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Title: Epidemiology of asthma hospitalizations among American Indian and Alaska Native people and the general United States population

Running Head: Asthma hospitalizations in the United States

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No conflicts of interest exist for any author.

Abstract

Background. Asthma, a common chronic disease among adults and children in the United States, results in nearly half a million hospitalizations annually. There has been no evaluation of asthma hospitalizations for AI/AN people since a previous study using data for 1988-2002. In this study, we describe the epidemiology and trends for asthma hospitalizations among AI/AN people and the general US population for 2003-2011.

Methods. Hospital discharge records with a first-listed diagnosis of asthma for 2003-2011 were examined for AI/AN people, using Indian Health Service (IHS) data, and for the general US population, using the Nationwide Inpatient Sample. Average annual crude and age-adjusted hospitalization rates were calculated.

Results. The average annual asthma hospitalization rates for AI/AN people and the general US population decreased from 2003-2005 to 2009-2011 (32% and 11% [standard error (SE): 3%], respectively). The average annual age-adjusted rate for 2009-2011 was lower for AI/AN people (7.6/10,000 population) compared to the general US population (13.2/10,000, 95% CI: 12.8-13.6). Age-specific AI/AN rates were highest among infants and children 1-4 years of age. IHS regional rates declined in all regions except Alaska.

Conclusions. Asthma hospitalization rates are decreasing for AI/AN people and the general US population despite increasing prevalence rates. AI/AN people experienced a substantially lower age-adjusted asthma hospitalization rate compared to the general US population. While the rates for AI/AN infants and children 1-4 years of age have declined substantially, they remain higher compared to other age groups. Improved disease management and awareness should help to further decrease asthma hospitalizations, particularly among young children.

Abbreviations:

AI/AN: American Indian and Alaska Native; *ICD-9-CM*: International Classification of Diseases, 9th Revision, Clinical Modification; *IHS*: Indian Health Service; *NIS*: Nationwide Inpatient Sample; *HCUP*: Healthcare Cost and Utilization Project; *SE*: standard error; *CI*: confidence interval; *LRTIs*: lower respiratory tract infections

Introduction

Asthma is a common chronic disease among both adults and children in the United States, affecting more than 25 million people and resulting in nearly half a million hospitalizations annually.¹⁻⁴ The prevalence of asthma in the United States has increased over the past few decades.^{1,2} Conversely, asthma hospitalization rates have declined since the late 1980s for both the general US population^{4,5} and for American Indian and Alaska Native (AI/AN) people.⁵ Asthma hospitalization rates for AI/AN people increased during the 1980s;^{6,7} recent reports have shown AI/AN people to have similar or slightly higher prevalence rates^{1,2,8-10} and slightly lower hospitalization rates⁵ compared to the general US population.

Higher asthma prevalence and hospitalization rates have consistently been reported among both young children and females; however, males have higher rates in young childhood and women have higher rates in early to late adulthood.^{2,4,5,11} Asthma prevalence varies by race, with the highest rates among those of black race.^{1,2,11} There has been no evaluation of asthma hospitalizations for AI/AN people since a previous study for 1988-2002.⁵ In this study, we describe the trends for asthma hospitalizations among AI/AN people and the general US population for 2003-2011.

Materials and Methods

Asthma hospitalizations during 2003-2011 were examined for AI/AN people and the general US population. An asthma hospitalization was defined as a hospital discharge record with the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) code for asthma (493) listed as the first diagnosis.¹² The unit of analysis was a hospitalization.

Asthma hospitalizations for AI/AN people were analyzed using the Indian Health Service (IHS) direct and contract health service inpatient visit data which consist of all hospital discharge records from IHS-operated, tribally-operated, and community hospitals contracted with IHS to provide healthcare services to eligible AI/AN people.^{13,14} The IHS is comprised of administrative areas that are grouped into geographic regions. IHS California and Portland administrative areas were not included in the analysis because neither had IHS- or tribally-operated hospitals, California did not report contract health service inpatient data by diagnosis, and Portland had limited contract health services for inpatient care.¹³ Population denominators were based on the annual IHS user populations for fiscal years 2003-2011; the annual IHS user population consists of all registered AI/AN persons who received IHS-funded healthcare at least once during the previous three years.¹⁴

For the general US population, asthma hospitalizations were examined using the Nationwide Inpatient Sample (NIS).^{15,16} The NIS is a nationally-representative sample of hospitals conducted by the Healthcare Cost and Utilization Project (HCUP) in collaboration with participating states and includes a 20% sample of participating US community hospitals.¹⁵ Participating hospitals are short-term, nonfederal general and specialty hospitals sampled annually from up to 45 states. Estimates of the number of hospitalizations were calculated using

the HCUP weighting methodology.¹⁷ To account for the NIS sample design, SUDAAN software was used to calculate standard errors (SEs) for hospitalization estimates used to calculate 95% confidence intervals (CIs) and for percent rate change comparing 2003-2005 to 2009-2011. Population denominators were based on the National Center for Health Statistics bridged race population estimates.^{18,19}

Because use of these datasets specifically prohibits re-identification of patients, data are not individually identifiable per Health and Human Services Office for Human Research Protections guidance; therefore, the analysis is not considered to involve human subjects and not subject to IRB review requirements.

Hospitalization records were analyzed by sex, age group (<1, 1-4, 5-19, 20-44, 45-64, and ≥65 years), region, year, and time period (2003-2005 and 2009-2011). Average annual crude and age-adjusted hospitalization rates were calculated as the number of hospitalizations per 10,000 corresponding population. Age-adjusted rates were calculated using the direct method with the 2000 projected US population as the standard.²⁰ Poisson regression was used to compare unadjusted rates by sex, age group, time period, and region for AI/AN people;²¹ rate ratios with corresponding 95% confidence intervals were used to compare rates among the general US population.²² In-hospital fatality rates were computed as the percent of asthma hospitalizations with a fatal outcome. Month of hospital admission and associated diagnoses, specifically including lower respiratory tract infections (LRTIs; ICD-9-CM codes: 011, 022.1, 031.0, 033, 095.1, 466, 480-488, 510, 511.1, 513, 517.1, and 770.0), were also examined.

Results

During 2003-2011, there were 10,116 asthma hospitalizations among AI/AN people in the IHS healthcare system accounting for 1.5% of all AI/AN hospitalizations. The average annual asthma hospitalization rate for AI/AN people decreased 32% from 2003-2005 to 2009-2011 ($p < 0.0001$, Table 1). For the general US population, an estimated 3,820,242 (SE: 49,382) asthma hospitalizations occurred during 2003-2011, accounting for 1.2% (SE: 0.01%) of all hospitalizations, and the average annual hospitalization rate decreased 11% (SE: 3%) from 2003-2005 to 2009-2011 (Table 2). The average annual age-adjusted rate for 2009-2011 was lower for AI/AN people (7.6/10,000) compared to the general US population (13.2/10,000, 95% CI: 12.8-13.6).

The average annual hospitalization rate for females was higher than that for males among both AI/AN people and the general US population (Tables 1 and 2). The rate decreased 35% for AI/AN males ($p < 0.0001$) and 30% for AI/AN females ($p < 0.0001$) from 2003-2005 to 2009-2011 (Table 1). Decreases among US males (14%, SE: 4%) and females (8%, SE: 3%) were significant but of smaller magnitude compared to those for AI/AN people (Table 2). Comparison of age-adjusted rates by sex for 2009-2011 revealed lower rates among AI/AN males (5.7/10,000) and females (9.0/10,000) compared to males (10.4/10,000, 95% CI: 10.0-10.7) and females (15.6/10,000, 95% CI: 15.2-16.0) in the general US population.

During 2009-2011, average annual age-specific hospitalization rates varied substantially among age groups for AI/AN people and for the general US population. AI/AN rates were highest among infants (children < 1 year of age) and children 1-4 years of age, lower in late childhood and early adulthood, and increased among older adults (Table 1); age-specific rates for the general US population followed a similar pattern to that observed for AI/AN people except

the rate among infants was not among the highest age-specific rates (Table 2). Compared to the general US population, age-specific AI/AN rates were lower for all age groups with the exception of infants (Figure 1). Among both AI/AN people and the general US population, the hospitalization rate was higher for males in younger age groups (<5 years of age) and for females in older age groups (≥ 20 years; Figure 2). The rate decreased for all age groups among AI/AN people, with greater declines seen among infants (63%) and those 1-4 years of age (42%) compared to older age groups (range: 24%-29%; Table 1). For the US population, the rate remained stable for those 45-64 and ≥ 65 years of age while declining among all other age groups; the greatest decline was observed among infants (52%, SE: 4%; Table 2).

Examination of the AI/AN hospitalization rate by region showed significant decreases in all IHS regions with the exception of Alaska ($p=0.42$, Table 1). IHS regional rates varied markedly for 2009-2011, with higher rates in the Southwest (10.1/10,000) and Alaska (9.0/10,000) regions and lower rates in the Northern Plains East (1.8/10,000) and Southern Plains (3.1/10,000) regions (Table 1). The rate for the general US population declined in all regions except for the Northeast (Table 2). US regional rates varied substantially with the highest rate in the Northeast (19.7/10,000, 95% CI: 17.4-21.9) and the lowest rate in the West region (9.2/10,000, 95% CI: 8.5-10.0; Table 2).

Nearly one-third (32%) of AI/AN hospitalizations occurred during the winter months of January-March, whereas only 18% occurred during the months of June-August (Figure 3). This winter peak was particularly notable for infants (39% of hospitalizations) and those 1-4 years of age (38%). A similar winter peak was not evident for the general US population, with consistent numbers of hospitalizations for September-May, although there was a decline in hospitalizations during June-August (17%, SE: 0.1%) (Figure 3). There was, however, a slight winter peak

(January-March) for age groups <1 year (31% [SE: 0.5%] occurring during January-March), 45-64 (30% [SE: 0.1%]), and ≥ 65 years of age (33% [SE: 0.2%]).

An LRTI was listed for 21% of asthma hospitalizations among AI/AN people; this proportion varied by age group and was highest among infants (30%) and children 1-4 years of age (29%). For the general US population, an LRTI was listed for 18% (SE: 0.1%) of asthma hospitalizations; the proportion was highest among infants (26%, SE: 0.5%), those 1-4 years of age (21%, SE: 0.3%), and those ≥ 65 years of age (20%, SE: 0.2%). A fatal outcome occurred for 0.1% (n=7) of AI/AN asthma hospitalizations overall and 0.3% (n=4) for adults ≥ 65 years of age. Fatal outcomes occurred more often for the general US population, occurring for 0.3% (SE: 0.01%) of asthma hospitalizations overall and 1.0% (SE: 0.03%) for adults ≥ 65 years of age.

Discussion

Despite increasing prevalence of asthma in the United States,^{1,2,8,23} asthma hospitalization rates for AI/AN people and the general US population continue to decline.⁵ Decreasing rates were observed for males and females in both populations, all age groups for AI/AN people, and age groups <45 years of age for the general US population, with more substantial decreases occurring for AI/AN people. Decreasing hospitalization rates may result in part from a more intensive treatment algorithm in outpatient settings, better asthma treatment plans, and/or increased patient education. Improved asthma treatment and education, however, would likely not explain the more rapidly declining rates among AI/AN people compared to the general US population. Another possible reason is increased use of inhaled corticosteroids;^{24,25} however, the largest decreases were observed for both AI/AN and US infants and children 1-4 years of age and physicians are generally more reluctant to prescribe inhaled corticosteroids for young children.^{24,26} Declining rates among young children may result from more accurate discharge diagnoses. Published guidelines for the diagnosis of asthma²⁷ and bronchiolitis²⁸ may have contributed to fewer misdiagnoses of asthma thereby reducing the asthma hospitalization rate.

AI/AN people experience a substantially lower age-adjusted asthma hospitalization rate than the general US population, despite having a similar or slightly higher asthma prevalence.^{9,10,29} Age-specific rates were similar for infants in both populations despite being lower for AI/AN people in all other age groups; this may be due in part to higher rates of bronchiolitis and wheezing with LRTIs among AI/AN infants compared to other US infants.³⁰ The lower rates of asthma hospitalization among AI/AN people may be related to differences in physician diagnosis of asthma or health care access and utilization. Poverty and residence in urban areas have been shown to be associated with higher asthma hospitalization rates.^{31,32}

Compared to the general US population, a greater proportion of AI/AN people reside in rural areas,³³ which may contribute to lower rates among AI/AN people. Although AI/AN people have lower household income and a higher poverty rate than the general US population,³⁴ they also have potentially greater access to routine health care which could increase their access to inhaled corticosteroids and other controller medications. Additionally, some AI/AN individuals may receive health care outside the IHS/tribal system, causing AI/AN hospitalization rates to appear lower.

Among AI/AN people and the general US population, asthma hospitalization rates were higher for females, and age-specific rates varied, with high rates among young children decreasing into early adulthood and then increasing again among older adults.^{2,4,5} Diagnostic substitution of asthma for bronchiolitis as well as the role of bronchiolitis and other LRTIs in exacerbating asthma symptoms may contribute to higher asthma hospitalization rates among young AI/AN or US children.^{31,35} Asthma diagnosis in infants is controversial because of the difficulty in obtaining objective measurements and uncertainty in predicting asthma in wheezing infants.²⁷ The rapid decline in hospitalization rates among young children in both populations, however, has reduced the substantially higher rates among infants and children 1-4 years of age to nearly similar levels compared to older adults. Rates were higher among males in young age groups (<5 years of age) and females in older age groups (≥ 20 years of age).⁵ This phenomenon has been widely observed^{2,4,5,11} and may be due to differences in airway behavior resulting from sociocultural and biological effects related to sex and gender.³⁶

The IHS Southwest region for AI/AN people and the Northeast region for the general US population continue to have the highest regional rates.⁵ Regional differences in asthma hospitalization rates may result from differing environmental risk factors, diagnostic practice,

asthma presentation, or other comorbid conditions.^{25,35,37} The Southwest and Alaska IHS regions experience high LRTI hospitalization rates compared with other IHS regions and the general US population,³⁸ which could result in increased asthma hospitalization rates. In the IHS Alaska region, household crowding and a lack of indoor water service may contribute to increased LRTIs.³⁹⁻⁴¹ However, LRTI rates are decreasing in Alaska as well as other IHS regions, most likely due to a combination of improved household and environmental conditions and introduction of pneumococcal conjugate vaccine in 2000.³⁰ The winter peak of asthma hospitalizations was more pronounced among AI/AN people, particularly for young children, suggesting the possible influence of LRTIs in asthma exacerbation.⁵ Other possible explanations include higher upper respiratory tract infection rates among AI/AN people during the winter and increased exposure to indoor air pollutants resulting from more time spent indoors. Use of indoor wood-burning stoves among AI/AN people has been linked to poor indoor air quality⁴² and higher rates of LRTIs⁴³ and is possibly also related to increased asthma hospitalizations.

Some limitations of the present study should be considered. Hospital diagnoses of asthma may be incomplete or inaccurate due to use of ICD-9-CM coding to identify asthma hospitalizations, and diagnostic coding may vary by practice or geographic region. The first-listed diagnosis was used to identify asthma hospitalizations in order to limit misclassification of non-asthma hospitalizations; however, this conservative method does not include any true asthma hospitalizations for which asthma is not the first-listed diagnosis. The unit of analysis was a hospitalization, thus multiple hospitalizations for the same patient and/or hospital transfers were included in the analysis. The denominator for AI/AN people was estimated as the number of AI/AN people who used the IHS/tribal healthcare system, whereas the denominator for the general US population was estimated from US census data; this may affect the comparability of

rates between the two populations. However, AI/AN people included in the IHS user population would be those people at risk for having an asthma hospitalization included in this study. Additionally, AI/AN individuals may receive health care outside the IHS/tribal system which would result in an underestimate of AI/AN hospitalizations.

Conclusions

Asthma hospitalization rates continue to decrease for AI/AN people and the general US population despite increasing prevalence rates and have declined more rapidly for AI/AN people. Compared to the general US population, AI/AN people have a substantially lower age-adjusted asthma hospitalization rate, despite having similar or higher prevalence. While the rates for young AI/AN children have declined substantially, they still remain higher than for older age groups. Improved disease management and awareness should help to further decrease asthma hospitalization rates, particularly among young children. Educational programs and interventions like those provided through the CDC's National Asthma Control Program⁴⁴ are important in reducing poor outcomes associated with asthma, such as hospitalization and death.

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Author Contributions:

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Table 1. Number and average annual rate of asthma hospitalization among American Indian/Alaska Natives, Indian Health Service/Tribal, 2003-2005 and 2009-2011

Characteristic	2003-2005		2009-2011			2003-2005 vs. 2009-2011
	No.	Rate [†]	No.	Rate [†]	RR (95% CI)	Percent Rate Change
Overall	3,939	10.8	2,924	7.3	-	-32.4%*
Sex						
Male	1,651	9.5	1,180	6.2	Reference	-34.7%*
Female	2,288	12.0	1,744	8.4	1.4 (1.3-1.5)	-30.0%*
Age group (years)						
< 1	302	53.6	108	19.7	5.2 (4.2-6.3)	-63.1%*
1-4	985	33.0	611	19.2	5.0 (4.5-5.6)	-41.9%*
5-19	776	6.9	566	5.1	1.3 (1.2-1.5)	-26.2%*
20-44	722	5.4	559	3.8	Reference	-28.9%*
45-64	736	12.2	685	8.9	2.3 (2.1-2.6)	-27.4%*
≥ 65	418	18.2	395	13.8	3.6 (3.2-4.1)	-23.8%*
Region						
Alaska	356	9.5	376	9.0	5.0 (3.8-6.6)	-5.3%
East	169	14.3	118	7.9	4.4 (3.2-6.0)	-44.8%*
Northern Plains East	119	4.5	56	1.8	Reference	-60.0%*
Northern Plains West	718	12.9	496	8.5	4.7 (3.6-6.2)	-34.1%*
Southern Plains	554	6.2	307	3.1	1.7 (1.3-2.3)	-50.0%*
Southwest	2,023	14.0	1,571	10.1	5.6 (4.3-7.3)	-27.9%*

Abbreviations: RR: rate ratio, CI: confidence interval

[†] Unadjusted rate per 10,000 corresponding population

*Significant change from 2003-2005 to 2009-2011.

Table 2. Number and average annual rate of asthma hospitalizations among the general United States population, 2003-2005 and 2009-2011

Characteristic	2003-2005		2009-2011			2003-2005 vs. 2009-2011
	No. (SE)	Rate [†] (95% CI)	No. (SE)	Rate [†] (95% CI)	RR (95% CI)	Percent Rate Change (SE)
Overall	1,332,056 (30,822)	15.2 (14.5-15.9)	1,254,874 (27,564)	13.5 (12.9-14.1)	-	-10.8% (2.8)*
Sex						
Male	520,694 (15,722)	12.1 (11.4-12.8)	471,206 (13,685)	10.3 (9.7-10.9)	Reference	-14.4% (3.6)*
Female	801,273 (15,978)	17.9 (17.2-18.6)	777,430 (15,155)	16.5 (15.9-17.1)	1.6 (1.5-1.7)	-8.0% (2.6)*
Age group (years)						
< 1	44,310 (2,225)	36.9 (33.3-40.6)	21,328 (1,259)	17.8 (15.8-19.9)	2.5 (2.2-2.8)	-51.7% (3.7)*
1-4	211,952 (10,113)	44.8 (40.6-49.0)	163,278 (9,031)	33.6 (29.9-37.2)	4.6 (4.1-5.2)	-25.1% (5.5)*
5-19	220,077 (10,617)	11.8 (10.7-13.0)	181,419 (9,477)	9.6 (8.6-10.6)	1.3 (1.2-1.5)	-18.8% (5.8)*
20-44	261,535 (5,656)	8.4 (8.0-8.8)	225,308 (5,284)	7.2 (6.9-7.6)	Reference	-13.9% (2.7)*
45-64	328,623 (6,792)	15.4 (14.8-16.1)	377,078 (7,889)	15.4 (14.8-16.0)	2.1 (2.0-2.3)	-0.2% (2.9)
≥ 65	262,514 (4,946)	24.2 (23.3-25.0)	284,022 (5,464)	23.4 (22.5-24.3)	3.2 (3.0-3.4)	-3.2% (2.6)
Region						
Northeast	331,343 (20,865)	20.3 (17.8-22.8)	326,901 (19,043)	19.7 (17.4-21.9)	2.1 (1.8-2.4)	-3.0% (8.3)
Midwest	282,180 (11,822)	14.4 (13.2-15.5)	259,294 (9,463)	12.9 (12.0-13.8)	1.4 (1.2-1.6)	-10.1% (5.0)*
South	506,985 (16,380)	16.0 (15.0-17.0)	468,767 (15,331)	13.6 (12.7-14.5)	1.5 (1.3-1.6)	-14.7% (3.9)*
West	211,548 (10,325)	10.5 (9.5-11.5)	199,911 (8,515)	9.2 (8.5-10.0)	Reference	-12.3% (5.7)*

Abbreviations: SE: standard error, CI: confidence interval, RR: rate ratio

[†] Unadjusted rate per 10,000 corresponding population

*Significant change from 2003-2005 to 2009-2011.

Figure Legend

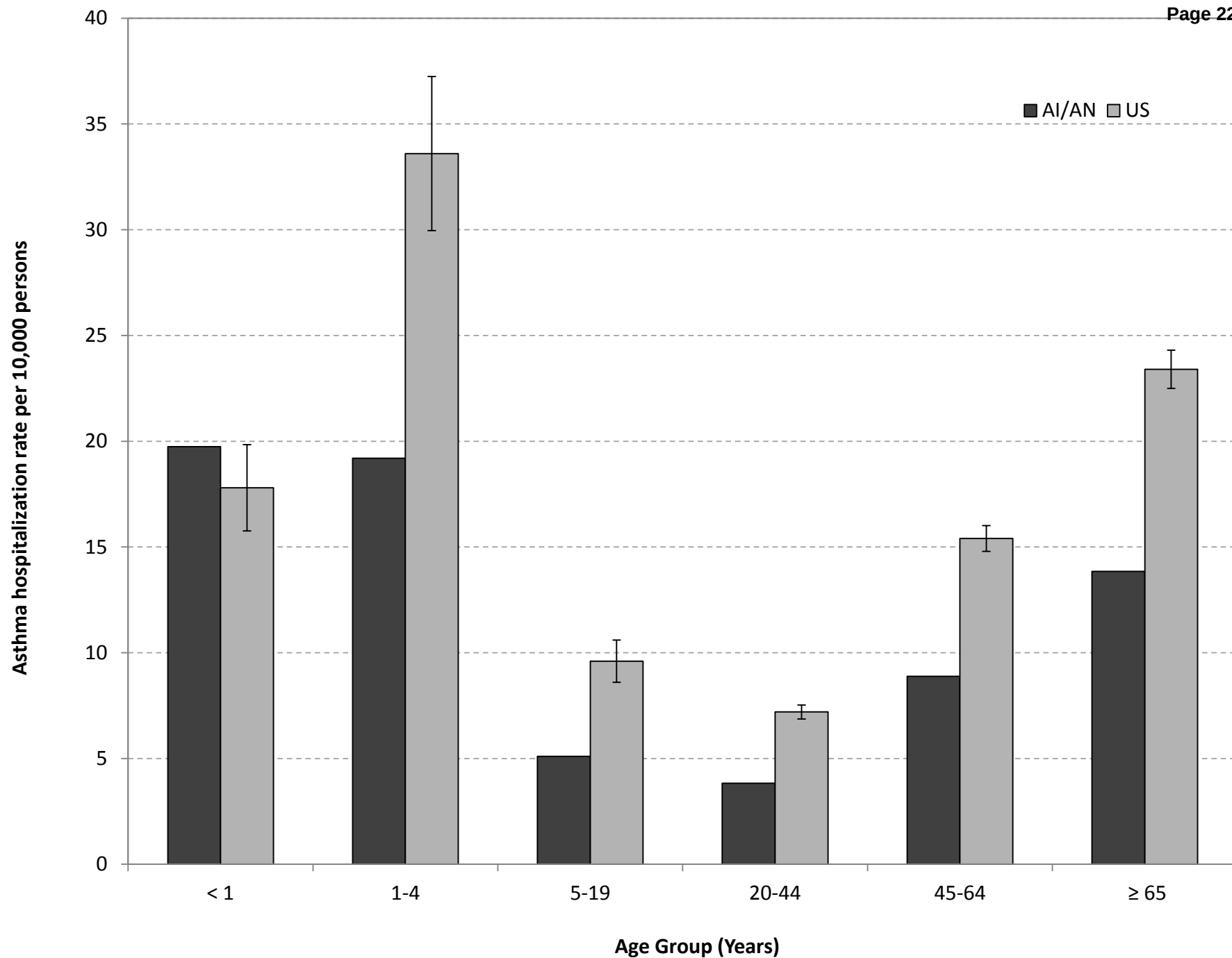
Figure 1. Age-specific average annual asthma hospitalization rates among AI/AN people and the general United States population, 2009-2011*

*Error bars represent 95% confidence intervals

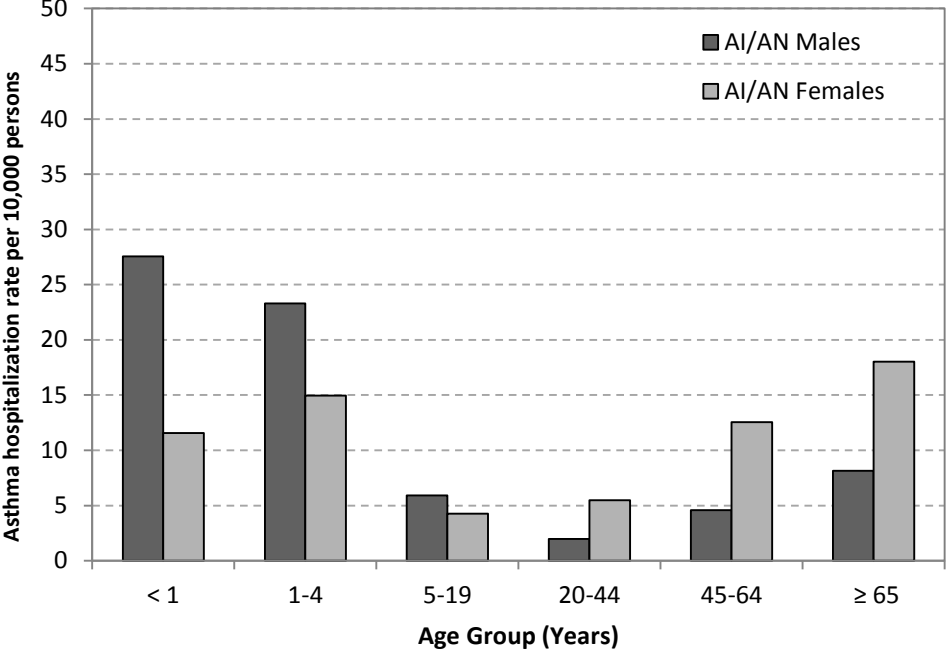
Figure 2. Age-specific average annual asthma hospitalization rates by sex among (A) AI/AN people and (B) the general United States population, 2009-2011*

*Error bars represent 95% confidence intervals

Figure 3. Asthma hospitalizations by admission month among AI/AN people and the general United States population, 2003-2011



(A)



(B)

