

Asthma, Environmental Risk Factors, and Hypertension Among Arab Americans in Metro Detroit

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Abstract Asthma and obesity-related health problems disproportionately impact low-income ethnic minority communities residing in urban areas. Environmental risk factors, particularly those related to housing and indoor air, may impact the development or exacerbation of asthma. There is increasing evidence to suggest a link between obesity-related health problems and asthma. Previous studies have also reported that immigrant status may influence myriad risk factors and health outcomes among immigrant populations. The Arab American Environmental Health Project (AAEHP) was the first study to explore environmental health problems among Arab Americans. This paper examined whether hypertensive status modified the relationship between environmental risk factors and asthma among Arab Americans in metro Detroit. An environmental risk index (ERI) was used to quantify household

environmental risk factors associated with asthma. Physician diagnosed hypertension was self-reported, and asthma status was determined using responses to a validated symptoms checklist and self-reported diagnosis by a physician. Hypertension significantly modified the relationship between ERI and asthma in this study population. The positive association between household environmental risk factors and asthma was stronger among participants diagnosed with hypertension. Effect modification of the relationship between environmental risk factors and asthma could have serious implications among high-risk communities. However, further research is needed to elucidate the relationships between hypertension, environmental risk factors, and asthma.

Keywords Asthma · Hypertension · Arab ·
Indoor air pollution · Environmental risk factors

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Introduction

The global epidemics of asthma [1, 2] and obesity-related health problems [3] have resulted in public health crises. There are approximately 15 million current asthmatics in the United States [2] and the prevalence of asthma in North America has increased by approximately 50% each decade [4]. The burden of obesity-related health problems [5–8] including hypertension is also increasing [9, 10]. Global prevalence of hypertension has been estimated at 26% [11] and 7.6 million premature deaths per year worldwide have been attributed to hypertension [12].

The disproportionate burden of asthma morbidity and mortality among urban-dwelling, low SES, and ethnic minority populations in the U.S. has been well documented [13–17]. Asthma has been cited as a major source of health

disparities among minority and low socioeconomic groups [17]. LeNoir reported that Hispanic and African Americans were two to six times more likely to die of asthma compared with white asthmatics [4].

There are also major racial and ethnic disparities in cardiovascular and metabolic health problems including obesity, hypertension, cardiovascular disease, and diabetes [18–20]. Obesity and hypertension have received considerable attention due to their role as risk factors for adverse cardiovascular and metabolic events [2, 6]. Minor et al. [20] suggested that racial and ethnic disparities in cardiovascular outcomes maybe largely explained by disparities in hypertension. Finally, there is some evidence that immigrant status may be related to asthma [21, 22] as well as metabolic and cardiovascular health problems [23–26].

In order to improve disease management and health outcomes, it is vital to understand the impact of obesity, hypertension, and other metabolic/cardiovascular conditions on asthma, particularly in high-risk communities. There is some evidence to suggest a link between cardiovascular/metabolic health problems and asthma [27–29]. However, these links are poorly understood, and the role of environmental risk factors in those relationships has yet to be explored.

Disproportionate exposure to environmental risk factors may contribute to asthma disparities in low SES, urban-dwelling, and ethnic minority groups [1, 4, 16, 17, 30]. Poor housing quality has received considerable attention in recent years as a potential determinant of health, particularly among ethnic minorities residing in low-income urban areas [31–35]. Environmental risk factors associated with substandard housing have been implicated in a wide range of health outcomes [36] and the impact of household environmental insults on asthma outcomes has been well documented [1, 37–40]. Substandard housing has also been associated with increased stress and anxiety [30, 41], which may have a significant impact on multiple disease outcomes including asthma [42–46] and cardiovascular or metabolic health problems [47–49].

Poor housing quality, high levels of pollution, barriers to quality health care and other risk factors found in urban immigrant reception areas such as Detroit, Michigan may have significant health impacts, particularly among vulnerable populations. This confluence of environmental and socio-demographic risk factors for asthma has been explored among various ethnic minority and immigrant groups [21, 22, 50–52]. However, the Arab American Environmental Health Project (AAEHP) was the first study focused on asthma and environmental disease burden among Arab Americans.

AAEHP previously published the prevalence of asthma and other chronic health problems among Arab Americans in metro Detroit [53, 54]. Preliminary analyses of

relationships between environmental risk factors (ERI) and chronic disease burden in this population were also reported [53, 54]. The current paper explored whether hypertensive status modified the relationship between environmental risk factors and asthma among Arab Americans in the metro Detroit area.

Methods

The Arab American Environmental Health Project (AAEHP) conducted household surveys in 600 Arab American homes in the metro Detroit area. The research was conducted in collaboration between Arab Community Center for Economic and Social Services (ACCESS) and the University of Michigan School of Public Health according to the community based participatory research model [55, 56]. The study design and methods were described in detail by Johnson et al. [53].

Questionnaire Development

The household survey was developed in collaboration with a community council comprised of bilingual Arab American community stakeholders including local teachers, health care professionals, and other community advocates. The community council guided the research in every phase of the study including identification of research goals, development of study design, questionnaire development and revision, and prioritizing research questions during data analysis. For example, based on feedback from the community council, questions that were difficult to understand in translation or deemed unlikely to elicit meaningful responses in the study community were removed from the questionnaire. Translation of wheeze and other asthma-related outcomes was reviewed and approved by this group.

Community Environmental Health Advocates

Trained community environmental health advocates conducted all household surveys. Community health advocates were all bilingual Arab Americans living in metro Detroit; several were trained as physicians. In addition to their professional experience, community advocates received 40 h of training in environmental hazard assessment, household risk factor evaluation, and basic principles of environmental justice directed by the project manager (a bilingual Arab American physician). Community environmental health advocates also participated in a series of workshops led by environmental health experts. All community environmental health advocates were trained to understand and discuss asthma-related issues including symptoms. Following training, community health advocates

conducted eight home visits under the supervision of the project manager. Community advocates were able to provide additional feedback about survey questions after administering the questionnaire in these homes. Community advocates of various backgrounds were matched with geographic areas in Detroit based on predominant dialect spoken in those areas to optimize communication between community advocates and participants.

Household Selection

Households were selected from four regions in the Detroit metropolitan area: Dearborn, Hamtramck, Oak Park, and Detroit Seven Mile zone. These areas encompass the predominantly Arab-American immigrant reception pool in Detroit, and some of the heaviest industrial polluters in Wayne County. The proportional representation of participants from each area—57% from Dearborn, 17% from Hamtramck, 16% from Detroit Seven Mile, and 10% from Oak Park—was based on rough estimates of the number of Arab Americans living in each area.

Participants in Dearborn were selected randomly from a database of Arab American households developed for a previous ACCESS study based on property tax information. Addresses were collected from property assessment data for Oak Park, Hamtramck, and the Detroit Seven Mile area. Property assessment data was augmented with a list of individual apartment numbers compiled by researchers walking or driving through the study neighborhoods. Addresses were randomly selected from the resulting databases.

Prior to the attacks on the World Trade Center in New York on September 11th 2001, advocates approached both Arab and non-Arab American households in the process of recruiting Arab American participants. This recruitment method was used to select households in Oak Park. After the attacks on September 11th, face-to-face screening became uncomfortable and potentially dangerous for the community health advocates. In response to this challenge, advocates compiled lists of Arab American households in Hamtramck and the Detroit Seven Mile area using block-by-block survey of predominantly Arab American neighborhoods. Households in Hamtramck and the Detroit Seven Mile were randomly selected from these lists.

Household Survey

Community advocates initially approached families directly by knocking on the door. The household assessment survey was administered at the initial meeting if an adult (18+) household member was willing to participate. If the household member was unable to do the interview during the initial

meeting, the advocates arranged appointments to administer the survey at a more convenient time.

Community health advocates administered questionnaires orally to household participants and filled in subsequent responses. Questionnaires were administered in either English or Arabic based on participant preference. All of the interviewers were native Arab speakers, and most of the interviews were conducted in Arabic. Participating households received a baseline incentive of \$50 upon completion of the survey. The survey was carried out between August 2001 and January 2002.

The study design and research methods for the AAEHP were approved by the University of Michigan Institutional Review Board (IRB) in accordance with federal regulations. Interviewers obtained written informed consent from adult members of the household before administering the survey. The consent form adhered to the provisions outlined by the University of Michigan IRB and was available to participants in both English and Arabic.

Response Rate

Advocates approached each eligible household at least four times. If they were unable to conduct or schedule an interview within this timeframe, the household was classified as a refusal. These default refusals included households in which no one was home during four separate visits.

Of the 706 households that were eligible, only 12% refused to participate directly or were excluded after four unsuccessful attempts to contact the household. A total of 618 household surveys were completed. Of the 618 completed surveys, 600 were used in the analysis. One of the original community advocates left the project after completing 15 surveys; these surveys were subsequently omitted from the final analysis. Survey data from three additional households were excluded from the analysis because they were incomplete. Pilot surveys conducted during community advocate training were not included in the analysis.

The AAEHP gathered information about the 600 adult respondents, 432 spouses, and 430 children as part of the household survey. The complete dataset includes data for a total of 1,462 individuals. This paper focused on data for the 600 adult respondents who participated in the household survey.

Environmental Risk Index

The survey included a ranking scheme for 17 critical risk and protective factors that were used to estimate the environmental risk index (ERI) for each household [53]. The ERI focused on shared household exposures, e.g., risk factors present in living spaces utilized by the entire household such as the kitchen or the family room, or exposures such as

heating source or temperature that affect the entire home rather than individual spaces such as a bedroom. The environmental risk index considered physical features of the home (e.g., year built, housing material, central air conditioning, basement, heating source, furnace type and filter, garage presence/proximity to home/and usage, weather-proofing, clothes drier, pesticide application on property, water leaks in the home, pet ownership, cockroach problems, and daytime indoor temperature) as well as some subjective evaluation (such as difficulty in getting the landlord to make repairs and self-reported quality of the home).

Risk factors were assigned positive scores and protective factors were assigned negative scores. Score magnitude for each risk or protective factor was based on the strength of its association with asthma in the literature. Scores for the individual questions were added together to form a summary ERI value for each household. ERI score ranged from 1 to 17 with a mean and median of 6.0. ERI was considered as a continuous variable scaled by interquartile range (IQR) and as a binary variable (top 10% versus lower 90%) in the analyses presented in this paper.

Asthma and Other Chronic Health Problems

The survey assessed self-reported asthma and doctor-diagnosed asthma in the study population. Doctor-diagnosed asthma was defined as a positive response to the question: “have you ever been diagnosed with asthma by a physician?” Self-reported asthma was based on response to questions about symptoms and hospitalization. Community advocates administered the asthma diagnostic checklist, a series of 13 yes/no questions developed by the American College of Allergy, Asthma & Immunology and used in a national screening program to identify potential asthmatics [57]. The checklist has also been used as a screening tool in numerous clinical settings including the University of Michigan Health Services [58].

Respondents who answered yes to four or more of the checklist questions were considered to be at some risk for asthma. In addition to responding yes to 4 or more questions on the asthma diagnostic checklist, participants identified as “at risk” for asthma had to report wheezing symptoms with or without a cold, or wheezing that caused breathing difficulty in a separate section of the survey in order to be classified as self-reported asthmatics. Both doctor-diagnosed and self-reported asthmatics were considered asthmatic in the statistical analysis; however, some analyses were limited to participants with doctor-diagnosed asthma or asthma-related hospitalization. The survey assessed the prevalence of other doctor-diagnosed health problems including allergies, hypertension, high cholesterol, heart disease, diabetes, frequent bladder infections, frequent ear infections, frequent sinus infections, cancer, and chronic fatigue.

Covariates

The study assessed numerous socio-demographic factors including age, sex, education, employment status, and health care access. Age was divided into three categories for stratified analyses: 18–30, 31–50, and 51–71 or older. Education ranged from no formal schooling to post-graduate degree. Reporting a regular family doctor was used as a surrogate for health care access in the analyses. Unemployment was coded as a three-level variable. Participants who were unemployed and looking for work were assigned an unemployment value of two; participants who reported having full-time employment outside of the home were assigned an unemployment value of zero; and those who were retired, students, housewives, on disability, or employed part-time were assigned an unemployment score of one. Smoking was assessed for a subset of the participants ($N = 200$). Analyses adjusting for environmental tobacco smoke (ETS) were considered for this subset of the study population.

Statistical Analyses

Statistical analyses were performed using SAS 8.0 (SAS Institute, Cary, North Carolina, USA). Basic descriptive statistics were generated using univariate and frequency analysis. Multivariate regression analyses were used to assess ERI and hypertension as independent predictors of asthma, and to evaluate whether ERI was associated with hypertension. All tests were considered statistically significant at $\alpha < 0.05$. Associations with a P value greater than 0.050 and less than 0.10 were considered to be marginally significant.

Potential effect modification of the relationship between ERI and asthma by hypertension was evaluated by testing the statistical significance of the multiplicative interaction term (Model 1).

Model 1:

$$\begin{aligned} \text{Asthma} = & \beta_0 + \beta \text{ Hypertension} * \text{ERI} + \beta \text{ Hypertension} \\ & + \beta \text{ ERI} + \beta \text{ age} + \beta \text{ sex} \\ & + \beta \text{ health care access} + \beta \text{ education} \end{aligned}$$

Effect modification was also evaluated using the Likelihood Ratio test (LR): $\text{LR} = [-2 \ln L(\text{reduced})] - [-2 \ln L(\text{full})]$ to compare a multivariate model that included a multiplicative interaction term for ERI and hypertension (Model 1) with a multivariate model omitting the interaction term (Model 2).

Model 2:

$$\begin{aligned} \text{Asthma} = & \beta_0 + \beta \text{ Hypertension} + \beta \text{ ERI} + \beta \text{ age} \\ & + \beta \text{ sex} + \beta \text{ health care access} + \beta \text{ education} \end{aligned}$$

The full model for the LR test contained an interaction term for ERI and hypertension in addition to ERI, hypertension and potential confounders, while the nested model included all variables in the full model with the exception of the multiplicative interaction term. LR was tested for significance using the Chi Square table, with degrees of freedom (df) equal to the difference in parameter number between the full and nested models (e.g., for the comparisons reported in this paper $df = 1$).

Stratum-specific odds ratios for participants with and without hypertension were generated using interaction models with stratum specific parameter estimates for ERI and hypertensive status (Model 3).

Model 3:

$$\begin{aligned} \text{Asthma} = & \beta_0 + \beta \text{ Hypertension*ERI} \\ & + \beta \text{ Non - Hypertension*ERI} \\ & + \beta \text{ Hypertension} + \beta \text{ age} + \beta \text{sex} \\ & + \beta \text{ health care access} + \beta \text{education} \end{aligned}$$

where non-hypertension = 0 when hypertension = 1, and non-hypertension = 1 when hypertension = 0.

Odds ratios for stratum-specific ERI were similar for models including stratum-specific confounders (e.g., hypertension*age and non-hypertension*age), therefore,

stratum-specific parameter estimates from the simplified model (Model 3) were reported in this paper.

Results

Descriptive Statistics

Women accounted for 58% of the study population (Table 1). Approximately 40% of the study participants had completed high school and 19% were employed full time outside of the home. These frequencies were similar when self-reported asthmatics were omitted from the study population. The prevalence hypertension was 18% in the study population and 16% of study participants were asthmatic. ERI score ranged from 1 to 17 with a mean and median score of 6.0. IQR for ERI score was 4.0.

Factors Associated with Hypertension

Logistic regression analyses of socio-demographic and environmental factors associated with hypertension are presented in Table 2. Age and health care access were positively associated with hypertension. The prevalence of hypertension did not vary by gender or education. ERI

Table 1 Demographic characteristics, environmental risk factors, and health outcomes among Arab Americans in metro Detroit

	Total study population (<i>N</i> = 590)	Self-reported asthmatics omitted (<i>N</i> = 559)	Hypertensive (<i>N</i> = 105)	Non-hypertensive (<i>N</i> = 485)
	Frequency (%)			
Age				
18–30 years	32	32	6.7	37
31–50 years	40	40	22	44
51–70+ years	28	28	71	19
Sex				
Female	58	59	52	59
Male	42	41	48	41
Education				
Less than high school education	59	58	78	55
High school only	21	22	16	22
Any post secondary education	20	20	6	23
Health care access				
Regular family doctor	84	85	96	82
Health outcomes				
Asthmatic	16	11	28	13
Hypertensive	18	18	–	–
	Mean score (Range)			
Environmental risk factors				
Environmental risk index (ERI)	6.0 (1.0–17)	6.0 (1.0–17)	6.6 (1.0–17)	6.0 (1.0–17)

Table 2 Logistic regression analysis of factors associated with hypertension among Arab Americans in metro Detroit

	Total study population (N = 590)			Self-reported asthmatics omitted (N = 559)		
	OR	95% CI	P value	OR	95% CI	P value
<i>Univariate models</i>						
Socio-demographic factors						
Age	2.2	[1.89, 2.62]	<0.0001	2.4	[1.99, 2.82]	<0.0001
Sex (Reference = Male)	0.75	[0.49, 1.15]	0.19	0.79	[0.51, 1.22]	0.29
Health care access (regular family doctor)	5.5	[1.98, 15.4]	0.0011	5.1	[1.82, 14.2]	0.0019
Education	0.72	[0.64, 0.81]	<0.0001	0.70	[0.62, 0.80]	<0.0001
Environmental risk factors						
ERI Score (top 10% versus lower 90%)	1.7	[0.94, 3.02]	0.078	1.7	[0.93, 3.18]	0.084
ERI Score (per IQR)	1.2	[0.88, 1.56]	0.29	1.1	[0.84, 1.55]	0.40
<i>Multivariate models</i>						
Socio-demographic factors						
Age ^a	2.1	[1.77, 2.57]	<0.0001	2.3	[1.87, 2.79]	<0.0001
Sex (Reference = Male) ^a	1.1	[0.67, 1.94]	0.62	1.2	[0.71, 2.19]	0.44
Health care access (regular family doctor) ^a	3.6	[1.21, 10.4]	0.021	3.4	[1.14, 10.1]	0.028
Education ^a	0.95	[0.83, 1.09]	0.47	0.94	[0.81, 1.08]	0.39
Environmental risk factors						
ERI Score (top 10% versus lower 90%) ^b	1.6	[0.80, 3.21]	0.18	1.7	[0.82, 3.64]	0.15
ERI Score (per IQR) ^b	1.1	[0.80, 1.55]	0.53	1.1	[0.76, 1.56]	0.64

^a Adjusted odds ratios from multivariate models including age, sex, health care access, education, and ERI score (per IQR)

^b Adjusted for age, sex, health care access, and education

score was not significantly associated with hypertension, although there was a marginally significant positive association between binary ERI score (top 10% versus lower 90%) and hypertension in univariate models.

Factors Associated with Asthma

Logistic regression analyses of factors associated with asthma are presented in Table 3. Age was positively associated with asthma in univariate models; however the association between age and asthma was no longer significant in multivariate models including sex, health care access, education and ERI score. Health care access was positively associated with asthma in univariate and multivariate analyses, although the association between health care access and asthma only achieved statistical significance in univariate analyses excluding self-reported asthmatics. Education was inversely associated with asthma in univariate models, but this association was only marginally significant in multivariate models. Asthma prevalence did not vary by gender.

ERI score was positively associated with asthma in multivariate models adjusting for age, sex, health care access, and education (Table 3). The odds of having asthma increased by 1.5 per IQR (IQR = 4.0) of ERI score and participants with the highest ERI scores (top 10%) were 2.5 times more likely to have asthma compared with the rest of the study population. Associations between ERI and asthma were similar for models with and without self-reported asthmatics, although only the comparison of

high versus low ERI score achieved statistical significance when self-reported asthmatics were excluded.

Hypertension was significantly associated with asthma adjusting for age, sex, health care access, education and ERI score (Table 3). However, there was evidence of a positive (multiplicative) interaction between ERI score and hypertension as predictors of asthma (Tables 3, 4). This interaction was statistically significant in multivariate models (Table 3). Comparison of models including an interaction term for ERI and hypertension (Model 1) with models omitting the interaction term (Model 2) using the Likelihood Ratio test suggested that Model 1 (including multiplicative interaction between ERI and hypertension) was a better model for this study population (p value < 0.001).

Model 1:

$$\begin{aligned} \text{Asthma} = & \beta_0 + \beta \text{Hypertension} * \text{ERI} + \beta \text{Hypertension} \\ & + \beta \text{ERI} + \beta \text{age} + \beta \text{sex} \\ & + \beta \text{health care access} + \beta \text{education} \end{aligned}$$

Model 2:

$$\begin{aligned} \text{Asthma} = & \beta_0 + \beta \text{Hypertension} + \beta \text{ERI} + \beta \text{age} \\ & + \beta \text{sex} + \beta \text{healthcare access} + \beta \text{education} \end{aligned}$$

Stratum-specific odds ratios for participants with and without hypertension (Model 3) are presented in Table 4. The odds of reporting asthma were approximately 2.4 times greater per IQR increase in ERI among

Table 3 Logistic regression analysis of factors associated with asthma among Arab Americans in metro Detroit

	Total study population (<i>N</i> = 590)			Self-reported asthmatics omitted (<i>N</i> = 559)		
	OR	95% CI	<i>P</i> value	OR	95% CI	<i>P</i> value
<i>Univariate models</i>						
Socio-demographic factors						
Age	1.2	[1.02, 1.33]	0.027	1.1	[0.96, 1.34]	0.13
Sex (Reference = Male)	0.75	[0.48, 1.17]	0.21	0.87	[0.51, 1.48]	0.60
Health care access (regular family doctor)	2.1	[0.98, 4.50]	0.056	3.9	[1.18, 12.6]	0.025
Education	0.87	[0.78, 0.97]	0.012	0.82	[0.72, 0.94]	0.0056
Environmental risk factors						
ERI Score (top 10% versus lower 90%)	2.4	[1.37, 4.32]	0.0024	2.1	[1.07, 4.30]	0.031
ERI Score (per IQR)	1.5	[1.09, 1.97]	0.012	1.3	[0.89, 1.84]	0.18
Comorbidity						
Hypertension	2.7	[1.66, 4.50]	<0.0001	3.4	[1.92, 6.06]	<0.0001
<i>Multivariate models</i>						
Socio-demographic factors						
Age ^a	1.0	[0.89, 1.21]	0.63	0.98	[0.81, 1.18]	0.82
Sex (Reference = Male) ^a	0.71	[0.44, 1.15]	0.16	0.74	[0.41, 1.32]	0.30
Health care access (regular family doctor) ^a	2.1	[0.96, 4.62]	0.064	3.7	[1.10, 12.2]	0.034
Education ^a	0.88	[0.78, 1.00]	0.056	0.83	[0.71, 0.97]	0.020
Environmental risk factors						
ERI Score (top 10% versus lower 90%) ^b	2.5	[1.40, 4.60]	0.0021	2.3	[1.14, 4.84]	0.021
ERI Score (per IQR) ^b	1.5	[1.08, 1.99]	0.014	1.3	[0.88, 1.88]	0.18
Comorbidity						
Hypertension ^c	2.3	[1.30, 4.22]	0.0045	3.4	[1.68, 6.78]	0.0006
Interaction between ERI and hypertension						
ERI Score (per IQR) * Hypertension ^d	2.1	[1.02, 4.20]	0.043	2.8	[1.23, 6.54]	0.015

^a Adjusted odds ratios from multivariate models including age, sex, health care access, education, and ERI score (per IQR)

^b Adjusted for age, sex, health care access, and education

^c Adjusted for age, sex, health care access, education, and ERI score (per IQR)

^d Adjusted for age, sex, health care access, education, ERI score (per IQR), and hypertension

Table 4 Stratum-specific odds ratios for ERI and asthma for study participants with and without hypertension^a

	Odds ratios for participants with hypertension			Odds ratios for participants without hypertension		
	OR	95% CI	<i>P</i> value	OR	95% CI	<i>P</i> value
Total study population (<i>N</i> = 590)						
ERI Score (top 10% versus lower 90%)	3.9	[1.34, 11.4]	0.012	1.9	[0.89, 4.08]	0.099
ERI Score (per IQR)	2.4	[1.31, 4.28]	0.0042	1.1	[0.78, 1.68]	0.50
Self-reported asthmatics omitted (<i>N</i> = 559)						
ERI Score (top 10% versus lower 90%)	4.3	[1.35, 13.6]	0.014	1.3	[0.42, 3.83]	0.67
ERI Score (per IQR)	2.3	[1.22, 4.45]	0.011	0.82	[0.48, 1.40]	0.47

^a Stratum-specific odds ratios for ERI and asthma adjusted for age, sex, education, and health care access

participants with hypertension. Odds ratios for ERI and asthma among participants without hypertension were close to one per change in IQR.

The relationship between ERI and asthma did not vary significantly by gender (data not shown). ERI score appeared to be a stronger predictor of asthma among older adults (51–70+ years), but further analyses suggested that this apparent association was due to the high prevalence of hypertension among older adults (data not shown).

Discussion

This study explored relationships between environmental risk factors, hypertension and asthma among Arab American adults in the metro Detroit area. Asthma and hypertension were more common among respondents with low SES, while hypertension was more common among older adults in the study population. As reported in previous publications, [53, 54] the environmental risk index (ERI), a summary measure of household environmental risk factors, was positively

associated with asthma. ERI was not significantly associated with hypertension in multivariate models. This study also found that the relationship between ERI and asthma was significantly stronger among study participants with hypertension.

Few studies have explored the burden of chronic health problems among Arab Americans, and no previous studies have reported asthma prevalence in this population. Asthma prevalence among Arab Americans in the current study was compared with state, national, and international prevalence of asthma in a previous publication [53]. The prevalence of hypertension in the current study was consistent with the results of previous studies among Arab Americans. Hatahet et al. [59] reported high prevalence of risk factors for heart disease including obesity, hypertension and high cholesterol among Arab Americans residing in Southeast Michigan, while Dallo and James [60] reported a hypertension prevalence of 16% among Chaldean-American women in metro Detroit.

Socio-Demographic and Environmental Risk Factors for Asthma and Hypertension

Age was positively associated with hypertension, but not with asthma, in multivariate models adjusting for socio-demographic and environmental risk factors. Education was inversely associated with both asthma and hypertension; although associations between education and hypertension did not achieve statistical significance in multivariate models. The prevalence of asthma and hypertension did not vary by gender in this study population.

Socio-demographic risk factors for hypertension and asthma among Arab Americans were consistent with previously reported risk factors for asthma and hypertension. In the U.S. and other developed nations, the risk and prevalence of hypertension has been identified as higher among ethnic minority, low SES, and older age groups [61–64]. Low SES and ethnicity have also been identified as independent risk factors for asthma [65, 66]. As in the general population, SES indicators such as education and employment have also been inversely associated with systolic and diastolic blood pressure in a previous study among Arab Americans [60].

The environmental risk index (ERI) score was positively associated with asthma, but not with hypertension in multivariate models adjusting for socio-demographic confounders. The relationship between ERI score and asthma was consistent with the goal of developing the environmental risk index to assess household environmental risk factors for asthma. The relationship between ERI and asthma has been discussed in depth by Johnson et al. [53]. Although environmental risk factors such as low-level lead exposure [67, 68] have been associated with hypertension, there is no

evidence in the literature to suggest that household environmental risk factors for asthma were associated with hypertension. Therefore it was unsurprising that an instrument designed to assess environmental risk factors for asthma was not predictive of hypertensive status.

Asthma, ERI, and Hypertension

In the current study, the relationship between household environmental risk factors and asthma was stronger among participants with physician-diagnosed hypertension compared to those without a diagnosis of hypertension. There are several possible explanations for this apparent effect modification. For example, hypertension could act as a surrogate for a true effect modifier, most likely a shared risk factor for both asthma and hypertension. Alternately, hypertensive status could indicate increased susceptibility for asthma development. Increased susceptibility could arise from shared pathways and/or mechanisms of pathology associated with both asthma and hypertension, or increased susceptibility for asthma development due to physiological changes associated with hypertension. Although biological pathways and susceptibility are discussed in this paper as potential explanations for the interaction between environmental risk factors and hypertension as predictors of asthma, the cross-sectional nature of the current study limits our interpretation of this effect modification.

Hypertension could have acted as a surrogate for a risk factor that was not measured in the current study. For example, the true effect modifier could be a shared risk factor for asthma and hypertension that was not measured in the study population. There are several important risk factors shared by asthma and hypertension. Obesity has been linked with the development of both asthma [69–73] and hypertension [9, 10, 74–76]. Psychosocial stress has also been implicated in causal pathways for asthma [42–46] and hypertension [47–49]. Finally, environmental tobacco smoke (ETS) has been associated with both the development and exacerbation of asthma [77–81] and hypertension [82–85]. ETS was not assessed for all of the participants in this study, therefore the role of ETS could not be considered in the current analyses. However, among the subset of participants ($N = 200$) for whom ETS data was collected, the interaction between ERI and hypertension was similar, $P < 0.05$ (data not shown).

With the exception of ETS, there is little evidence in the literature to suggest shared environmental risk factors for asthma and hypertension. Low-level lead exposure has been causally associated with hypertension [67, 68] and a few studies have explored a potential association between lead exposure and asthma; however, current evidence is inconclusive. Pugh [86] found a significant association between lead poisoning and asthma among high-risk

children in Saginaw, Michigan, while Myers et al. [87] found no significant association between asthma and lead poisoning among children in Chicago, Illinois. Both studies were limited by design issues such as small sample size and accurate assessment of disease outcomes in the age group considered by the study. It is possible that the interaction observed in the current study could be due to unmeasured environmental insults, e.g., traffic pollution; however, further research is needed to explore this possibility.

Obesity may be the strongest risk factor associated with both hypertension and asthma in the literature. The role of obesity in hypertension has been well characterized [9, 10, 74–76] and there is growing evidence that obesity plays a causal role in asthma etiology [69–73]. However, the mechanism for increased asthma risk remains unclear. Several pathways including leptin or adiponectin production, mechanical changes in the smooth muscles of the airways, increased estrogen levels, and shared genes for asthma and obesity have been explored [9, 10, 73]. It has been suggested that the association between obesity and asthma could be explained by pathophysiological changes associated with hypertension [73]. Shared risk factors such as ETS, obesity, and stress have also been posited as potential explanations for asthma disparities among urban dwelling, low SES, and ethnic minority groups [15–17]. Further research is needed to determine the respective roles of hypertension and obesity in asthma outcomes and susceptibility.

An interaction between environmental risk factors and hypertension as predictors of asthma could be explained by shared mechanisms or pathways involved in disease pathology for both asthma and hypertension. Similarities between airway and vascular remodeling characteristic of asthma and hypertension, respectively, were identified in the early 1990s [88]. Recent research suggests that these pathways may include shared mechanisms such as differentiation and regulation of (vascular and airway) smooth muscle cells [89–91]. For example, abnormal contraction of smooth muscle cells regulated by myosin II through Ca^{2++} independent phosphorylation of regulatory myosin light chain has been implicated in the pathology of both asthma and hypertension [91].

Previous research suggests that endothelial dysfunction plays an integral role in the pathology of asthma and hypertension [73, 74, 92, 93]. Endothelins (ET), a family of peptides that influence vasoconstriction and vasodilation, have been identified as important factors in hypertension [9, 94–96]. ET has also been implicated in various pathways involved in asthma pathogenesis including bronchoconstriction, inflammation, airway remodeling, and mucous cell hyperplasia [73].

There is also evidence from previous studies that oxidative stress, inflammatory mediators, and inflammation, e.g., reactive oxygen species (ROS), may play a role in

both obesity-related hypertension [74, 76, 97–99] and asthma [29, 70, 71, 73]. Markers of oxidative stress such as reactive oxygen species (ROS) may reflect disease induced tissue damage. However, there is also some evidence that ROS can exacerbate disease processes, e.g., Damjanovi and Barton [100] reported potential vasoconstrictive properties of ROS.

Many of the mechanisms and pathways described above could play a role in the development of both asthma and hypertension. Alternately, increased levels of ET, ROS, and other factors associated with hypertension could contribute to asthma outcomes following the development of hypertension. Hypertensive status could also confer susceptibility with respect to asthma development through physiological changes associated with hypertension. In a recent review article, Shore [73] suggested several possible mechanisms through which hypertension could impact asthma outcomes. For example, hypertension induced heart failure could lead to peribronchial edema, which could exacerbate detachment of the airway wall from the lung parenchyma [73] and contribute to airway hyper-responsiveness.

The biological mechanisms and pathways identified in previous studies may provide potential explanations for the findings reported in the current study. However, the AAEHP did not collect data that could provide support for these hypotheses. Furthermore, the cross-sectional study design of the AAEHP precludes any causal inferences based on these analyses. Thus, the interpretations discussed in this paper remain speculative. While the results of this study were suggestive, further research is needed to determine whether hypertension acts as a risk factor for asthma and to explore the interaction between hypertension, environmental risk factors, and asthma.

The Arab American Environmental Health Project was the first to consider hypertension as a potential effect modifier of the relationship between environmental risk factors and asthma. However, several study characteristics limited the current analysis. The sample size was relatively small for assessing potential effect modification and performing stratified analyses. In addition, many additional variables that could have provided insight about the relationships reported in this paper were not assessed in the study population. For example, information about obesity, stress and post-traumatic stress disorder were not collected at the individual level for participants in this study; and ETS was collected for only a subset of the households in the study. Finally, the cross-sectional study design precluded conclusions about causality. Despite these limitations, the strength of the interaction between ERI and hypertension as predictors of asthma status in the current study suggests that this relationship warrants further scrutiny. Further research is needed to explore and evaluate this interaction among diverse populations.

Immigrant communities face a confluence of risk factors including dietary changes that may increase risk for metabolic and cardiovascular health problems including obesity and hypertension. New immigrants may also experience disproportionate exposure to environmental risk factors through substandard housing and residence in urban areas heavily impacted by ambient air pollution. While these issues have been explored in depth among other immigrant communities, AAEHP was the first study to assess asthma among Arab Americans and the first to explore potential modification of the relationship between environmental risk factors and asthma by metabolic/cardiovascular health problems.

The results of the current study suggest that individuals in this community with both hypertension and a high burden of environmental risk factors were more likely to have asthma. Effect modification of the relationship between environmental risk factors and asthma by hypertension could have serious implications among high-risk communities with a disproportionate burden of both asthma and cardiovascular/metabolic health problems. However, while these results are suggestive, further research is needed to confirm these findings and elucidate mechanisms or pathways that may explain the impact of hypertension on relationships between environmental risk factors and asthma.

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References

- Eggleston PA. The environment and asthma in US inner cities. *Chest*. 2007;132(5, Suppl):782S–8S. doi:[10.1378/chest.07-1906](#).
- Braman SS. The global burden of asthma. *Chest*. 2006;130(1, Suppl):4S–12S. doi:[10.1378/chest.130.1_suppl.4S](#).
- James WP. The epidemiology of obesity: the size of the problem. *J Intern Med*. 2008;263(4):336–52. doi:[10.1111/j.1365-2796.2008.01922.x](#).
- LeNoir MA. Asthma in inner cities. *J Natl Med Assoc*. 1999;91(8, Suppl):1S–8S.
- Reynolds K, He J. Epidemiology of the metabolic syndrome. *Am J Med Sci*. 2005;330(6):273–9. doi:[10.1097/00000441-200512000-00004](#).
- Behn A, Ur E. The obesity epidemic and its cardiovascular consequences. *Curr Opin Cardiol*. 2006;21(4):353–60. doi:[10.1097/01.hco.0000231406.84554.96](#).
- Batsis JA, Nieto-Martinez RE, Lopez-Jimenez F. Metabolic syndrome: from global epidemiology to individualized medicine. *Clin Pharmacol Ther*. 2007;82(5):509–24. doi:[10.1038/sj.clpt.6100355](#).
- Rana JS, Nieuwdorp M, Jukema JW, Kastelein JJ. Cardiovascular metabolic syndrome—an interplay of, obesity, inflammation, diabetes and coronary heart disease. *Diabetes Obes Metab*. 2007;9(3):218–32. doi:[10.1111/j.1463-1326.2006.00594.x](#).
- Francischetti EA, Genelhu VA. Obesity-hypertension: an ongoing pandemic. *Int J Clin Pract*. 2007;61(2):269–80. doi:[10.1111/j.1742-1241.2006.01262.x](#).
- Mathew B, Patel SB, Reams GP, Freeman RH, Spear RM, Villarreal D. Obesity-hypertension: emerging concepts in pathophysiology and treatment. *Am J Med Sci*. 2007;334(1):23–30. doi:[10.1097/MAJ.0b013e3180959e4e](#).
- Kearney PM, Whelton M, Reynolds K, Muntner P, Whelton PK, He J. Global burden of hypertension: analysis of worldwide data. *Lancet*. 2005;365(9455):217–23.
- Lawes CM, Vander Hoorn S, Rodgers A. Global burden of blood-pressure-related disease, 2001. *Lancet*. 2008;371(9623):1513–8. doi:[10.1016/S0140-6736\(08\)60655-8](#).
- Evans R 3rd. Epidemiology of asthma in childhood. *Paediatrician*. 1991;18(4):250–6.
- Crain EF, Weiss KB, Bijur PE, Hersh M, Westbrook L, Stein RE. An estimate of the prevalence of asthma and wheezing among inner-city children. *Pediatrics*. 1994;94(3):356–62.
- Federico MJ, Liu AH. Overcoming childhood asthma disparities of the inner-city poor. *Pediatr Clin North Am*. 2003;50(3):655–75. doi:[10.1016/S0031-3955\(03\)00045-2](#).
- Gold DR, Wright R. Population disparities in asthma. *Annu Rev Public Health*. 2005;26:89–113. doi:[10.1146/annurev.publhealth.26.021304.144528](#).
- Wright RJ, Subramanian SV. Advancing a multilevel framework for epidemiologic research on asthma disparities. *Chest*. 2007;132(5, Suppl):757S–69S. doi:[10.1378/chest.07-1904](#).
- Kurian AK, Cardarelli KM. Racial and ethnic differences in cardiovascular disease risk factors: a systematic review. *Ethn Dis*. 2007;17(1):143–52.
- Davis AM, Vinci LM, Okwuosa TM, Chase AR, Huang ES. Cardiovascular health disparities: a systematic review of health care interventions. *Med Care Res Rev*. 2007;64(5, Suppl):29S–100S. doi:[10.1177/1077558707305416](#).
- Minor DS, Wofford MR, Jones DW. Racial and ethnic differences in hypertension. *Curr Atheroscler Rep*. 2008;10(2):121–7. doi:[10.1007/s11883-008-0018-y](#).
- Rottem M, Szyper-Kravitz M, Shoenfeld Y. Atopy and asthma in migrants. *Int Arch Allergy Immunol*. 2005;136(2):198–204. doi:[10.1159/000083894](#).
- Holguin F, Mannino DM, Antó J, Mott J, Ford ES, Teague WG, et al. Country of birth as a risk factor for asthma among Mexican Americans. *Am J Respir Crit Care Med*. 2005;171:103–8. doi:[10.1164/rccm.200402-143OC](#).
- Wylie-Rosett J, Mossavar-Rahmani Y, Gans K. Recent dietary guidelines to prevent and treat cardiovascular disease, diabetes, and obesity. *Heart Dis*. 2002;4(4):220–30. doi:[10.1097/00132580-200207000-00005](#).
- Gordon-Larsen P, Harris KM, Ward DS, Popkin BM. National Longitudinal Study of Adolescent Health. Acculturation and overweight-related behaviors among Hispanic immigrants to the US: the National Longitudinal Study of Adolescent Health. *Soc Sci Med*. 2003;57(11):2023–34. doi:[10.1016/S0277-9536\(03\)00072-8](#).
- Candib LM. Obesity and diabetes in vulnerable populations: reflection on proximal and distal causes. *Ann Fam Med*. 2007;5(6):547–56. doi:[10.1370/afm.754](#).
- Gilbert PA, Khokhar S. Changing dietary habits of ethnic groups in Europe and implications for health. *Nutr Rev*. 2008;66(4):203–15.
- Chowdhuri S, Crook ED, Taylor HA Jr, Badr MS. Cardiovascular complications of respiratory diseases. *Am J Med Sci*. 2007;334(5):361–80.

28. Dogra S, Arderm CI, Baker J. The relationship between age of asthma onset and cardiovascular disease in Canadians. *J Asthma*. 2007;44(10):849–54. doi:[10.1080/02770900701752391](https://doi.org/10.1080/02770900701752391).
29. Nathan C. Epidemic inflammation: pondering obesity. *Mol Med* 2008;14(7–8):485–92.
30. Chaudhuri N. Interventions to improve children's health by improving the housing environment. *Rev Environ Health*. 2004; 19(3–4):197–222.
31. Manuel J. A healthy home environment? *Environ Health Perspect*. 1999;107(7):A352–7. doi:[10.2307/3434388](https://doi.org/10.2307/3434388).
32. Krieger J, Higgins DL. Housing and health: time again for public health action. *Am J Public Health*. 2002;92(5):758–68.
33. Saegert SC, Klitzman S, Freudenberg N, Cooperman-Mroczek J, Nassar S. Healthy housing: a structured review of published evaluations of US interventions to improve health by modifying housing in the United States, 1990–2001. *Am J Public Health*. 2003;93(9):1471–7.
34. Samet JM, Spengler JD. Indoor environments and health: moving into the 21st Century. *Am J Public Health*. 2003;93(9): 1489–93.
35. Jacobs DE, Kelly T, Sobolewski J. Linking public health, housing, and indoor environmental policy: successes and challenges at local and federal agencies in the United States. *Environ Health Perspect*. 2007;115(6):976–82.
36. Wu F, Jacobs D, Mitchell C, Miller D, Karol MH. Improving indoor environmental quality for public health: impediments and policy recommendations. *Environ Health Perspect*. 2007;115(6): 953–7.
37. Eggleston PA, Buckley TJ, Breyse PN, Wills-Karp M, Kleeberger SR, Jaakkola JJ. The environment and asthma in US inner cities. *Environ Health Perspect*. 1999;107(Suppl 3):439–50.
38. Eggleston PA. Environmental causes of asthma in inner city children. The National Cooperative Inner City Asthma Study. *Clin Rev Allergy Immunol*. 2000;18(3):311–24. doi:[10.1385/CRIAI.18.3.311](https://doi.org/10.1385/CRIAI.18.3.311).
39. IOM (Institute of Medicine) Committee on the assessment of asthma and indoor air clearing the air: asthma and indoor exposures. Washington, DC: National Academy Press; 2000.
40. Jones AP. Asthma and the home environment. *J Asthma*. 2000; 37(2):103–24. doi:[10.3109/02770900009055434](https://doi.org/10.3109/02770900009055434).
41. Sandel M, Wright RJ. When home is where the stress is: expanding the dimensions of housing that influence asthma morbidity. *Arch Dis Child*. 2006;91(11):942–8. doi:[10.1136/adc.2006.098376](https://doi.org/10.1136/adc.2006.098376).
42. Lehrer P, Feldman J, Giardino N, Song HS, Schmalzing K. Psychological aspects of asthma. *J Consult Clin Psychol*. 2002; 70(3):691–711. doi:[10.1037/0022-006X.70.3.691](https://doi.org/10.1037/0022-006X.70.3.691).
43. Wright RJ. Stress and atopic disorders. *J Allergy Clin Immunol*. 2005;116:1301–6. doi:[10.1016/j.jaci.2005.09.050](https://doi.org/10.1016/j.jaci.2005.09.050).
44. Vig RJ, Forsythe P, Vliagoftis H. The role of stress in asthma: insight from studies on the effect of acute and chronic stressors in models of airway inflammation. *Ann N Y Acad Sci*. 2006; 1088:65–77. doi:[10.1196/annals.1366.023](https://doi.org/10.1196/annals.1366.023).
45. Chen E, Miller GE. Stress and inflammation in exacerbations of asthma. *Brain Behav Immun*. 2007;21(8):993–9. doi:[10.1016/j.bbi.2007.03.009](https://doi.org/10.1016/j.bbi.2007.03.009).
46. Wright RJ. Further evidence that the wealthier are healthier: negative life events and asthma-specific quality of life. *Thorax*. 2007;62:106–8. doi:[10.1136/thx.2006.067926](https://doi.org/10.1136/thx.2006.067926).
47. Rosmond R. Role of stress in the pathogenesis of the metabolic syndrome. *Psychoneuroendocrinology*. 2005;30(1):1–10. doi:[10.1016/j.psyneuen.2004.05.007](https://doi.org/10.1016/j.psyneuen.2004.05.007).
48. Kyrou I, Chrousos GP, Tsigos C. Stress, visceral obesity, and metabolic complications. *Ann N Y Acad Sci*. 2006;1083:77–110. doi:[10.1196/annals.1367.008](https://doi.org/10.1196/annals.1367.008).
49. Innes KE, Vincent HK, Taylor AG. Chronic stress and insulin resistance-related indices of cardiovascular disease risk, part I: neurophysiological responses and pathological sequelae. *Altern Ther Health Med*. 2007;13(4):46–52.
50. Huh J, Prause JA, Dooley CD. The impact of nativity on chronic diseases, self-rated health and comorbidity status of Asian and Hispanic immigrants. *J Immigr Minor Health*. 2008;10(2):103–18. doi:[10.1007/s10903-007-9065-7](https://doi.org/10.1007/s10903-007-9065-7).
51. Brugge D, Lee AC, Woodin M, Rioux C. Native and foreign born as predictors of pediatric asthma in an Asian immigrant population: a cross sectional survey. *Environ Health*. 2007;6:13. doi:[10.1186/1476-069X-6-13](https://doi.org/10.1186/1476-069X-6-13).
52. Rodriguez MA, Winkleby MA, Ahn D, Sundquist J, Kraemer HC. Identification of population subgroups of children and adolescents with high asthma prevalence: findings from the third national health and nutrition examination survey. *Arch Pediatr Adolesc Med*. 2002;156(3):269–75.
53. Johnson MM, Nriagu JO, Hammad AS, Savoie KL, Jamil HJ. Asthma prevalence and severity in Arab American communities in the Detroit area Michigan. *J Immigr Health*. 2005;7(3):165–78. doi:[10.1007/s10903-005-3673-x](https://doi.org/10.1007/s10903-005-3673-x).
54. Johnson MM, Nriagu JO, Hammad AS, Savoie KL, Jamil HJ. Environmental disease burden in Arab American communities of the Detroit area: prevalence and severity. *Ethn Dis*. 2005; 15(1, Suppl 1):S49–51.
55. O'Fallon LR, Dearth A. Community-based participatory research as a tool to advance environmental health sciences. *Environ Health Perspect*. 2002;110(Suppl 2):155–9.
56. Parker EA, Israel BA, Williams M, Brakefield-Caldwell W, Lewis TC, Robins T, et al. Community action against asthma: examining the partnership process of a community-based participatory research project. *J Gen Intern Med*. 2003;18(7):558–67. doi:[10.1046/j.1525-1497.2003.20322.x](https://doi.org/10.1046/j.1525-1497.2003.20322.x).
57. ACAAI (American College of Allergy Asthma and Immunology). Nationwide asthma screening program. 2004; www.acaai.org/public/lifeQuality/lq.htm.
58. University of Michigan Health Services. 2004; <http://www.med.umich.edu/wheas/test.htm>.
59. Hatahet W, Khosla P, Fungwe TV. Prevalence of risk factors to coronary heart disease in an Arab-American population in southeast Michigan. *Int J Food Sci Nutr*. 2002;53(4):325–35. doi:[10.1080/09637480220138124](https://doi.org/10.1080/09637480220138124).
60. Dallo FJ, James SA. Acculturation and blood pressure in a community-based sample of Chaldean-American women. *J Immigr Minor Health*. 2000;2(3):145–53. doi:[10.1023/A:1009560903668](https://doi.org/10.1023/A:1009560903668).
61. Task Force Report. Prevention of coronary heart disease in clinical practice. *Eur Heart J*. 1998;19:1434–503. doi:[10.1053/euhj.1998.1243](https://doi.org/10.1053/euhj.1998.1243).
62. Huether SE, McCance KL. Understanding pathophysiology. St. Louis, MO: Mosby Inc.; 2000.
63. NAAS (National Academy on an Aging Society). Heart disease: A disabling yet preventable condition. 2000; www.agingociety.org/agingociety/publications/chronic/index.html.
64. Arderm CI, Janssen I. Metabolic syndrome and its association with morbidity and mortality. *Appl Physiol Nutr Metab*. 2007;32 (1):33–45. doi:[10.1139/H06-099](https://doi.org/10.1139/H06-099).
65. Grant EN, Lyttle CS, Weiss KB. The relation of socioeconomic factors and racial/ethnic differences in US asthma mortality. *Am J Public Health*. 2000;90(12):1923–5.
66. Lester LA, Rich SS, Blumenthal MN, Togias A, Murphy S, Malveaux F, et al. Collaborative Study on the Genetics of Asthma. Ethnic differences in asthma and associated phenotypes: collaborative study on the genetics of asthma. *J Allergy Clin Immunol*. 2001;108(3):357–62. doi:[10.1067/mai.2001.117796](https://doi.org/10.1067/mai.2001.117796).
67. Vaziri ND, Sica DA. Lead-induced hypertension: role of oxidative stress. *Curr Hypertens Rep*. 2004;6(4):314–20. doi:[10.1007/s11906-004-0027-3](https://doi.org/10.1007/s11906-004-0027-3).

68. Nriagu JO, Meliker JR, Johnson MM. Environmental risks and disease burdens in developing countries. In: Frumkin H, editor. *Environmental health: from global to local*. San Francisco: Jossey-Bass; 2005.
69. Ford ES. The epidemiology of obesity and asthma. *J Allergy Clin Immunol*. 2005;115(5):897–909. doi:[10.1016/j.jaci.2004.11.050](https://doi.org/10.1016/j.jaci.2004.11.050).
70. Schaub B, von Mutius E. Obesity and asthma, what are the links? *Curr Opin Allergy Clin Immunol*. 2005;5(2):185–93. doi:[10.1097/01.all.0000162313.64308.b5](https://doi.org/10.1097/01.all.0000162313.64308.b5).
71. Beuther DA, Weiss ST, Sutherland ER. Obesity and asthma. *Am J Respir Crit Care Med*. 2006;174(2):112–9. doi:[10.1164/rccm.200602-231PP](https://doi.org/10.1164/rccm.200602-231PP).
72. Hersoug LG, Linneberg A. The link between the epidemics of obesity and allergic diseases: does obesity induce decreased immune tolerance? *Allergy*. 2007;62(10):1205–13. doi:[10.1111/j.1398-9995.2007.01506.x](https://doi.org/10.1111/j.1398-9995.2007.01506.x).
73. Shore SA. Obesity and asthma: possible mechanisms. *J Allergy Clin Immunol*. 2008;121(5):1087–93. doi:[10.1016/j.jaci.2008.03.004](https://doi.org/10.1016/j.jaci.2008.03.004).
74. Meyers MR, Gokce N. Endothelial dysfunction in obesity: etiological role in atherosclerosis. *Curr Opin Endocrinol Diabetes Obes*. 2007;14(5):365–9.
75. Vogt B, Bochud M, Burnier M. The association of aldosterone with obesity-related hypertension and the metabolic syndrome. *Semin Nephrol*. 2007;27(5):529–37. doi:[10.1016/j.semnephrol.2007.07.009](https://doi.org/10.1016/j.semnephrol.2007.07.009).
76. Yanai H, Tomono Y, Ito K, Furutani N, Yoshida H, Tada N. The underlying mechanisms for development of hypertension in the metabolic syndrome. *Nutr J*. 2008;7:10. doi:[10.1186/1475-2891-7-10](https://doi.org/10.1186/1475-2891-7-10).
77. Koenig JQ. Air pollution and asthma. *J Allergy Clin Immunol*. 1999;104(4 part 1):717–22. doi:[10.1016/S0091-6749\(99\)70280-0](https://doi.org/10.1016/S0091-6749(99)70280-0).
78. Strachan DP. The role of environmental factors in asthma. *Br Med Bull*. 2000;56(4):865–82. doi:[10.1258/0007142001903562](https://doi.org/10.1258/0007142001903562).
79. Landau LI. Parental smoking: asthma and wheezing illnesses in infants and children. *Paediatr Respir Rev*. 2001;2(3):202–6. doi:[10.1053/prrv.2001.0141](https://doi.org/10.1053/prrv.2001.0141).
80. Eisner MD. Environmental tobacco smoke and adult asthma. *Clin Chest Med*. 2002;23(4):749–61. doi:[10.1016/S0272-5231\(02\)00033-3](https://doi.org/10.1016/S0272-5231(02)00033-3).
81. Chippes BE. Determinants of asthma and its clinical course. *Ann Allergy Asthma Immunol*. 2004;93(4):309–15.
82. Sleight P. Smoking and hypertension. *Clin Exp Hypertens*. 1993;15(6):1181–92. doi:[10.3109/10641969309037104](https://doi.org/10.3109/10641969309037104).
83. Omvik P. How smoking affects blood pressure. *Blood Press*. 1996;5(2):71–7. doi:[10.3109/08037059609062111](https://doi.org/10.3109/08037059609062111).
84. Cacciola RR, Guarino F, Polosa R. Relevance of endothelial-haemostatic dysfunction in cigarette smoking. *Curr Med Chem*. 2007;14(17):1887–92. doi:[10.2174/092986707781058832](https://doi.org/10.2174/092986707781058832).
85. Yun AJ, Bazar KA, Lee PY, Gerber A, Daniel SM. The smoking gun: many conditions associated with tobacco exposure may be attributable to paradoxical compensatory autonomic responses to nicotine. *Med Hypotheses*. 2005;64(6):1073–9. doi:[10.1016/j.mehy.2004.11.040](https://doi.org/10.1016/j.mehy.2004.11.040).
86. Pugh PL. Assessing the comorbidity of lead and asthma among children in urban areas of Saginaw, Michigan. Masters thesis, University of Michigan School of Public Health; 2005.
87. Myers SN, Rowell B, Binns HJ. Lead poisoning and asthma: an examination of comorbidity. *Arch Pediatr Adolesc Med*. 2002;156(9):863–6.
88. Stewart AG, Tomlinson PR, Wilson J. Airway wall remodelling in asthma: a novel target for the development of anti-asthma drugs. *Trends Pharmacol Sci*. 1993;14(7):275–9. doi:[10.1016/0165-6147\(93\)90130-C](https://doi.org/10.1016/0165-6147(93)90130-C).
89. Goncharova EA, Goncharov DA, Krymskaya VP. Assays for in vitro monitoring of human airway smooth muscle (ASM) and human pulmonary arterial vascular smooth muscle (VSM) cell migration. *Nat Protoc*. 2006;1(6):2933–9. doi:[10.1038/nprot.2006.434](https://doi.org/10.1038/nprot.2006.434).
90. Rzucidlo EM, Martin KA, Powell RJ. Regulation of vascular smooth muscle cell differentiation. *J Vasc Surg*. 2007;45(Suppl A):A25–32. doi:[10.1016/j.jvs.2007.03.001](https://doi.org/10.1016/j.jvs.2007.03.001).
91. Yamada A, Hirose K, Hashimoto A, Iino M. Real-time imaging of myosin II regulatory light-chain phosphorylation using a new protein biosensor. *Biochem J*. 2005;385(2):589–954. doi:[10.1042/BJ20040778](https://doi.org/10.1042/BJ20040778).
92. Jonk AM, Houben AJ, de Jongh RT, Serné EH, Schaper NC, Stehouwer CD. Microvascular dysfunction in obesity: a potential mechanism in the pathogenesis of obesity-associated insulin resistance and hypertension. *Physiology (Bethesda, MD)*. 2007;22:252–60. doi:[10.1152/physiol.00012.2007](https://doi.org/10.1152/physiol.00012.2007).
93. Grossman E. Does increased oxidative stress cause hypertension? *Diabetes Care*. 2008;31(Suppl 2):S185–9. doi:[10.2337/dc08-s246](https://doi.org/10.2337/dc08-s246).
94. Diamant M, Tushuizen ME. The metabolic syndrome and endothelial dysfunction: common highway to type 2 diabetes and CVD. *Curr Diabetes Rep*. 2006;6(4):279–86. doi:[10.1007/s11892-006-0061-4](https://doi.org/10.1007/s11892-006-0061-4).
95. Kohan DE. Endothelin-1 and hypertension: from bench to bedside. *Curr Hypertens Rep*. 2008;10(1):65–9. doi:[10.1007/s11906-008-0013-2](https://doi.org/10.1007/s11906-008-0013-2).
96. Tostes RC, Fortes ZB, Callera GE, Montezano AC, Touyz RM, Webb RC, et al. Endothelin, sex and hypertension. *Clin Sci*. 2008;114(2):85–97. doi:[10.1042/CS20070169](https://doi.org/10.1042/CS20070169).
97. De la Fuente M, Hernanz A, Vallejo MC. The immune system in the oxidative stress conditions of aging and hypertension: favorable effects of antioxidants and physical exercise. *Antioxid Redox Signal*. 2005;7(9–10):1356–66. doi:[10.1089/ars.2005.7.1356](https://doi.org/10.1089/ars.2005.7.1356).
98. Alam I, Lewis K, Stephens JW, Baxter JN. Obesity, metabolic syndrome and sleep apnoea: all pro-inflammatory states. *Obes Rev*. 2007;8(2):119–27. doi:[10.1111/j.1467-789X.2006.00269.x](https://doi.org/10.1111/j.1467-789X.2006.00269.x).
99. Calabro P, Yeh ET. Intra-abdominal adiposity, inflammation, and cardiovascular risk: new insight into global cardiometabolic risk. *Curr Hypertens Rep*. 2008;10(1):32–8. doi:[10.1007/s11906-008-0008-z](https://doi.org/10.1007/s11906-008-0008-z).
100. Damjanovi M, Barton M. Fat intake and cardiovascular response. *Curr Hypertens Rep*. 2008;10(1):25–31. doi:[10.1007/s11906-008-0007-0](https://doi.org/10.1007/s11906-008-0007-0).