Original Article

Asthma and Allergic Disorders in Uganda: A Population-Based Study Across Urban and Rural Settings

Brooks W. Morgan, MSPH[a], Trishul Siddharthan, MD[a], Matthew R. Grigsby, MSPH[a], Suzanne L. Pollard, PhD[a], Robert Kalyesubula, MBBCh, MMed[b], Robert A. Wise, MD[a], Bruce Kirenga, MBBCh, MMed[b], and William Checkley, MD, PhD[a,c] *Baltimore, Md; and Kampala, Uganda*

What is already known about this topic? Asthma and allergic disorders have been heavily linked to urbanization and associated lifestyle and environmental exposures. Unplanned urbanization in the form of periurban sprawl is increasing quickly in sub-Saharan Africa.

What does this article add to our knowledge? We use a population-based cohort of adults in urban and rural areas to compare the prevalence, risk factors, and population attributable fractions of allergic disorders, spotlighting the burden and causes of disease in Uganda.

How does this study impact current management guidelines? Asthma is not currently being diagnosed or treated appropriately in Uganda. Our data indicate that asthma and allergic disorders constitute a sizable health burden, requiring attention from hospitals and the Ministry of Health.

BACKGROUND: Allergic diseases are increasing in sub-Saharan Africa, but few studies have characterized the burden among adults.

OBJECTIVE: We conducted a study to evaluate the prevalence and risk factors of allergic disorders in urban and rural Uganda.

METHODS: We present a cross-sectional analysis of enrollment data from a population-based cohort study of adults aged ≥35 years in urban and rural Uganda. Sociodemographic and both lifetime and 12-month respiratory symptoms data were collected and spirometry was conducted following standard guidelines.

RESULTS: In 1,308 adults (median age 43.8 years and 52.3% female), we found an age-adjusted prevalence of 6.8% for asthma (9.8% urban, 4.3% rural; $P < .001$), 11.9% for allergic rhinitis (16.4% urban, 7.8% rural; $P < .001$), and 8.2% for eczema (9.9% urban, 7.8% rural; $P = .15$). Urbanization was the primary driver of asthma, accounting for 61.4% of cases (95% confidence interval [CI] 22.0% to 83.4%), and was the strongest risk factor for any allergic illness (odds ratio [OR] = 1.87, 95% CI 1.39-2.51). Parental asthma was not associated with allergic illness. Asthma was associated with a lower forced expiratory volume in 1 second (FEV_1) by 0.56 *z* scores (95% CI 0.33-0.80). We found a dose-response association between lower quintiles of the FEV_1/forced vital capacity ratio and both hospitalization (OR = 1.77, 95% CI 1.21-2.59) and impairment in daily activities (1.65, 1.20-2.27).

CONCLUSIONS: Asthma and allergic rhinitis were twice as prevalent in urban settings. Asthma was associated with greater impairment and worse lung function outcomes. We identified a high prevalence of allergic disorders in Uganda, which can be expected to increase due to urbanization and resultant exposures throughout early development. © 2017 American Academy of Allergy, Asthma & Immunology (J Allergy Clin Immunol Pract 2017;■:■-■)

Key words: *Asthma; Allergies; Rhinitis; Eczema; Uganda; Sub-Saharan Africa; Epidemiology; Risk factors; Population attributable fraction*

Asthma is a chronic respiratory disease characterized by airway inflammation, which causes difficulty breathing and affects more than 358 million people worldwide.[1] The prevalence of asthma is increasing quickly in low- and middle-income countries (LMICs) even as it declines in high-income countries, and the majority of

[a]Division of Pulmonary and Critical Care, School of Medicine, Johns Hopkins University, Baltimore, Md
[b]Department of Medicine and Lung Institute, College of Health Sciences, Makerere University, Kampala, Uganda
[c]Department of International Health, Johns Hopkins Bloomberg School of Public Health, Baltimore, Md

This study was supported in part by the Fogarty International Center (5R25TW009340) and by COPD Discovery Award from Johns Hopkins University.

Conflicts of interest: R. A. Wise reports grants and/or personal fees from AstraZeneca/Medimmune, Boehringer Ingelheim, Contrafect, GlaxoSmithKline, Pfizer, Pulmonx, Roche, Spiration, Sunovion, Teva, Pearl Therapeutics, Merck, and Bonti outside the submitted work. The rest of the authors declare that they have no relevant conflicts of interest.

Received for publication September 16, 2017; revised November 2, 2017; accepted for publication November 20, 2017.

Available online ■■

Corresponding author: William Checkley, MD, PhD, Division of Pulmonary and Critical Care, School of Medicine, Johns Hopkins University, 1830 E. Monument Street, Room 555, Baltimore, MD 21205. E-mail: wcheckl1@jhmi.edu.

2213-2198

https://doi.org/10.1016/j.jaip.2017.11.032

Abbreviations used
ACQ- Asthma control questionnaire
ATS- American thoracic society
BMI- Body mass index
CI- Confidence interval
ERS- European respiratory society
FEV_1- Forced expiratory volume in 1 second
FVC- Forced vital capacity
HIV- Human immunodeficiency virus
LiNK- Lung function in Nakaseke and Kampala study
LMIC- Low- and middle-income country
OR- Odds ratio
PAF- Population attributable fraction
WHO- World Health Organization

deaths from asthma occur in LMICs.[1,2] Asthma and allergic disorders contribute significantly to morbidity, mortality, and economic burden, including both direct (monetary) and indirect (impaired productivity) costs.[2] Urbanization is one of the most important risk factors for allergic disorders, which can be explained in part by the adoption of poor nutrition, reduced physical activity, and environmental factors such as traffic and industry-related air pollution.[3-5] The prevalence of asthma is expected to rise in sub-Saharan Africa as rural to urban migration rapidly increases.[6]

Representative of this demographic transition, the urban population in Uganda grew from 800,000 in 1980 to 7.4 million in 2014.[7] This growth was largely unplanned, periurban sprawl, which increases exposure to ground and house allergens as well as air pollution from dust and traffic, all of which have been previously linked to increased asthma and allergic disorders in LMIC settings.[8-12] To date, there has been only 1 population-based study of respiratory disease among adults in rural Uganda, which focused on chronic obstructive pulmonary disease.[13] Data on the prevalence of allergic illness and risk factors are required to direct public health policy and medical treatment programs in Uganda.

We hypothesized that, based on previous literature and due to unplanned urban sprawl, asthma and other allergic disorders would be more prevalent in urban regions. To investigate this, we conducted a cross-sectional analysis of a population-based cohort study of urban and rural areas in Uganda. We also sought to identify risk factors and their population attributable fractions (PAFs) and document the prevalence of lifestyle impairment-related asthma outcomes and differences in care-seeking behavior between sites.

METHODS

Study setting

The study was carried out in 2 settings in Uganda with differing levels of urbanization. Kampala, the capital, has an estimated 416,000 households and a population of 1.5 million.[7] Nakaseke is a rural health district approximately 50 km north-northwest of Kampala that includes a central periurban community. Nakaseke comprises 43,000 households and 197,000 people.[7] Air quality in Kampala is poor, with a mean of 5.3 times the World Health Organization (WHO)-recommended level of daily particulate matter ($PM_{2.5}$), and is worse in industrial areas and residential neighborhoods with unpaved roads.[14] Although there are currently no published data on air quality in Nakaseke, it is a long distance from major city centers (50 km from downtown Kampala and 14 km from the nearest highway).

Study design

Participants were enrolled in the Lung Function in Nakaseke and Kampala (LiNK) study, a population-based cohort study whose primary objective was to characterize the prevalence and risk factors for chronic respiratory diseases in adults in urban and rural settings of Uganda.[15] The study aimed to enroll 2,000 participants, 1,000 from each site. In participation with the Uganda Bureau of Statistics, we randomly selected 25 enumeration areas in each site using probability proportional to size sampling, as outlined by the WHO Expandable Programme on Immunization.[16,17] Within each of these enumeration areas, 1 adult was randomly sampled per household until 40 people were enrolled.

Inclusion criteria included age $\geq$35 years, full-time residency of the catchment area, and the ability to provide informed consent. Exclusion criteria included pregnancy, active pulmonary infection, active tuberculosis, and recent surgery. Trained field workers administered demographic and health surveys using tablet computers with Open Data Kit software (University of Washington, Seattle, Wash) before asking participants to perform spirometry. Consent, surveys, spirometry, and other tests were administered in Luganda, the local language. The study protocol was approved by the institutional review boards of the Johns Hopkins School of Medicine in Baltimore, Md, and both the Uganda National Council of Science and Technology and Mulago National Referral Hospital in Kampala, Uganda.

We developed a survey concerning asthma diagnosis and control, rhinitis, eczema, and certain risk factors. Spirometry was conducted using flow-based, portable spirometers (Easy-On-PC, ndd, Zurich, Switzerland). We calculated z scores for forced expiratory volumes using the National Health and Nutrition Examination Survey (NHANES) African American reference population.[18] Spirometry was conducted following American Thoracic Society/European Respiratory Society (ATS/ERS) guidelines.[19] Tests were graded based on standardized guidelines for interpretation and quality control.[20]

Potential risk factors

Household size was defined by how many people, including the participant, live in their home. Exposure to biomass was defined as use of wood or charcoal for household cooking or heating. Unventilated cooking area was defined as a cooking space without a chimney or window that opens to the outside. Unimproved household water source was defined as using surface water or an unprotected well, or purchasing water from a tanker or cart. Unimproved household flooring was defined as sand, wood, or bare ground. Education was dichotomized into primary or less or greater than primary based on the highest level of school completed. In this area, completion of primary schooling equates to 7 years of education, whereas completion of secondary schooling equates to 13 years. Current smoking was defined as self-report of currently using any tobacco product, including cigarettes, cigars, and pipes. Personal history of human immunodeficiency virus (HIV) and tuberculosis were defined as self-report of ever being diagnosed with those conditions. Asthma in a family member was defined as self-report of a diagnosis of asthma in any member of the family, whereas parental asthma was specific to the mother or father. Body mass index (BMI) was calculated as weight/height^2 (kg/m^2). Obesity was defined as BMI $\geq$30 kg/m^2.

TABLE I. Demographics and risk factors comparison by field site

Variable	Kampala (51.8%, n = 677)	Nakaseke (48.2%, n = 631)	*P* value
Demographics: % (n) or median (IQR)			
Age (y)	41.0 (36.3-49.0)	46.7 (40.2-56.4)	<.001
Being female	51.6% (349)	53.1% (335)	.58
Body mass index (kg/m^2)	24.9 (21.7-29.3)	22.7 (20.6-25.9)	<.001
Primary education or less	48.7% (330)	80.0% (504)	<.001
Household size >3 people	72.2% (489)	65.0% (410)	.005
Unimproved water	5.5% (37)	8.2% (52)	.05
Unimproved floor	6.4% (43)	80.8% (510)	<.001
Unventilated cooking area	61.5% (415)	51.0% (322)	<.001
Risk factors: % (n)			
Current smoking	9.9% (67)	16.3% (103)	.001
Obesity (body mass index ≥30 kg/m^2)	21.2% (143)	9.5% (60)	<.001
Self-reported HIV	10.4% (62)	9.5% (47)	.65
Self-reported tuberculosis	3.1% (20)	2.1% (13)	.28
Current rhinitis	16.8% (97)	7.5% (44)	<.001
Current eczema	10.7% (61)	8.1% (48)	.13
Household biomass use	93.6% (630)	99.5% (628)	<.001
Asthma in a family member	22.7% (137)	0.5% (3)	<.001
Asthma in a parent	4.8% (29)	0.2% (1)	<.001

HIV, Human immunodeficiency virus; *IQR*, interquartile range.

Outcome definitions

Using questions adapted from the World Health Survey and the European Community Respiratory Health Survey, asthma was defined as meeting one of 3 criteria during the enrollment interview: (1) self-report of a previous diagnosis of asthma by a physician, (2) current use of medication for asthma (confirmed by the interviewer), or (3) self-report of wheezing in 12 months.[21,22] Asthma control was ascertained via the Asthma Control Questionnaire (ACQ).[23] We defined uncontrolled asthma as an ACQ score of 1 or greater.[24] Current rhinitis was defined as sneezing, runny or blocked nose, or itchy eyes without cold or flu-like symptoms within 12 months.[25] Current eczema was defined as itchy skin or rash in the prior 12 months.[25] Allergic multimorbidity was defined as a self-report of both asthma and either rhinitis or eczema. Lifestyle impairment outcomes included hospitalization for breathing within 12 months and impediment in performing daily activities due to breathing. Care-seeking behavior was dichotomized into "does not seek care" or "visits health facility" when feeling wheezy or short of breath.

Biostatistical methods

The primary analytical aims were to estimate age-adjusted prevalence of asthma and other allergic disorders and characterize risk factors associated with these conditions. After calculating prevalence estimates of asthma and other allergic disorders in these populations, 95% confidence intervals (CI) were calculated. Age-adjusted estimates were obtained by direct standardization of our site estimates to the Ugandan age distribution as provided by the Ugandan Bureau of Statistics. Chi-squared tests were used to determine differences in categorical data. Multivariable linear and logistic regression models were built to identify risk factors of allergic illnesses (asthma, rhinitis, and eczema) and the association between the presence of allergic disorders and lifestyle impairment. To identify risk factors, we modeled each allergic disorder as a binary outcome with the selected risk factor as a dependent variable. Tests of impairment included the outcome as the independent variable and allergic disorder as a dependent variable. All multivariable models were adjusted for age, sex, BMI, current smoking status, and site to reduce confounding. PAF was calculated using standard methods.[26] Analyses were performed in Stata version 13 (StataCorp, College Station, Tex) and R (www.r-project.org, Vienna, Austria).

RESULTS

Participant characteristics

A total of 1,769 participants were enrolled between November 2015 and June 2016. An asthma and allergic disorder-specific questionnaire was introduced mid-January 2016. Up to 2 telephone attempts were made to contact previously enrolled participants. A total of 461 (26.1%) could not be included in this analysis because of insufficient data to identify asthma. A total of 1,308 participants with complete data were included in the analysis (Table I).

There were differences in urbanization (34.9% vs 51.7%, $P < .001$), prevalence of women (59.4% vs 52.3%, $P = .008$), prevalence of post-treatment pulmonary tuberculosis (5.6% vs 2.6%, $P = .010$), prevalence of unimproved water source (3.9% vs 6.8%, $P = .027$), prevalence of unimproved household flooring (68.0% vs 42.3%, $P < .001$), and household use of biomass fuel (98.9% vs 96.5%, $P = .008$) when comparing excluded versus included individuals, respectively (Table E1, available in this article's Online Repository at www.jaci-inpractice.org). Age, BMI, education, household size, smoking, HIV status, asthma in the family, and kitchen ventilation did not vary between excluded and included individuals. Of those included, participants from Kampala were younger, more educated, and less likely to smoke cigarettes than participants from Nakaseke. Finally, 116 participants (8.9%) were further excluded from the analyses of lung function because of poor quality spirometry data.

Risk factors and health outcomes for allergic disorders

We plotted the crude and age-adjusted prevalence of allergic disorders by site in Figure 1. The overall age-adjusted prevalence

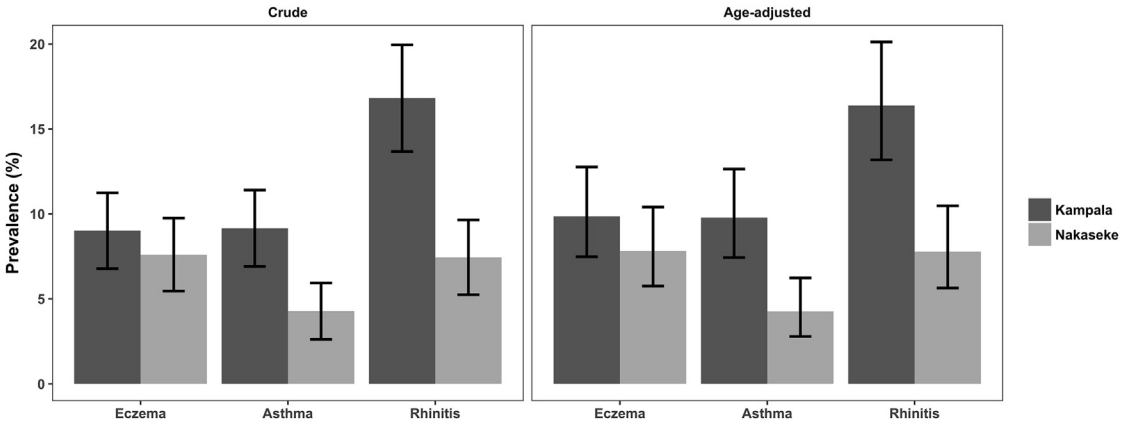

FIGURE 1. Crude and age-adjusted prevalence of allergic illness by site.

of asthma in adults in our sample was 6.8% (95% CI 5.4% to 8.4%). Asthma was more prevalent in Kampala (9.8%; 95% CI 7.4% to 12.6%) than in Nakaseke (4.3%; 95% CI 2.8% to 6.2%; $P < .001$). The age-adjusted prevalence of rhinitis was 11.9% overall (95% CI 10.0% to 14.1%), 16.4% in Kampala (95% CI 13.2% to 20.1%), and 7.8% in Nakaseke (95% CI 5.6% to 10.5%), a significant difference by site ($P < .001$). We found an 8.2% overall age-adjusted prevalence of eczema (95% CI 6.7% to 10.0%) that did not vary by site: 7.8% in Nakaseke (95% CI 5.8% to 10.4%) and 9.9% in Kampala (95% CI 7.5% to 12.8%). Concerning allergic multimorbidity, of those with asthma, 40.5% (95% CI 30.6% to 51.1%) had 1 or both of rhinitis and eczema. Multimorbidity was more common among women (46.9%; 95% CI 33.2% to 61.1%) than in men (32.5%; 95% CI 19.6% to 48.7%; $P = .17$). Of a subset of 34 participants with asthma who took the ACQ, 50% (17) had poorly controlled or uncontrolled asthma.

The overall prevalence of wheeze in the last 12 months was 4.4% (95% CI 3.4% to 5.6%) and did not vary by site: 3.7% in Nakaseke (95% CI 2.2% to 5.1%) and 5.0% in Kampala (95% CI 3.4% to 6.7%; $P = .22$). Although the prevalence of recent wheeze did not vary between sites among men, it was significantly different for women (Table II). Medication use and previous physician diagnosis of asthma were also much more common in our urban site than in our rural site. Furthermore, the prevalence of eczema was similar between men and women in the rural site, whereas it was far more prevalent among women in the urban site.

Those with allergic disorders (asthma, rhinitis, or eczema) differed from those without in terms of urbanization, household size, and flooring type (Table E2, available in this article's Online Repository at www.jaci-inpractice.org). In addition, there were differences in the prevalence of an unventilated cooking area and the presence of a family member with asthma between groups. After adjusting by age, sex, BMI, and current smoking, urban living remained strongly associated with asthma as well as having rhinitis (multivariable results in Table III and single variable results in Table E3, available in this article's Online Repository at www.jaci-inpractice.org). Associations were also seen between eczema and asthma, although neither were significant in Nakaseke after stratifying by site (Kampala: OR = 4.29, 95% CI 2.20 to 8.39; Nakaseke: OR = 1.15, 95% CI 0.26 to 5.1). A strong association was found between asthma and having any family member diagnosed with asthma, although nearly all the reports of family asthma came from Kampala. No association was seen between asthma and having a parent diagnosed with asthma. The protective association between unimproved household flooring and allergic illness (Table E2) disappeared after stratifying by site, which was strongly associated with floor material. Unventilated cooking space was a strong independent predictor of both rhinitis and eczema and remained significant for rhinitis across strata of sex, site, and reported biomass exposure. Eczema was the sole allergic disease associated with age; reduced risk was seen in older people.

The odds of being hospitalized for breathing in 12 months and the odds of reporting one's daily activities were impaired by

TABLE II. Sex-specific prevalence estimates of allergic illness

Variable	Kampala	Nakaseke	Total
Allergic illness: percent (95% CI)			
Men			
Asthma (combined)	7.9 (5.5, 11.4)	4.7 (2.8, 7.8)	6.4 (4.7, 8.6)
Physician diagnosis of asthma	2.1 (1.0, 4.4)	0.3 (0.0, 2.4)	1.3 (0.6, 2.5)
Recent use of medication	4.9 (3.0, 7.8)	0.7 (0.2, 2.7)	2.9 (1.8, 4.5)
Current wheeze	3.7 (2.1, 6.3)	3.7 (2.1, 6.6)	3.7 (2.5, 5.5)
Current rhinitis	15.8 (11.9, 20.6)	6.0 (3.8, 9.5)	10.9 (8.6, 13.8)
Current eczema	7.2 (4.7, 10.9)	8.2 (5.5, 12.0)	7.7 (5.7, 10.2)
Women			
Asthma (all causes)	10.3 (7.5, 14.0)	3.9 (2.3, 6.6)	7.2 (5.5, 9.4)
Physician diagnosis of asthma	3.2 (1.8, 5.6)	0.9 (0.3, 3.7)	2.0 (1.2, 3.4)
Recent use of medication	7.7 (5.4, 11.1)	0.3 (0.0, 2.1)	4.1 (2.8, 5.9)
Current wheeze	6.3 (4.2, 9.4)	3.6 (2.0, 6.2)	5.0 (3.6, 6.9)
Current rhinitis	17.8 (13.8, 22.6)	8.7 (6.0, 12.4)	13.2 (10.7, 16.1)
Current eczema	14.0 (10.5, 18.5)	8.0 (5.5, 11.6)	10.9 (8.7, 13.7)

CI, Confidence interval.

TABLE III. Risk factors for allergic illness adjusted for age, sex, body mass index, current smoking, and site

Variable	Asthma (6.8%, n = 89)	Rhinitis (12.1%, n = 141)	Eczema (9.4%, n = 109)
Risk factors: odds ratio (95% CI) for illness against nonillness			
Urban site (Kampala)	**2.32 (1.42, 3.80)**	**2.46 (1.65, 3.68)**	1.27 (0.83, 1.94)
Age ≥50 y	1.25 (0.78, 2.01)	1.04 (0.69, 1.55)	**0.56 (0.34, 0.91)**
Being female	1.06 (0.66, 1.69)	1.24 (0.84, 1.84)	**1.58 (1.01, 2.45)**
Body mass index (kg/m^2)	1.02 (0.98, 1.07)	1.00 (0.96, 1.04)	1.00 (0.96, 1.04)
Primary education or less	1.28 (0.79, 2.07)	1.01 (0.68, 1.50)	0.97 (0.62, 1.52)
Household size >3 people	1.42 (0.85, 2.37)	1.38 (0.91, 2.08)	**1.78 (1.10, 2.89)**
Unimproved water	1.36 (0.60, 3.07)	0.54 (0.21, 1.38)	0.71 (0.28, 1.80)
Unimproved floor	1.62 (0.78, 3.34)	0.80, (0.43, 1.47)	1.02 (0.53, 1.96)
Unventilated cooking area	1.32 (0.84, 2.08)	**2.32 (1.55, 3.48)**	**2.12 (1.37, 3.30)**
Current smoking	1.11 (0.56, 2.18)	0.95 (0.53, 1.72)	1.28 (0.69, 2.38)
Obesity (body mass index ≥30 kg/m^2)	1.61 (0.93, 2.78)	1.07 (0.66, 1.73)	1.01 (0.58, 1.76)
Self-reported HIV	1.20 (0.57, 2.52)	1.02 (0.54, 1.93)	1.53 (0.84, 2.81)
Self-reported tuberculosis	0.88 (0.20, 3.79)	0.95 (0.32, 2.80)	0.63 (0.15, 2.70)
Household biomass use	1.30 (0.38, 4.40)	1.00 (0.40, 2.49)	0.56 (0.22, 1.41)
Asthma in a family member	**4.12 (2.29, 7.40)**	**1.96 (1.16, 3.30)**	1.31 (0.69, 2.49)
Asthma in a parent	2.18 (0.79, 6.00)	1.99 (0.81, 4.89)	1.05 (0.30, 3.63)
Asthma	–	**3.55 (2.11, 5.96)**	**3.20 (1.79, 5.72)**
Current rhinitis	**3.52 (2.10, 5.93)**	–	**5.76 (3.67, 9.04)**
Current eczema	**3.22 (1.79, 5.76)**	**5.76 (3.66, 9.06)**	–

CI, Confidence interval; *HIV*, human immunodeficiency virus.
Bold indicates statistical significance ($P < .05$).

breathing were both much higher among participants with asthma than those with rhinitis or eczema, although each was associated with poorer outcomes (Table IV). Subgroup analyses indicated that those with uncontrolled asthma reported higher odds of hospitalization for breathing (OR = 3.79, 95% CI 0.51 to 28.0) and impediment of daily activities due to breathing (OR = 5.01, 95% CI 0.63 to 40.1) compared with those with controlled asthma, although neither were significant.

On average, participants with asthma had deficits of 0.31, 0.56, and 0.68 *z* scores in FVC, FEV_1, and FEV_1/FVC ratio, respectively, when compared with those without asthma. In addition, there was a dose-response relationship between ordered quintiles of FEV_1/FVC ratio and poor clinical outcomes (Table E4, available in this article's Online Repository at www.jaci-inpractice.org). The odds of hospitalization for breathing were 1.77 times higher for each lower quintile, whereas the odds of impediment of daily activities due to breathing rose by a factor of 1.65. Those in the lowest quintile of FEV_1/FVC ratio were much more likely to report hospitalization (OR = 10.1) and life impediment (OR = 6.36) than those in the highest quintile.

The presence of asthma among those with eczema was associated with increased reports of hospitalization and decreased lung performance by spirometry compared with the effect of asthma among those without eczema, indicating that eczema may modify the effect of asthma on health outcomes (Table V).

Population attributable fractions

We plotted the PAFs of potential risk factors for asthma (Figure 2). The greatest modifiable drivers of asthma were urban living, household size >3 people, and having an unimproved source of water. Family history of asthma was a driver of asthma in Kampala but could not be calculated in Nakaseke due to low prevalence. Unventilated cooking area was a large driver of rhinitis in our cohort, while that and larger household size were drivers of eczema.

Health care–seeking behavior

One quarter of our sample opted to seek care when experiencing breathing problems (Table VI). This varied by site: 43.7% of participants in Nakaseke visited a hospital or clinic compared with 10.6% in Kampala. However, when restricted to those with recent wheeze, 50.0% of those in Kampala visited a facility compared with 31.6% in Nakaseke. Residents of Nakaseke who reported wheeze were diagnosed with asthma at a lower rate than in Kampala.

DISCUSSION

We conducted a population-based, cross-sectional study examining the prevalence, risk factors, and attributable fractions of allergic disorders among adults in urban and rural Uganda. To our knowledge, this is the first study of its kind in Uganda and one of very few in East Africa. We found an age-adjusted prevalence of asthma of 6.8%, which was significantly higher in our urban site than our rural site and comparable with the 7.4% prevalence found in the USA.[27] The 4.4% prevalence of current wheeze in our sample falls at the lower end of results from studies of adult asthma in Africa.[4,28-31] Important modifiable drivers of allergic disorders included urbanization, the presence of an unventilated cooking area, and large household size. These results play a valuable role in understanding the growing burden of allergic disease across East Africa—especially in light of increasing urbanization—and highlight the importance of addressing asthma through improved diagnosis and treatment.

Allergic illness was strongly associated with urbanization, which has been previously described, and may be due to a combination of pollution and poor sanitation secondary to

TABLE IV. Single variable and multivariable measures of impairment due to allergic illness; adjusted for age, sex, BMI, current smoking, and site

	Asthma (6.8%, n = 89)		Rhinitis (12.1%, n = 141)		Eczema (9.4%, n = 109)	
Variable	Single variable	Multivariable	Single variable	Multivariable	Single variable	Multivariable
Outcomes: odds ratio or change in mean in illness against non-illness						
Hospitalization	**20.9 (8.12, 53.7)**	**16.1 (6.08, 42.8)**	**7.12 (2.84, 17.9)**	**5.14 (2.01, 13.1)**	**4.46 (1.66, 12.0)**	**3.95 (1.41, 11.0)**
Daily activities impeded by breathing	**26.4 (11.5, 60.6)**	**21.4 (9.42, 48.5)**	**6.83 (3.09, 15.1)**	**5.31 (2.42, 11.6)**	2.27 (0.84, 6.16)	**3.33 (1.35, 8.24)**
FVC z score*	**−0.38 (−0.63, −0.13)**	**−0.31 (−0.54, −0.08)**	0.04 (−0.17, 0.26)	0.02 (−0.17, 0.22)	−0.13 (−0.36, 0.10)	−0.01 (−0.23, 0.20)
FEV_1 z score*	**−0.60 (−0.85, −0.35)**	**−0.56 (−0.80, −0.33)**	0.05 (−0.16, 0.26)	0.00 (−0.19, 0.20)	−0.10 (−0.33, 0.13)	0.00 (−0.21, 0.22)
FEV_1/FVC ratio z score*	**−0.63 (−0.88, −0.38)**	**−0.68 (−0.93, −0.43)**	0.03 (−0.18, 0.24)	−0.06 (−0.26, 0.15)	0.09 (−0.14, 0.32)	0.04 (−0.19, 0.27)

BMI, Body mass index; *FEV_1*, forced expiratory volume in 1 s; *FVC*, forced vital capacity.
Bold indicates statistical significance ($P < .05$).
*Pre-bronchodilator.

TABLE V. Modification of association of asthma on health outcomes by coexistence of other allergic illness

Variable	Rhinitis (−) (67.5%, n = 54)	Rhinitis (+) (32.5%, n = 26)	*P* value	Eczema (−) (77.2%, n = 61)	Eczema (+) (22.8%, n = 18)	*P* value
Outcomes: odds ratio or change in mean						
Hospitalization	10.6 (2.82, 39.9)	18.7 (2.92, 119.6)	.11	12.0 (3.77, 37.9)	27.2 (2.39, 308.7)	.16
Daily activities impeded by breathing	39.0 (12.4, 122.8)	4.57 (1.29, 16.2)	.71	22.4 (8.84, 56.9)	10.9 (1.68, 70.7)	.66
FVC z score*	−0.34 (−0.63, −0.05)	−0.52 (−1.02, −0.03)	.45	−0.29 (−0.57, −0.02)	−0.67 (−1.21, −0.14)	.08
FEV_1 z score*	−0.63 (−0.92, −0.34)	−0.72 (−1.20, −0.24)	.68	−0.55 (−0.83, −0.27)	−1.04 (−1.59, −0.49)	.11
FEV_1/FVC ratio z score*	−0.72 (−1.04, −0.40)	−0.69 (−1.17, −0.22)	.91	−0.70 (−1.00, −0.40)	−0.91 (−1.43, −0.39)	.81

FEV_1, Forced expiratory volume in 1 s; *FVC*, forced vital capacity.
P value is for effect of modification.
*Pre-bronchodilator.

sprawl and adoption of westernized lifestyle.[3-5] Similar to Thacher et al[32] and Gaviola et al,[33] we did not see a relationship between asthma and biomass exposure; however, biomass was difficult to model as both sites used it at an extremely high rate: 93.6% in Kampala and 99.5% in Nakaseke. Moreover, we were unable to distinguish the effects of differing types of biomass fuels from urbanization, because biomass-using residents of Nakaseke overwhelmingly used wood (91.6%), whereas those in Kampala preferred charcoal (86.3%). Although it is known to be a risk factor, we did not see an association between asthma and having a parent with asthma.[34-36] This was likely due to the extremely low number of positive responses we encountered (2.6% overall), indicative of the reduced likelihood that an older person in this region would have ever been diagnosed with asthma.

We found more allergic illness in women than men in Kampala and similar rates in Nakaseke, which aligns with research suggesting that, although males may have more allergic illness during childhood, they are surpassed by females in adolescence.[37] Our results indicate that current wheeze did not vary between sites in men but varied significantly in women, afflicting nearly twice as many in the urban area. This interesting pattern was previously observed in Tanzania, though no explanation was offered.[29] Other studies failed to find this discrepancy.[30] Similarly, although nearly twice as many women report symptoms of eczema in Kampala compared with Nakaseke, in men there was no difference. Future research should consider the potential mechanisms behind this pattern. Forty percent of those with asthma had comorbid rhinitis or eczema, less than suggested by previous research but showing clumping of allergic illness.[38,39] As expected, a higher percentage of adult female asthmatics had comorbid rhinitis or eczema than males.[40]

Our finding of a robust association between eczema and asthma solely in our urban site mirrors results from the International Study of Asthma and Allergies in Childhood Phase II study, which found a similar relationship in affluent countries but not in nonaffluent countries.[41] Endara et al[42] postulate that connection between eczema and asthma in urban settings may be related to lower rates of helminth infection during childhood. Uganda provides a unique setting to explore this relationship because of a high prevalence of parasitic infections in rural populations. Previous research reports a childhood prevalence of *Schistosoma mansoni* of 33.8% in Luwero and 57.7% in Nakasongola—2 districts that border Nakaseke—compared with 4.1% in Kampala.[43,44] It was noted that most infected schoolchildren in Kampala had arrived to the city from other high-infection areas.[44] Furthermore, our findings of increased self-reported life impairment and hospitalization associated with asthma among those with eczema compared with those without eczema follow previous findings of a correlation between positive eczema status and increased asthma severity.[45]

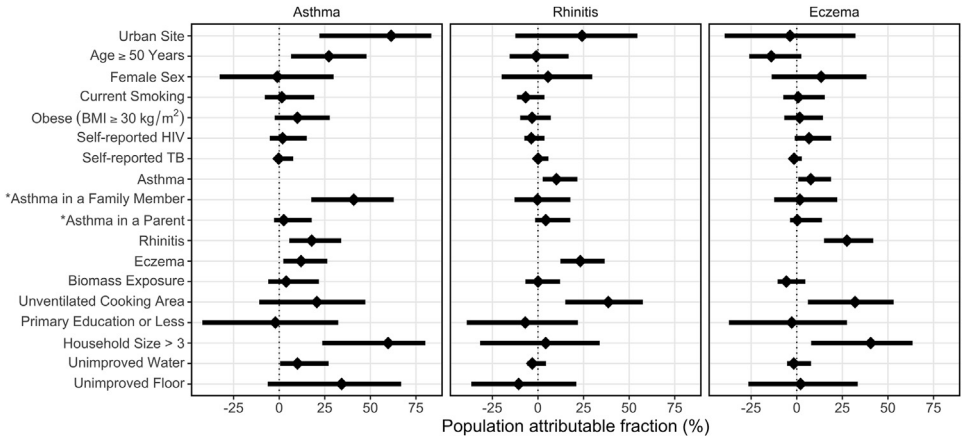

FIGURE 2. Population attributable fraction for factors related to asthma, rhinitis, and eczema. *Family history of asthma only modeled in Kampala (urban site) due to lack of positive responses in Nakaseke (rural site). *BMI*, Body mass index; *HIV*, human immunodeficiency virus; *TB*, tuberculosis.

Residents of Nakaseke reported a lower prevalence of asthma diagnosis (0.6% vs 2.7% individual; 0.5% vs 22.7% household) and medication usage (0.5% vs 6.4%) than residents of Kampala, respectively; however, the prevalence of recent wheeze was similar (3.7% vs 5.0%). These data suggest that, although the prevalence of asthma symptoms may be similar between settings, those in the rural setting were less likely to be diagnosed and treated. Because our definition of asthma included physician diagnosis and medication use in addition to wheeze, it is possible that the higher prevalence of asthma in Kampala may be explained in part by the greater availability of diagnostic health services and asthma treatment options. Although residents of Nakaseke reported seeking care for breathing at a health facility at a generally high rate, fewer of the subset who reported recent wheeze sought care than their counterparts in Kampala. The prevalence of uncontrolled asthma was the same at each site, failing to explain the discrepancy. A qualitative study in Masindi—a nearby rural region—found that asthma was known but poorly understood and that wheezing was considered worthy of seeking care.[46] Residents felt that the local hospital favored "town" over "country" people and mistrusted them when it came to alleviating their respiratory symptoms.[46] Finally, consistent drug stock-outs may have a decreased popular opinion of public health centers and turned residents away from seeking care.[47] This difference in care seeking could explain some of the disparity in physician diagnosis and use of medications for asthma in Nakaseke (Table VI). Future qualitative research should seek to expand on perception of respiratory illness and care-seeking behavior in similar regions.

Strengths of our study include ATS/ERS-standardized spirometric methods and a large population-based cohort of adults that allowed for comparisons between urban and rural areas; however, our results are limited in some respects. Questionnaires about asthma, eczema, and rhinitis were not administered to all participants, although we attempted to contact as many as possible. We were unable to measure allergic sensitization nor asthma severity in our short survey, nor measure the prevalence of helminthic infections. Finally, all spirometry values reported in this paper are pre-bronchodilator, as we obtained only post-bronchodilator measurements on those who demonstrated obstruction after initial testing.

TABLE VI. Care-seeking behavior between field sites

Variable	Kampala	Nakaseke	*P* value
Among all study participants: (n = 1,144)			
Seeks care at hospital or clinic for breathing issues	10.6% (58)	43.7% (260)	<.001
Among those reporting recent wheeze: (n = 57)			
Seeks care at hospital or clinic for breathing issues	50.0% (16)	31.6% (6)	.20
Received past diagnosis of asthma from physician	32.4% (11)	8.7% (2)	.037
Currently taking medications for breathing	52.9% (18)	4.4% (1)	<.001

In the first large population-based study of adults in Uganda, we found a high prevalence of allergic disorders that varies with urbanization and is correlated with many factors common in LMIC settings. Furthermore, we found local patterns in care-seeking behavior that may explain a portion of the discrepancy in the identification and treatment of asthma in rural communities. As urbanization in sub-Saharan Africa increases—with resultant urban sprawl—the prevalence of asthma and allergic disorders will increase. Although health systems in the region are oriented toward addressing communicable diseases, there is an imperative to address the growing burden of noncommunicable respiratory and allergic diseases and improve the diagnosis and management of these conditions.

Acknowledgments

The LiNK study was conducted by Johns Hopkins University (USA) in close collaboration with ACCESS Uganda and the Makerere Lung Institute (Uganda). LiNK was supported by the Fogarty International Center (5R25TW009340). We thank Faith Nassali and Denis Mawanda for making the study possible. Finally, we thank the participants of the LiNK cohort study.

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ONLINE REPOSITORY

TABLE E1. Demographics and risk factors comparison included vs excluded participants

Variable	Included (73.9%, n = 1,308)	Excluded (26.1%, n = 461)	*P* value
Demographics: % (n) or median (IQR)			
Urban site (Kampala)	51.7% (677)	34.9% (161)	<.001
Age (y)	43.8 (37.4-52.9)	44.8 (38.4-53.9)	.06
Being female	52.3% (684)	59.4 (274)	.008
Body mass index (kg/m^2)	23.8 (21.1-27.7)	23.2 (21.3-27.9)	.33
Primary education or less	63.8% (834)	68.7% (314)	.06
Household size >3 people	68.7% (899)	69.6% (318)	.73
Unimproved water	6.8% (89)	3.9% (18)	.027
Unimproved floor	42.3% (553)	68.0% (310)	<.001
Unventilated cooking area	43.6% (569)	40.4% (184)	.25
Risk factors: % (n)			
Current smoking	13.0% (170)	13.8% (63)	.67
Obesity (body mass index ≥30 kg/m^2)	15.5% (203)	16.1% (74)	.80
Self-reported HIV	10.0% (109)	10.9% (44)	.60
Self-reported tuberculosis	2.6% (33)	5.6% (17)	.010
Household biomass use	96.5% (1,258)	98.9% (446)	.008
Asthma in a family member	11.9% (140)	13.9% (39)	.35
Asthma in a parent	2.6% (30)	2.8% (8)	.79

HIV, Human immunodeficiency virus; *IQR*, interquartile range.

TABLE E2. Demographics and risk factors comparison by allergic illness (asthma, rhinitis, or eczema) status

Variable	No illness (80.0%, n = 1,046)	Any allergic illness (20.0%, n = 262)	*P* value
Demographics: % (n) or median (IQR)			
Urban site (Kampala)	48.6% (508)	64.5% (169)	<.001
Age (y)	44.0 (37.4-53.1)	42.8 (37.3-51.9)	.09
Being female	51.2% (535)	56.9% (149)	.10
Body mass index (kg/m^2)	23.7 (21.0-27.6)	24.2 (21.5-28.2)	.06
Primary education or less	64.3% (673)	61.5% (161)	.38
Household size >3 people	67.1% (702)	75.2% (197)	.012
Unimproved water	7.4% (77)	4.6% (12)	.11
Unimproved floor	44.6% (466)	33.3% (87)	.001
Unventilated cooking area	53.2% (556)	69.4% (181)	<.001
Risk factors: % (n)			
Current smoking	13.2% (138)	12.2% (32)	.67
Obesity (body mass index ≥30 kg/m^2)	14.6% (153)	19.2% (50)	.07
Self-reported HIV	9.5% (82)	11.8% (27)	.31
Self-reported tuberculosis	2.7% (27)	2.4% (6)	.80
Household biomass use	96.6% (1,008)	96.2% (250)	.76
Asthma in a family member	9.4% (89)	22.4% (51)	<.001
Asthma in a parent	2.0% (19)	4.8% (11)	.015

HIV, Human immunodeficiency virus; *IQR*, interquartile range.

TABLE E3. Single variable risk factors for allergic illness

Variable	Asthma (n = 89, 6.8%)	Rhinitis (n = 141, 12.1%)	Eczema (n = 109, 9.4%)
Risk factors: odds ratio (95% CI) for illness against nonillness			
Urban site (Kampala)	**2.26 (1.42, 3.59)**	**2.51 (1.72, 3.66)**	1.36 (0.91, 2.02)
Age ≥50 y	1.05 (0.66, 1.66)	0.87 (0.59, 1.27)	**0.55 (0.34, 0.89)**
Being female	1.13 (0.73, 1.74)	1.24 (0.87, 1.77)	1.47 (0.99, 2.21)
Body mass index (kg/m^2)	1.04 (0.99, 1.08)	1.03 (0.99, 1.06)	1.02 (0.98, 1.06)
Primary education or less	1.01 (0.65, 1.59)	0.77 (0.54, 1.11)	0.95 (0.63, 1.43)
Household size >3	1.51 (0.91, 2.50)	1.49 (0.99, 2.23)	**1.85 (1.15, 2.98)**
Unimproved water	1.20 (0.54, 2.68)	0.49 (0.20, 1.25)	0.68 (0.27, 1.71)
Unimproved floor	0.65 (0.41, 1.03)	**0.44 (0.30, 0.65)**	0.80 (0.54, 1.20)
Unventilated cooking area	1.38 (0.88, 2.16)	**2.55 (1.71, 3.79)**	**2.24 (1.44, 3.46)**
Current smoking	0.94 (0.49, 1.81)	0.76 (0.43, 1.34)	0.98 (0.55, 1.78)
Obesity (body mass index ≥30 kg/m^2)	**1.88 (1.13, 3.12)**	1.40 (0.89, 2.20)	1.23 (0.73, 2.08)
Self-reported HIV	1.19 (0.58, 2.46)	1.08 (0.59, 2.01)	1.58 (0.87, 2.85)
Self-reported TB	0.88 (0.21, 3.75)	1.04 (0.36, 2.99)	0.62 (0.15, 2.63)
Household biomass use	1.04 (0.32, 3.44)	0.69 (0.28, 1.70)	0.57 (0.23, 1.40)
Asthma in a family member	**4.53 (2.73, 7.49)**	**2.71 (1.68, 4.39)**	1.53 (0.85, 2.75)
Asthma in a parent	**2.90 (1.08, 7.79)**	**2.77 (1.15, 6.67)**	1.21 (0.36, 4.08)
Asthma	—	**4.07 (2.46, 6.76)**	**3.22 (1.82, 5.68)**
Current rhinitis	**4.07 (2.46, 6.76)**	—	**5.85 (3.76, 9.08)**
Current eczema	**3.22 (1.82, 5.68)**	**5.85 (3.76, 9.08)**	—

CI, Confidence interval; *HIV*, human immunodeficiency virus; *TB*, tuberculosis.
Bold indicates statistical significance ($P < .05$).

TABLE E4. Quality of life outcomes based on quintiles of the pre-bronchodilator FEV_1/FVC ratio

Variable	Hospitalization	Life impediment
Group: odds ratio (95% CI)		
Ordinal (per quintile)	**1.77 (1.21, 2.59)**	**1.65 (1.20, 2.27)**
Nominal (independent)		
Q1 (highest)	Ref	Ref
Q2	1.05 (0.06, 17.0)	1.00 (0.20, 5.09)
Q3	6.69 (0.76, 59.0)	1.58 (0.34, 7.23)
Q4	7.86 (0.92, 67.1)	1.60 (0.35, 7.32)
Q5 (lowest)	**10.1 (1.17, 87.4)**	**6.36 (1.70, 23.8)**

BMI, Body mass index; *CI*, confidence interval; *FEV_1*, forced expiratory volume in 1 s; *FVC*, forced vital capacity.
All models adjusted for age, sex, site, BMI, and current smoking. Bold indicates statistical significance ($P < .05$).