthma in the consanguineous families from the United Arab Emirates. *J Asthma* 2009;4:175–8.
31. Bener A, Abdulrazzaq YM, Al-Mutawwa J, Debusse P. Genetic and environmental factors associated with asthma. *Hum Biol* 1996;68:405.
32. Marsh D, Neely J, Breazeale D, Ghosh B, Freidhoff L, Ehrlich-Kautzky E, et al. Linkage analysis of IL4 and other chromosome 5q31.1 markers and total serum immunoglobulin E concentrations. *Science* 1994;264:1152–6.
33. Rosenwasser LJ, Klemm DJ, Dresback JK, Inamura H, Mascali JJ, Klinnert M, et al. Promoter polymorphisms in the chromosome 5 gene cluster in asthma and atopy. *Clin Exp Allergy* 1995;25(Suppl 2):74–8.
34. Walley AJ, Cookson WO. Investigation of an interleukin-4 promoter polymorphism for associations with asthma and atopy. *J Med Genet* 1996;33:689–92.
35. Noguchi E, Shibasaki M, Arinami T, Takeda K, Maki T, Miyamoto T, et al. Evidence for linkage between asthma/atopy in childhood and chromosome 5q31-q33 in a Japanese population. *Am J Respir Crit Care Med* 1997;156:1390–3.
36. Hijazi Z, Haider MZ. Interleukin-4 gene promoter polymorphism [C590T] and asthma in Kuwaiti Arabs. *Int Arch Allergy Immunol* 2000;122:190–4.
37. Noguchi E, Shibasaki M, Arinami T, Takeda K, Yokouchi Y, Kawashima T, et al. Association of asthma and the interleukin-4 promoter gene in Japanese. *Clin Exp Allergy* 1998;28:449–53.
38. Tadmouri GO, Nair P, Obeid T, AlAli MT, Al Khaja N, Hamamy HA. Consanguinity and reproductive health among Arabs. *Reprod Health* 2009;6:17.
39. March M, Sleiman P, Hakonarson H. Genome-wide association studies in asthma: progress and pitfalls. *Adv Genomics Genet* 2015;5:107–19.
40. Tamari M, Tomita K, Hirota T. Genome-wide association studies of asthma. *Allergol Int* 2011;60:247–52.
41. Al Anouti F, Chehadeh S, Osman E, ElGhazali G, Al Safar H. Investigating the association of vitamin D metabolism genes CYP2R1,

- CYP24A1 and CYP27B1 with vitamin D status in young adult Emiratis. *J Food Nutr Res* 2017;5:15–21.
42. Osman E, Al Anouti F, ElGhazali G, Haq A, Mirgani R, Al Safar H. Frequency of rs731236 (TaqI), rs2228570 (FokI) of vitamin-D receptor (VDR) gene in Emirati healthy population. *Meta Gene* 2015;6:49–52.
 43. Al Safar H, Chehadeh S, Abdel-Wareth L, Haq A, Jelinek H, ElGhazali G, et al. Vitamin D receptor gene polymorphisms among Emirati patients with type 2 diabetes mellitus. *J Steroid Biochem Mol Biol* 2018;175:119–24.
 44. Van der Meer IM, Middelkoop BJ, Boeke AJ, Lips P. Prevalence of vitamin D deficiency among Turkish, Moroccan, Indian and Sub-Sahara African populations in Europe and their countries of origin: an overview. *Osteoporosis Int* 2011;22:1009–21.
 45. Camargo CA, Rifas-Shiman SL, Litonjua AA, Rich-Edwards JW, Weiss ST, Gold DR, et al. Prospective study of maternal intake of vitamin D during pregnancy and risk of wheezing illnesses in children at age 2 years. *J Allergy Clin Immunol* 2006;117:721–2.
 46. Devereux G, Litonjua A, Turner S, Craig L, McNeill G, Martindale S, et al. Maternal vitamin D intake during pregnancy and early childhood wheezing. *Am J Clin Nutr* 2007;85:853–9.
 47. Zgaga L, Theodoratou E, Farrington S, Agakov F, Tenesa A, Walker M, et al. Diet, environmental factors, and lifestyle underlie the high prevalence of vitamin D deficiency in healthy adults in Scotland, and supplementation reduces the proportion that are severely deficient. *J Nutr* 2011;141:1535–42.
 48. Malik M, Bakir A. Prevalence of overweight and obesity among children in the United Arab Emirates. *Obes Rev* 2007;8:15–20.
 49. Yin K, Agrawal DK. Vitamin D and inflammatory diseases. *J Inflamm Res* 2014;7:69–87.
 50. Mahboub B, Santhakumar S, Soriano J, Pawankar R. Asthma insights and reality in the United Arab Emirates. *Ann Thorac Med* 2010;5:217–21.
 51. Al-Busaidi N, Soriano JB. Asthma control in Oman: national results within the Asthma Insights and Reality in the Gulf and the Near East (AIRGNE) Study. *Sultan Qaboos Univ Med J* 2011;11:45–51.
 52. Al-Shadli A, Bener A, Brebner J, Dunn E. Asthma diagnosis and management in adults: is the risk of underdiagnosis and undertreatment related to patients' education levels? *J Asthma* 2001;38:121.
 53. Al-Hazzaa HM, Musaiger AO. Physical activity patterns and eating habits of adolescents living in major Arab cities. The Arab Teens Lifestyle Study. *Saudi Med J* 2010;31:210–1.

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