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Patterns Of Asthma Exacerbation Related To Climate And Weather In The Northeast Kingdom Of Vermont

Quincy McKenzie Campbell
University of Vermont

PATTERNS OF ASTHMA EXACERBATION RELATED TO CLIMATE AND WEATHER IN THE NORTHEAST KINGDOM OF VERMONT

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Quincy M. Campbell

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Thesis Examination Committee:

Sarah Abrams, Ph.D., R.N., Advisor
Christine Vatovec, Ph.D., Chairperson
Lesley-Ann Dupigny-Giroux, Ph.D.
Ellen Watson, M.S.N., F.N.P.
Cynthia J. Forehand, Ph.D., Dean of the Graduate College

ABSTRACT

Asthma is a chronic respiratory disease characterized by long- and short-term inflammation and bronchospasm susceptible to multiple triggers that affects patients across the lifespan. Asthma management is a primary care priority in Vermont, where there continues to be an above-average prevalence of asthma among both children and adults as compared to other states. However, many of Vermont's children and *especially* adults with asthma are not participating in regular check-ups for asthma management that would best prevent exacerbation of asthma symptoms. Several climate and weather elements including, but not limited to, extreme temperatures and particulate matter are known asthma triggers. Vermont's high per capita use of old woodstoves, pockets of poverty and cold winters are all factors that might collide to adversely impact residents' asthma. Insights into how climate and weather might be related to peak periods of acute asthma exacerbation (AAE) among individuals living in the rural Northeast Kingdom of Vermont (NEK) could provide valuable, regionally focused public health information to primary care providers on the front lines of asthma management.

The objective of this research was to examine the potential relationship between the climate and weather of the NEK and visits for asthma exacerbation in the primary care setting. The research began with a retrospective chart review including visits to five different clinic sites in the NEK between 2009-2014 with the ICD-9 code for asthma exacerbation (493.xx) as the primary diagnosis. When visits were individually validated as an AAE, the clinic site, date of visit, and the patients' age and sex were documented. These validated visits were then analyzed against weather and climate data including temperature and air quality. Results suggest that while diurnal shifts and air quality do not show a strong relationship with AAEs in this area, colder days do appear to correlate to when patients visit primary care clinics in the NEK for AAEs.

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CHAPTER I: INTRODUCTION

1.1. Executive Summary

Asthma management is a primary care priority in Vermont, where there continues to be an above-average prevalence of asthma among both children and adults as compared to other states. Several climate and weather elements that are known asthma triggers include, but are not limited to, particulate matter, extreme temperatures and temperature fluctuations. Vermont's high per capita use of old woodstoves, pockets of poverty and cold winters are all factors that might collide to adversely impact residents' asthma. Presently, there is an absence of local research investigating the intersection of these potential asthma triggers for Vermonters. Insights into how climate and weather might be related to peak periods of asthma exacerbation among individuals who present to primary care in the rural Northeast Kingdom of Vermont could provide valuable, regionally focused public health information to primary care providers on the front lines of asthma management.

1.2. Background

1.2.1. Asthma

Asthma is currently understood to be a fairly common but complicated chronic respiratory disease with multiple etiologies (Buttaro, Trybulski, Polgar-Bailey & Sandberg-Cook, 2012; Zhang, Morrison-Carpenter, Holt & Callahan, 2013). The diagnosis of asthma is commonly made in the clinical setting through a history and physical exam, as well as with the use of pulmonary function tests (PFTs). More than simple bronchospasm, asthma is characterized by such clinical elements as short- and long-term inflammation of the respiratory airway, edema, narrowing of the airway, and increased secretions mediated by different allergic, lifestyle, environmental and inflammatory triggers (VanGarsse, Magie & Bruhnding, 2015). Those triggers range from pollen to humidity, cold air to exercise, smoke exposure to acute infection; the risk factors for asthma are also complicated but known to include low-socioeconomic status, obesity and primary and secondary smoke exposure (Vernon, Wiklund, Bell, Dale & Chapman, 2012; Zhang et al., 2013).

Asthma affects individuals across the life span, and effective management of symptoms relies on several elements including abstinence from triggers and management of other chronic or acute diseases (Guilbert, Garris, Jhingran, Bonafede, Tomaszewski, Bonus, . . . & Schatz, 2011). Asthma is a manageable—but not curable—chronic disease that requires ongoing care. When asthma becomes uncontrolled or exacerbated—also known as an "asthma attack"—an individual may experience respiratory symptoms such as "wheezing, coughing, shortness of breath, and chest tightness or pain" that can be very mild, sub-acute or acute in severity, and can often lead to an office or emergency department visit (Moorman, Akinbami, Bailey, Zahran, King, Johnson & Liu, 2012, p. 1). Accordingly, the long-term management of asthma symptoms and prevention of acute asthma exacerbations (AAEs) are important objectives in the primary care setting.

1.2.2. The Burden of Asthma

In the United States, asthma has been increasing in prevalence for over 50 years despite advances in medical treatment and pharmacotherapies; it currently affects an estimated 25 million people with a recent, shallow rise in prevalence of 1.2% between 2001 and 2009 (Akinbami, Moorman & Liu, 2011). Of those individuals, 52% experienced an exacerbation of asthma symptoms; this approximates to 4.2% of the total American population having an AAE in that time period. Unsurprisingly, even for individuals with relatively well controlled asthma, the effects of this condition ripple into many aspects of daily life including social and occupational roles, as well as potential missed school or work days, for which the huge negative economic implications have been well established (Guilbert et al., 2011; Sadatsafavi, Rousseau, Chen, Zhang, Lynd & Fitzgerald, 2014).

The cost of treating individuals for an AAE has also increased dramatically in the last decade—mostly attributed to an intensive use of respiratory and non-respiratory in-hospital resources (Hasegawa, Tsugawa, Brown & Camargo, 2013). In Vermont alone, this cost exceeds $7 million annually (Vermont Department of Health, 2013). Furthermore, those expensive hospitalizations for AAE are especially associated with poorer outcomes (Akinbami et al., 2011). If we only bear in mind the significant financial burden of asthma, it is essential to consider effective methods of reducing that encumbrance, which might be otherwise devoted to health promotion. As it has been for decades, the cornerstone of relieving this burden is patient and caregiver education provided in primary care (Moorman et al., 2012).

1.2.3. Asthma Management in Primary Care

Despite improvements in pharmacotherapies for asthma, the onus for effective management of asthma continues to rest with education of patients or caregivers in the primary care setting (Moorman et al., 2012; O'Laughlen, Rance, Rovnyak, Hollen & Cabana, 2013). Effective self-management is an essential tool in keeping asthma symptoms controlled (Akinbami et al., 2011; Wood & Bolyard, 2011). There are several applicable and evidence-based practice tools available in primary care settings to assess a patient's adherence to an asthma management/action plan. However, as Yates (2013) points out: like the stock market, "[r]elying on a patient's report of historical and current asthma control is usually insufficient to measure risk of future exacerbation," suggesting the necessity for combined efforts between provider *anticipation* and patient education for the most effective care (Yates, 2013, p. 44).

All together, despite the clear understanding and evidence underlining the importance of ongoing primary care management, patient education and adherence to pharmacotherapy, the prevalence of asthma continues to increase. Therefore, easier surveillance or methods of intervention are strongly merited. In addition to providing thorough patient education regarding the nature of asthma and its common triggers primary care prevention measures might be enhanced by the ability to *anticipate* potential exacerbations.

1.2.4. Asthma in Vermont

Asthma prevention and management is a salient public health issue in Vermont—known to be one of the healthiest states in the nation, yet it boasts an above-average prevalence of asthma (VDH, 2013). In 2009, the national asthma prevalence was 8.2% among the overall U.S. population (Akinbami et al., 2011). Comparably, the prevalence of asthma in Vermont was 11% among adults and 10% in children in 2010, and has remained somewhat stagnant in recent years despite public health promotion campaigns (VDH, 2013). Additionally, reducing the impact of asthma is a key aspect of the Healthy Vermonters 2020 goals, which include cutting the hospitalization rate related to asthma and increasing the percentage of patients advised on modifying risk behaviors including avoidance of triggers (Vermont Department of Health, 2012). An Asthma Action Plan (AAP) is one of the most critical primary care interventions for helping patients comprehend asthma symptoms, modify behaviors and avoid triggers. However, just under half of children and one-third of adults in Vermont report having ever received an AAP, a finding which tracks with the low rate of routine asthma care visits in primary care across the lifespan in the state (VDH, 2014). From the literature and Vermont Department of Health data, it is unclear if this low rate of AAP application is attributable to a lack of utilization by primary care providers *or* a paucity of patient visitation for health maintenance.

In Vermont, common asthma triggers are related to individuals' homes. The most frequently identified asthma triggers for Vermonters are, in order of prevalence: indoor pets, pets allowed in the bedroom, carpet in the bedroom, cooking with gas, woodstove use, and indoor tobacco smoking (VDH, 2013). In addition to the usual triggers, the Vermont Department of Health has identified several "hot spots" for asthma in Vermont, including the Springfield and Rutland health service areas (HSAs) and the Northeast

Kingdom (NEK). Related to this is the knowledge that asthma disproportionately affects people of lower socioeconomic status (Adamkiewicz et al., 2014; Fung, Graetz, Galbraith, Hamity, Huang, Vollmer . . . & Wu, 2014; VDH, 2013); the NEK—containing Essex, Orleans and Caledonia counties—represents some of the most impoverished communities in the state (U.S. Department of Labor, 2014). Because this population is at higher risk of chronic disease it should be a region of focus for primary care interventions related to asthma.

Beyond data surveillance, Vermont already has several programs in place to support patients and primary care providers in their understanding of asthma such as the Vermont Asthma Program, VCHIP (Vermont Child Health Improvement Program) and BluePrint for Health (Frankowski, Keating, Rexroad, Delaney, McEwing, Wasko . . . & Shaw, 2006; VDH, 2013). The monitoring and investigation performed through these operations has advanced valuable knowledge about triggers and some clinical aspects of managing asthma in Vermont, yet little is understood about the existence or character of climate- or weather-related AAEs in the state.

1.2.5. Asthma, Climate and Weather

Several federal agencies including the Centers for Disease Control and Prevention (CDC) and Environmental Protection Agency (EPA), and an international opinion from the World Health Organization (WHO), support the investigation of local and regional climate trends that may negatively impact human health[1]. The goal of those investigations is identifying better asthma prevention strategies (Houghton & English, 2014; Portier & Tart, 2010). Overall, research in geographic areas outside of Vermont has revealed regional differences in peak periods of AAE related to the local climate patterns (Davis, Malayer, Vandeventer, Royer, McKenzie & Williamson, 2005; May, Carim & Yadav, 2011; Buckley & Richardson, 2012; Lee, Sheridan & Lin, 2012; Ruffoni, Passalacqua, Ricciardolo, Furgani, Negrini, De Amici & Ciprandi, 2013; Cohen, Blau, Hoshen, Batat, & Balicer, 2014; Fitzgerald, Pantea & Lin, 2014; Kim, Lim & Kim, 2014). Globally, climate research has demonstrated innovative methods of forecasting and predicting periods of AAE (Fitzgerald, et al., 2014; Soyiri, Reidpath, & Sarran, 2013).

Vermont's geography creates a unique seasonal portrait of air quality, humidity and extreme temperature changes (National Climate Data Center, 2003). Weather patterns play strongly in the variations of air quality, but local and global man-made emissions also make a large impact. Vermont was recently ranked first in per capita woodstove particle emissions. According to Ring (2015), a "2008 survey of Vermont wood stove users found that more than half the woodstoves in use were made before 1990 and don't burn as cleanly or as efficiently as the newer models" (p. C8). This can

[1] It bears mentioning that at the root of this author's masters research is an acknowledgement of the negative global climate change impacts on regional health patterns and non-communicable disease such as asthma.

significantly impact both indoor and outdoor air quality[2] in the colder months. The rise in per capita emissions also follows a state-subsidized outdoor wood boiler change-out program that began in 2011. Intended to lower wood smoke particle emissions this program will be ending on June 30, 2015, with data on its results forthcoming (Vermont Department of Environmental Conservation, 2015).

Frigid temperatures and extreme diurnal shifts—the difference between night- and day-time temperatures—are also known asthma triggers (Buckley & Richardson, 2012; Fitzgerald et al., 2014; Kim et al., 2014). This is relevant to asthma in Vermont because despite a general warming trend the state continues to break records with its extreme cold temperatures and diurnal shifts (Betts, 2011; Tortora, 2015). This may be especially pronounced in the NEK, an isolated corner of the state with lower-elevation circumboreal forest and a true subarctic environment characterized by harsh winters and a short growing season; this landscape and climate has more in common with northern New Hampshire and Maine, as well as the Canadian tundra, than the remainder of Vermont (Johnson, 1998).

1.3. Summary Statement of the Problem

Asthma is a chronic respiratory disease characterized by long- and short-term inflammation and bronchospasm susceptible to multiple triggers that affects patients

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[2] Older woodstoves are thought to be more polluting because of inefficient or incomplete combustion of wood matter, which releases great amounts of harmful polycyclic aromatic hydrocarbons (PAH) into the local and global atmosphere (Shen, Huang, Wang, Zhu, Li, Shen . . . & Tao, 2013).

across the lifespan. However, many of Vermont's children and *especially* adults with asthma are not participating in or receiving regular check-ups for asthma management that would best prevent exacerbation of asthma symptoms. Furthermore, the combination of local weather and climate in Vermont with increased time spent indoors and using woodstoves in the winter might contribute to seasonal peaks in AAE among individuals living in the Northeast Kingdom. Therefore, an examination of how patients' seasonal environment might impact asthma symptoms could be an important preventative tool in the primary care setting.

1.4. Purpose of the Study

1.4.1. Research Question

The ability to focus asthma education initiatives or health maintenance visits around predictable periods of increased AAE could be an essential tool to primary care Nurse Practitioners (NPs). A study measuring AAEs across the entire state is unfeasible; therefore, the geographic area of focus for this research would be a health service area (HSA) within the Northeast Kingdom (NEK) of Vermont because of the region's documented above-average prevalence of asthma, low-income households, and unique climate of extreme weather and diurnal shifts (NCDC, 2003; Vermont Department of Health, 2014; USDOL, 2014).

The specific objective of this research is to seek insights into the potential seasonality of AAEs in Vermont. This research will be guided by a PICOT-format question: For individuals with asthma across the lifespan living in the NEK, does climate and weather data relate to periods of asthma exacerbation between 2009-2014?

1.4.2. Aims

This research will be pursued with the following specific aims. A retrospective chart review and analysis of local climate data will examine:

1. Episodic office visits for asthma exacerbation (ICD-9 code 493.xx) within Northern Counties Health Care offices over a 5-year time period between 2009-2014.
    a. Data collected will include date of visit, age, sex and clinic site.
2. Climate and weather data in the corresponding period and clinic location.
    a. Minimum and maximum temperature, diurnal shift, and air quality index.

The data will be analyzed to examine possible associations among climate, weather and AAEs for Vermonters of all ages in the Northeast Kingdom.

1.4.3. Significance

First, the results of this research will be specific to the region of study: the Northeast Kingdom of Vermont, an area known for its rural beauty and history, but also greater levels of poverty and subsequently, a population with increased risk for chronic disease such as asthma. There is little asthma research specific to Vermont where the prevalence of asthma continues to rise despite improvements in pharmacotherapy. If climate and weather trends exist for asthma exacerbation, the groundwork may be laid for future, focused public health campaigns aimed at prevention during seasonal periods of greater risk among both pediatric and adult patients seen in the primary care setting. For primary care providers juggling the myriad dimensions of health care simplifying delivery is essential. For patients living with asthma, public health promotions highlighting those periods of increased risk could be helpful to the self-management of this chronic disease.

1.5. Nursing Competencies and Theory

Asthma is a multifaceted chronic disease that demands a mirrored primary care response. The role of the NP in asthma management includes: prescription of maintenance medications such as inhaled corticosteroids (ICSs) and/or short-acting beta agonist (SABAs) rescue inhalers; patient and caregiver education about reducing exposure to known or suspected asthma triggers, as well as asthma being a chronic illness requiring ongoing supervision; management of co-morbidities; and providing treatment—or referral to treatment—for acute exacerbation of asthma. Compared to other health care providers, NPs demonstrate better compliance with accepted care standards such as the National Asthma Education Prevention Program (NAEPP) guidelines (O'Laughlen, Rance, Rovnyak, Hollen & Cabana, 2013).

Primary care NPs are critical to identifying effective prevention strategies, making ongoing assessments of asthma control and improving outcomes for patients diagnosed with asthma across the lifespan (Yates, 2013). The foundations of advanced nursing practice, and the basis for improving patient care, begin in nursing education and the core competencies of nursing practice.

1.5.1. NP Core Competencies

The specific Advanced-Practice Registered Nurse core competencies relevant to this research, as outlined by the National Organization of Nurse Practitioner Faculties (NONPF) in Thomas, Crabtree, Delaney, Dumas, Kleinpell, Logsdon . . . & Nativio (2012), include:

1. **Scientific foundations**: With an investigation into the correlations between asthma and the environment, this author is attempting to bridge several disciplines with the aim of better understanding and anticipating the public health effects of climate and weather.
2. **Leadership**: This interdisciplinary research works to promote collaboration with multiple stakeholders at the patient, state, public health and academic levels. Moreover, this research is focused on enhancing evidence-based practice in the primary care setting.

1.5.2. Theoretical Frameworks

Nursing theory does not yet take a strong position on the issues of sustainability or effects of climate on health (Anåker & Elf, 2014; Goodman, 2011). However, in this author's opinion, nursing-specific research examining the relationship between people and their environments represents a critical aspect of modern healthcare. One nursing model relating to this research is Jean Watson's Theory of Caring, which acknowledges the essential holism of a community's parts. Caring for a person in the context of their environment is a fundamental aspect of Watson's theory, and upholds the concept that an individual's health cannot be disconnected from their community, and perhaps vice versa (Butts & Rich, 2011). Other nursing scholars have made congruent arguments to consider ecology as an antecedent to patient health that should be given equal weight in the plan of care (Anåker & Elf, 2014). Among Watson's caring factors is providing "a supportive, protective, and/or corrective mental, physical, societal, and spiritual environment" for patients (Butts & Rich, 2011, p. 511). Undoubtedly, climate effects are among the most germane issues of this century. One way in which NPs can help patients to be more resilient to the health effects of climate and weather is to facilitate cleaner, healthier environments through increased awareness. Thus, supporting public health through an improved understanding of asthma seasonality is a modern expression of Watson's theory. It is within such caring tenets that the art and science of nursing overflows into ecology and promotes mutual wellbeing.

Yet, the health-promotion model that guides this research most is the Social Ecological Model (SEM), which identifies that behavior and health is affected by multiple levels of influence from a person's physical environment, community and society (McLeroy, Bibeau, Steckler & Glanz, 1988). As illustrated in Figure 1, the model places the individual in the context and continuum of reciprocal connections. Most importantly, the SEM highlights how environmental and social factors can be mutual targets for health promotion. Such as in the case of asthma and its seasonal influences, the focus of prevention can be on both the modification of individual behaviors and anticipating periods of harmful weather to avoid triggering asthma.

Figure 1: Social Ecological Model adapted from McLeroy et al., 1988

CHAPTER 2: LITERATURE REVIEW

2.1. Asthma Research

2.1.1. Epidemiology

Asthma is widely understood to be the most common chronic respiratory disease in the Western world, impacting individuals across the lifespan (Jackson, Sykes, Mallia, & Johnston, 2011; Sears, 2008; Vernon, Wiklund, Bell, Dale & Chapman, 2012). As mentioned in Chapter One, there are many known triggers leading to exacerbations of asthma including allergens, acute viral infection, temperature shifts, air pollution or stress. Among the U.S. population, females have a higher prevalence of asthma than males, although this trend is reversed in children under 17 years of age, and children have a greater prevalence of asthma than adults. The population most vulnerable to having an urgent visit related to asthma is children, while mortality associated with asthma is more likely among individuals over 18 years of age (Akinbami et al., 2011).

Adults have a slightly higher prevalence of asthma as compared to children in Vermont, which is opposite of national data (VDH, 2014). Comorbidities are more common among adults, and several studies cite a positive relationship between this and the frequency of exacerbations (Koga, Oshita, Kamimura, Koga, & Aizawa, 2006; Sears, 2008; Dougherty & Fahy, 2009). Poorer medication adherence, which is common among adults, is also associated with increased severity of asthma (Sears, 2008). For example, a recent meta-analysis reflected that good medical adherence is associated with less severe asthma exacerbations (Engelkes, Janssens, de Jongste, Sturkenboom & Verhamme, 2015). However, 43% of individuals with well-controlled asthma among all age groups reported an unscheduled office visit related to an exacerbation, suggesting that even 'good' patients need more guidance from time to time (Peters, Jones, Haselkorn, Mink, Valacer & Weiss, 2007).

The risk factors for asthma exacerbation are multifactorial. For instance, there is research—old and emerging—that continues to substantiate the social determinants of health (Wright, Rodriguez, & Cohen, 1998; Braveman & Gottlieb, 2014). One recent study from the United Kingdom further highlights the connection of low socio-economic status (SES) with poorer respiratory outcomes among children. It provides more evidence for the socio-environmental effects on 'Catarrhal Child Syndrome,' so called for its protracted upper respiratory infection exacerbations, which are related to asthma exacerbations, including prolonged recovery time (Jephcote, Ropkins & Chen, 2014). Chronic disease risks for persons of low SES may increase based solely on lack of patient education or knowledge in seeking timely health care, difficulty managing complex prescription plans, or a deficit of clean environments related to clustered living (Adamkiewicz, Spengler, Harley, Stoddard, Yang, Alvarez-Reeves & Sorensen, 2014). Further, smoking and obesity positively correlate with low SES and AAE, both of which increase in prevalence among adults (Vernon et al., 2012; Zhang et al., 2013).

2.1.2. Air Quality

Globally, air pollution is thought to account for fewer AAEs as compared to viruses or aeroallergens, however, factors such as particulate matter released from residential or industrial sources still represent important AAE triggers (Jackson et al., 2011). Particulate matter (PM) "consists of breathable particles […] such as heavy metals, polycyclic aromatic hydrocarbons (PAHs) and some volatile compounds," to which exposure has consistent associations with chronic respiratory disease (Feretti, Ceretti, De Donno, Moretti, Carducci, Bonetta . . . & Grp, 2014, p. 1). Sources of PM include industrial emissions, and more globally, wood smoke or forest fires (Shen et al., 2013; Ward, Palmer & Noonan, 2010). PM is further divided into a few categories based on size (in μm): PM_{10} is for 'coarse', $PM_{2.5}$ is for 'fine', and $PM_{0.1}$ is for 'ultrafine'. Smaller PM size—such as fine or ultrafine PM—is associated with greater health risks, as well as incidence and mortality for heart and respiratory disease (Anderson, Thundiyil, & Stolbach, 2012). $PM_{2.5}$ released from residential woodstoves is understood to be a significant contributor to local air pollution levels, especially from older, less efficient models with incomplete combustion (Shen et al., 2013). For example, using pre- and post-measurements following a woodstove change-out program, one study from the Rocky Mountains found a 20% average wintertime reduction in outdoor $PM_{2.5}$, with a 28% reduction in wood smoke-related outdoor $PM_{2.5}$; moreover, in a separate study, the same researchers found an average of 71% reduction in indoor $PM_{2.5}$ (Ward, Palmer, Bergauff, Hooper & Noonan, 2008; Ward et al., 2010). Woodstoves manufactured before 1990 contribute vastly more $PM_{2.5}$ air pollution because they predate stronger EPA regulations. Older woodstoves are commonly used among Vermonters, and increase in use during winter months in the Northern Hemisphere (Polissar, Hopke & Poirot, 2001; Ring, 2015; Shen et al., 2013). Therefore, examining air quality related to seasonal use of woodstoves in Vermont would be an important factor when considering patterns of AAEs in the state. However, the health effects of woodstove use in Vermont are largely unstudied.

2.1.3. Seasonality

Research conducted in the mid-20th century began to closely examine the relationship between air quality, weather, climate and human health. Related research also increased with the passage of the Clean Air Act and other climate action legislation in the 1960s (Dockery, Pope, Xu, Spengler, Ware, Fay . . . & Speizer, 1993; Krupnick & Morgenstern, 2002; Samet, 2011). As evidenced in this review, the cause-and-effect relationship between those factors and AAE has gradually burgeoned in the literature. The identification of seasonal trends resulting from a variety of triggers has been a common conclusion. However, the use of MeSH keywords "Vermont" and "asthma" with or without "climate," "season" or "weather" in PubMed, Ovid Medline and Web of Science databases elicited only irrelevant results on the topic. Therefore, there appears to be a dearth of any Vermont-based seasonal AAE research.

In the broader context of the whole U.S., the September peak in AAE is one seasonal phenomenon that is well documented among school-age children, but largely attributed to rhinovirus, as opposed to environmental triggers (Cohen et al., 2014; Sears & Johnston, 2007). One of these researchers demonstrated a smaller September rise in AAEs for adults in the U.S., and more importantly noted that asthma exacerbation in adults reaches the highest annual levels around Christmas, which parallels the timing of peak hospitalizations for respiratory tract infection in all age groups (Johnston, 2007). May et al. (2011) examined similar triggers in the Washington, D.C. metropolitan area, including upper respiratory infection (URI) diagnoses, among adult patients seen in the Emergency Department (ED) over a 12-month period, and observed an increase in AAE visits in the fall, but in a one-month lag period following peak ragweed levels. However, the researchers found no consistent trend between AAE admissions and pollen counts throughout the year of study. Another study also found a meaningful autumn increase of AAEs among elderly (>65-years-old) populations in urban Seoul, Korea when correlated to temperature change; however, the study did not adjust for pollen count because the authors felt it would not significantly alter the findings (Kim et al., 2014). A further limitation of this study was that only one monitoring station was used to measure temperature, though the sample population was from the larger metropolitan area. Moreover, in comparing the influence of temperature on human health, the lowest average temperature in the winter was -0.5°C, where as the average low for a NEK winter is between -15 to -14°C (NCDC, 2003). A study based in Genoa, Italy found positive correlations between AAEs and pollens, molds, wind speed, rainfall, air pollution with peaks in the fall *and* spring (Ruffoni et al., 2013). This study—based in a temperate climate in the northeast of Italy at 20 meters above sea level—in particular, suggests a causal link between asthma and seasonal changes in such an environment.

There have been several national and international studies examining the correlation between seasonal viral illnesses including influenza or URIs, such as May et al. (2011), which found no significant correlation between URI complaints and AAEs, which deviates from the findings of Cohen et al. (2014) and Johnson (2007) referenced above. Recently, one study used influenza trends from 2000-2008 to forecast asthma-related health impacts of the 2009 H1N1 influenza pandemic and found that in the U.S. asthma admissions were positively associated with influenza activity (Gerke, Yang, Tang, Foster, Cavanaugh & Polgreen, 2014). Therefore, around the globe, multivariate studies on asthma, seasonal illness and environment appear to reflect cyclical correlations. However, because seasonal illness can vary in timing and severity by region, more localized findings would be helpful in understanding risk and seasonality for Vermonters.

Studies have examined weather patterns such as cold spells and relative humidity. The cold weather effects on asthma are often irritation and bronchospasm caused by rapid dry and cooling of the airway (Bougault, Turmel, St-Laurent, Bertrand & Boulet, 2009). Geographically speaking, research based in New York State is the closest the literature comes to describing weather effects on asthma in Vermont: one study examined the effect of cold spells (three or more sequential days of temperatures at the 10^{th} percentile of the daily mean) on asthma admissions across the state over a 15-year period for the months between November and April (Fitzgerald et al., 2014). The findings reflect a lag of increased ED visits for AAEs in the days following a cold spell, which is likely mediated by the long-term inflammation process of asthma, and suggests a weather-based relationship for asthma in that region. However, only 2.8% of the study population came from the Adirondacks and Northern New York state, which is the region most comparable to the NEK. A similar New York statewide, year-round study examining weather-type variables such as the synergistic effects of temperature *and* humidity found that there were strong regional and age group differences in the seasonality of AAE (Lee et al., 2012). However, only a minority of the subjects was from non-urban areas, and the authors cited a need for related studies among more rural populations. While New England-level regional studies have some utility in public health planning, this research suggests that there is enough variation among populations that more localized research is merited.

Another method of assessing the seasonality of asthma is to examine prescriptions or prescription refills for asthma medication. One study from researchers at Johns Hopkins University found increases in asthma-related refills and prescriptions during September and January, which implied a surge in AAEs. The authors further recommended that routine, *anticipatory* asthma check-ups happen in the months prior (August and December) as an appropriate method of prevention for AAE (Butz, Thompson, Tsoukleris, Donithan, Hsu, Mudd . . . & Bollinger, 2008). However, the study population was 89% black and 100% urban, which reflects a different demographic than Vermont's NEK, which is almost heterogeneously white (USDOL, 2014). Regardless of etiology, most of the literature echoes the importance of surveillance in preempting triggers of manageable chronic disease exacerbation.

2.1.4. Primary Care

One of the frequent axioms of primary care is anticipatory guidance. While the purpose of such a concept may be obvious in providing care to children with rapidly growing/changing bodies and minds, the utility of anticipatory guidance throughout the lifespan has great merit. Preventative care of asthma goes beyond the purview of the typical age-based annual exam; it requires a separate, more frequent chronic care visit similar to hypertension, diabetes or mental health. Timing such visits in anticipation of peak AAE seasons would be helpful, especially with a *prompt* from the electronic health records system (EHR) to schedule an appropriate chronic care visit.

EHR reminders are especially valuable for primary care. For example, practices with EHRs prompting discussion of asthma care had more frequent discussions regarding triggers and modifying patient behaviors, which led to better patient outcomes (Pile, 2013). On the whole, however, rural primary care practices have more difficulty in providing evidence-based care and should be a focus of quality improvement projects such as in asthma management incorporated into EHRs (Cicutto, Dingae, & Langmack, 2014). Anticipation of peak periods of AAEs could be an important, focused intervention easily incorporated as a primary care EHR prompt.

2.2. Methods of Analysis

The majority of the research related to asthma and climate or weather used only a handful of statistical methods. After descriptive statistics and simple tests of association, several studies (Van Dole, Swern, Newcomb, & Nelsen, 2009; Ruffoni et al., 2013; Fitzgerald et al., 2014; Kim et al., 2014; Hervas, Utrera, Hervas-Masip, Hervas, & Garcia-Marcos, 2015) used a Poisson distribution, which is a common multiple regression analysis that is appropriate with dichotomous outcomes and categorical variables such as asthma and environment. Furthermore, Poisson's accounts for patient-time and multiple confounders (Oleckno, 2008). One study used negative binominal regression because of the wide distribution of daily number of visits (between zero and hundreds), as compared to Poisson's which is less ideal for such dramatic daily variation (Soyiri et al., 2013). Two studies (Gerke et al., 2014; May et al., 2011) used time-series analysis, which is a design that "permits the effect of the intervention to be estimated while taking into account secular trends or cyclic patterns" (Oleckno, 2008, p. 433). However, time-series models require an intervention within the study framework, which is less common in other related asthma-and-climate studies. One study (Buckley & Richardson, 2012) stood alone by using a case-crossover design, which is "used in circumstances where the risk of the outcome is elevated for only a short time following exposure," which is referred to as the hazard period (Oleckno, 2008, p. 307). The case-crossover design is very appropriate for examining the lag effects, and perhaps represents an important design for future study, but is so far less common in this genre of asthma research.

2.3. Summary

There are clear correlations between climate, weather and asthma, as well as a gap in Vermont-based research beyond the joint Vermont Department of Health and CDC data, which unfortunately, cannot be used for new research per the CDC agreement (J. Wolforth, Personal Communication, February 17, 2015). While there appears to be a great deal of justified attention paid to the seasonal prevention of infectious disease, there is a dearth of public health research in Vermont concerning the seasonality of chronic disease like asthma despite evidence of those patterns in other locations. Several studies highlight the associations between climate or weather shifts and periods of increased

AAEs across the lifespan. Limitations of these studies vary, from lacking local monitoring stations to only sampling in certain seasons. Furthermore, most of the research is focused on urban populations with distinctive confounders such as air pollution from transportation sources or aeroallergens that do not frequently affect Vermonters.

Finally, the primary care setting is the ideal context to deliver focused, seasonal anticipatory guidance on disease prevention strategies with the support of local, place-based data. The focus of this research will be investigating the relationship between AAEs seen in a primary care setting in the NEK of Vermont and the weather and climate elements that may trigger seasonal peaks in exacerbations.

CHAPTER 3: JOURNAL ARTICLE

Abstract

Asthma is a chronic respiratory disease characterized by long- and short-term inflammation and bronchospasm susceptible to multiple triggers that affects patients across the lifespan. Asthma management is a primary care priority in Vermont, where there continues to be an above-average prevalence of asthma among both children and adults as compared to other states. However, many of Vermont's children and *especially* adults with asthma are not participating in or receiving regular check-ups for asthma management that would best prevent exacerbation of asthma symptoms. Several climate and weather elements including, but not limited to, extreme temperatures and particulate matter are known asthma triggers. Vermont's high per capita use of old woodstoves, pockets of poverty and cold winters are all factors that might collide to adversely impact residents' asthma. Insights into how climate and weather might be related to peak periods of acute asthma exacerbation (AAE) among individuals living in the rural Northeast Kingdom of Vermont (NEK) could provide valuable, regionally focused public health information to primary care providers on the front lines of asthma management.

The objective of this research was to examine the potential relationship between the climate and weather of the NEK and visits for asthma exacerbation in the primary care setting. The research began with a retrospective chart review including visits to five different clinic sites in the NEK between 2009-2014 with the ICD-9 code for asthma exacerbation (493.xx) as the primary diagnosis. When visits were individually validated

as an AAE, the clinic site, date of visit, and patient's age and sex were documented. These validated visits were then analyzed against weather and climate data including temperature and air quality in a generalized linear model. The results suggest that while diurnal shifts and air quality do not show a strong relationship with AAEs in this area, visits to primary care clinics in the NEK for AAEs are attributable to colder periods.

Background and Introduction

More than simple bronchospasm, asthma is characterized by such clinical elements as short- and long-term inflammation of the respiratory airway, edema, narrowing of the airway, and increased secretions mediated by different allergic, lifestyle, environmental and inflammatory triggers (VanGarsse et al. 2015). Asthma is a manageable—but not curable—chronic disease that requires ongoing care. In the United States, asthma has been increasing in prevalence for over 50 years despite advances in medical treatment and pharmacotherapies. It currently affects an estimated 25 million people with a recent, shallow rise in prevalence of 1.2% between 2001 and 2009 (Akinbami et al. 2011). Of those individuals, 52% experienced an exacerbation of asthma symptoms; this approximates to a hypothetical 4.2% of the total American population having an AAE in that time period. Unsurprisingly, even for individuals with relatively well controlled asthma, the effects of this condition ripple into many aspects of daily life including social and occupational roles, as well as potential missed school or work days, for which the huge negative economic implications have been well established (Guilbert et al. 2011; Sadatsafavi et al. 2014).

Asthma prevention and management is a salient public health issue in the state of Vermont—known to be one of the healthiest states in the nation, yet it boasts an above-average prevalence of asthma (Vermont Department of Health 2013). In 2009, the national asthma prevalence was 8.2% among the overall U.S. population (Akinbami et al. 2011). Comparably, the prevalence of asthma in Vermont was 11% among adults in 2012 and 8-10% among children in 2011, and has remained somewhat stagnant in recent years despite public health promotion campaigns (Vermont Department of Health 2015). Additionally, reducing the impact of asthma is a key aspect of the Healthy Vermonters 2020 goals, which include cutting the hospitalization rate related to asthma and increasing the percentage of patients advised on modifying risk behaviors including avoidance of triggers (Vermont Department of Health 2012). An Asthma Action Plan (AAP) is one of the most common primary care interventions in Vermont for helping patients comprehend asthma symptoms, modify behaviors and avoid triggers. However, just under half of children and one-third of adults in Vermont report having ever received an AAP, a finding which tracks with the low rate of routine asthma care visits in primary care across the lifespan in the state (Vermont Department of Health 2014).

In Vermont, common asthma triggers appear to be related to individuals' homes. The most frequently identified asthma triggers for Vermonters are, in order of prevalence: indoor pets, pets allowed in the bedroom, carpet in the bedroom, cooking with gas, woodstove use, and indoor tobacco smoking (VDH 2013). In addition to the usual triggers, the Vermont Department of Health has identified several 'hot spots' for asthma in Vermont, including the Springfield and Rutland health service areas and the

Northeast Kingdom (NEK). Related to this is the knowledge that asthma disproportionately affects people of lower socioeconomic status (Adamkiewicz et al. 2014; Fung et al. 2014; VDH 2013); the NEK—containing Essex, Orleans and Caledonia counties—represents some of the most impoverished communities in the state (U.S. Department of Labor 2014). Because this population is at higher risk of chronic disease it should be a region of focus for primary care interventions related to asthma.

Vermont's geography also creates a unique seasonal portrait of air quality, humidity and extreme temperature changes (National Climate Data Center 2003). Weather patterns play strongly in the variations of air quality but local and global man-made emissions also make a large impact. Vermont was recently ranked first in per capita woodstove particle emissions. According to Ring (2015), a "2008 survey of Vermont wood stove users found that more than half the woodstoves in use were made before 1990 and don't burn as cleanly or as efficiently as the newer models." This can significantly impact both indoor and outdoor air quality in the colder months. Older woodstoves are thought to be more polluting because of inefficient or incomplete combustion of wood matter, which releases great amounts of harmful polycyclic aromatic hydrocarbons (PAH) into the local and global atmosphere (Shen et al. 2013).

Frigid temperatures and extreme diurnal shifts—the difference between night- and daytime temperatures—are also known asthma triggers (Buckley and Richardson 2012; Fitzgerald et al. 2014; Kim et al. 2014). This is relevant to asthma in Vermont because despite a general warming trend the state continues to break records with its extreme cold temperatures and diurnal shifts (Betts 2011; Tortora 2015). This may be especially pronounced in the NEK, an isolated corner of the state with lower-elevation circumboreal forest and a true subarctic environment characterized by harsh winters and a short growing season; this landscape and climate has more in common with northern New Hampshire and Maine, as well as the Canadian tundra, than the remainder of Vermont (Johnson 1998).

The cost of treating individuals for an AAE has also increased dramatically in the last decade—mostly attributed to an intensive use of respiratory and non-respiratory in-hospital resources (Hasegawa et al. 2013). In Vermont alone, this cost exceeds $7 million annually (VDH, 2013). Furthermore, those expensive hospitalizations for AAE are especially associated with poorer outcomes (Akinbami et al. 2011). If we only bear in mind the significant financial burden of asthma, it is essential to consider effective methods of reducing that encumbrance, which might be otherwise devoted to health promotion.

Despite improvements in pharmacotherapies for asthma, the onus for effective management of asthma continues to rest with education of patients or caregivers in the primary care setting (Moorman et al. 2012; O'Laughlen et al. 2013). However, as Yates (2013) points out: like the stock market, "[r]elying on a patient's report of historical and current asthma control is usually insufficient to measure risk of future exacerbation," suggesting the necessity for combined efforts between provider *anticipation* and patient education for the most effective care. Therefore, easier surveillance or methods of intervention are strongly merited to aid in provider anticipation of asthma exacerbation.

Nursing theory does not yet take a strong position on the issues of sustainability or effects of climate on health (Anåker and Elf 2014; Goodman 2011). However, in this author's opinion, nursing-specific research examining the relationship between people and their environments represents a critical aspect of modern healthcare. The health-promotion model that guides this research most is the Social Ecological Model (SEM), which identifies that behavior and health is affected by multiple levels of influence from a person's physical environment, community and society (McLeroy et al. 1988). The model places the individual in the context and continuum of reciprocal connections. Most importantly, the SEM highlights how environmental and social factors can be mutual targets for health promotion. Such as in the case of asthma and its seasonal influences, the focus of prevention can be on both the modification of individual behaviors and anticipating periods of harmful weather to avoid triggering asthma.

Beyond nursing theory, another goal of this research is to meet specific Nurse Practitioner Core Competencies such as scientific foundations and leadership, as outlined by the National Organization of Nurse Practitioner Faculties (NONPF) in Thomas, et al. (2012).

The results of this research will be specific to the region of study: the Northeast Kingdom of Vermont, an area known for its rural beauty and history, but also greater levels of poverty and subsequently, a population with increased risk for chronic disease such as asthma. There is little asthma research specific to Vermont. If climate and weather trends exist for AAEs, the groundwork may be laid for future, focused public health campaigns aimed at prevention during seasonal periods of greater risk among both pediatric and adult patients seen in the primary care setting. For primary care providers juggling the myriad dimensions of health care simplifying delivery is essential.

Methods

Methods of Analysis

The majority of the research related to asthma and climate or weather used only a handful of statistical methods. After descriptive statistics and simple tests of association, several studies (Fitzgerald et al. 2014; Hervas et al. 2015; Kim et al. 2014; Ruffoni et al. 2013; Van Dole et al. 2009) used a Poisson distribution, which is a common multiple regression analysis that is appropriate with dichotomous outcomes and categorical variables such as asthma and climate, and well suited for studies with less dramatic daily variation in data counts. Furthermore, Poisson's accounts well for multiple confounders (Oleckno 2008).

Asthma Data

This research employed a retrospective chart review including visits between 2009-2014 to five different clinic sites in the NEK with asthma exacerbation as the primary diagnosis. The time period from January 1, 2009 to December 31, 2014 was selected to capture a reasonable period of climate and weather fluctuations (L-A. Dupigny-Giroux, Personal Communication March 18, 2015). The five primary care clinic sites (in Concord, Danville, Hardwick, Island Pond and St. Johnsbury, Vermont) managed by Northern Counties Health Care, Inc. (NCHC) all used an integrated electronic health record (EHR) system to service patients in the three counties comprising the NEK of Vermont. A report from NCHC was generated solely for this research using billing history for visits in that time period with the International Classification of Diseases, Ninth Revision code 493.xx as the primary diagnosis code. Practice Partner® was the EHR in use at the clinic sites during the period of interest for the chart review, and was used to validate visits as an AAE. Visit exclusion criteria was: routine or previously scheduled visits characterized as non-acute; visits where the primary diagnosis code at discharge was other than asthma; and serial visits for the same exacerbation episode. If visits were validated as an AAE, the clinic site, date of visit, and patient's age and sex were documented.

The Institutional Review Board at the University of Vermont approved the study protocol. Written permission and support was obtained from NCHC, Inc. to access the patient records.

Climate and Weather Data

Climate and weather data including temperature and air quality index information for the corresponding periods and clinic locations were downloaded from the National Oceanic and Atmospheric Agency's National Climate Data Center (NCDC) and the U.S. Environmental Protection Agency (EPA) websites, respectively. Direct temperature data for the study period only existed for two clinic sites (Island Pond and St. Johnsbury), so that data was used as an analog for Danville (St. Johnsbury) and Concord (St. Johnsbury), and temperature data from Walden, VT was used as an analog for Hardwick. Presently, there is no Air Quality Index (AQI) monitoring in the NEK. The general direction of pollution drift moves from west to east; while AQI data from the region of New

Hampshire directly east of the study area would be an appropriate analog to local NEK data this area too lacks monitoring stations. The AQI monitoring stations closest to the study area are in Chittenden County, which capture both the larger air pollution drift from the Midwest and local emissions, but represent disparate topography and demographics from the NEK (NCDC 2003; USDOL 2014). Therefore, AQI data from Rutland County was used as the closest analog for the mountain and river valley topography as well as the demographics of the NEK (Poirot, R. Personal Communication October 9, 2015; USDOL 2014).

Analysis

The dates for validated AAE visits (N=1177) were integrated and matched with dates of climate and weather data. As outlined in Figure 1, a handful of visits (N=18) were excluded due to missing weather or climate data, and another group of visits (N=17) was excluded because of occurrence on weekends or major holidays when the majority of clinics are not open (New Years Eve and New Years Day, Memorial Day, Independence Day, Thanksgiving, Christmas Eve and Christmas Day), and therefore less reflective of the usual business seen at NCHC sites.

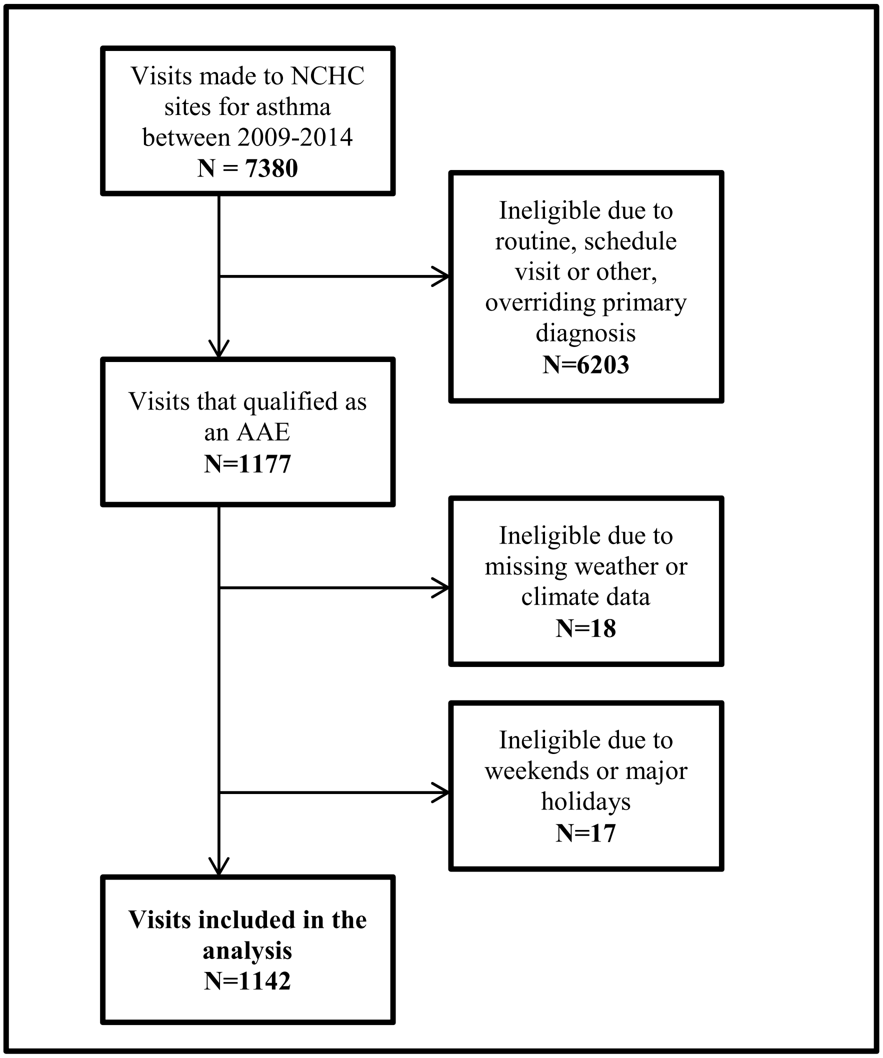

Figure 2: Inclusion chart

The remaining incidences of AAE visits (N=1142) were correlated against weather and climate data using a Spearman's correlation and a Poisson's model. Lee et al. (2012) suggested that the temperature or pollution exposure effects on asthma exacerbation might take several days to be reflected in the timing of patients seeking care. Therefore, an additional calculation of lag values for minimum temperature and diurnal shift was used to attempt to account for these factors up to three days preceding a visit. In order to create a count significant enough for analysis, the AAEs were summed by week. All exposure variables (temperature, diurnal shift, and air quality) were treated as continuous variables and controlled for in the model. Significant results at the $P \leq 0.05$ level are the main focus of the discussion, though near-significant ($P \leq 0.10$) results are also mentioned. The data were analyzed using the IBM Statistical Package for the Social Sciences (IBM SPSS, version 22.0).

Results

Characteristics of AAE visits

Among the 1142 visits for an AAE to NCHC clinic sites included in the analysis, there were clear peaks in the autumn (32.6% of visits) and winter (28.7% of visits) months (Table 1). Parenthetically, earlier days of the week (Monday-Wednesday) were strongly correlated with more asthma visits ($p = 0.000$). However, there was no difference between asthma visits by year of the study when accounting for the missing weather (and subsequently, asthma incidence) data for the first half of 2009. In general, both age groups establish a sharp dip in the summer followed by the rise in AAEs in September that eventually drops again slightly and remains steady through the spring months (Figure 2). However, the under-18 group shows a drop in October when the over-18 group continues to rise, and a rise in April when the over-18 group trends toward summer lows. Across all AAE visits, October had the highest mean by week (Figure 3). Similar to other asthma research findings, incidences for asthma visits are higher for males than females under 18-years-old, and the reverse for patients 18 years or older.

Table 1: Characteristics of AAE-related visits (NEK, VT, Jan 2009-Dec 2014)

Variable	Characteristic	No. visits	% of visits
Total AAE visits		1142	100.0
Sex	Male	331	29.0
	Female	***811***	***71.0***
Age	<18yo	226	19.8
	18yo or >	***916***	***80.2***
Visit Year	2009	122	10.7
	2010	184	16.1
	2011	214	18.7
	2012	207	18.1
	2013	***218***	***19.1***
	2014	197	17.3
Visit season	Spring (Mar-May)	303	26.6
	Summer (Jun-Aug)	139	12.2
	Fall (Sep-Nov)	***372***	***32.6***
	Winter (Dec-Feb)	328	28.7
Visit Month	January	109	9.5
	February	111	9.7
	March	111	9.7
	April	110	9.6
	May	82	7.2
	June	74	6.5
	July	29	2.5
	August	36	3.2
	September	125	10.9
	October	***134***	***11.7***
	November	113	9.9
	December	108	9.5
Day of the week	Monday	241	21.1
	Tuesday	***265***	***23.2***
	Wednesday	264	23.1
	Thursday	166	11.1
	Friday	206	18.0

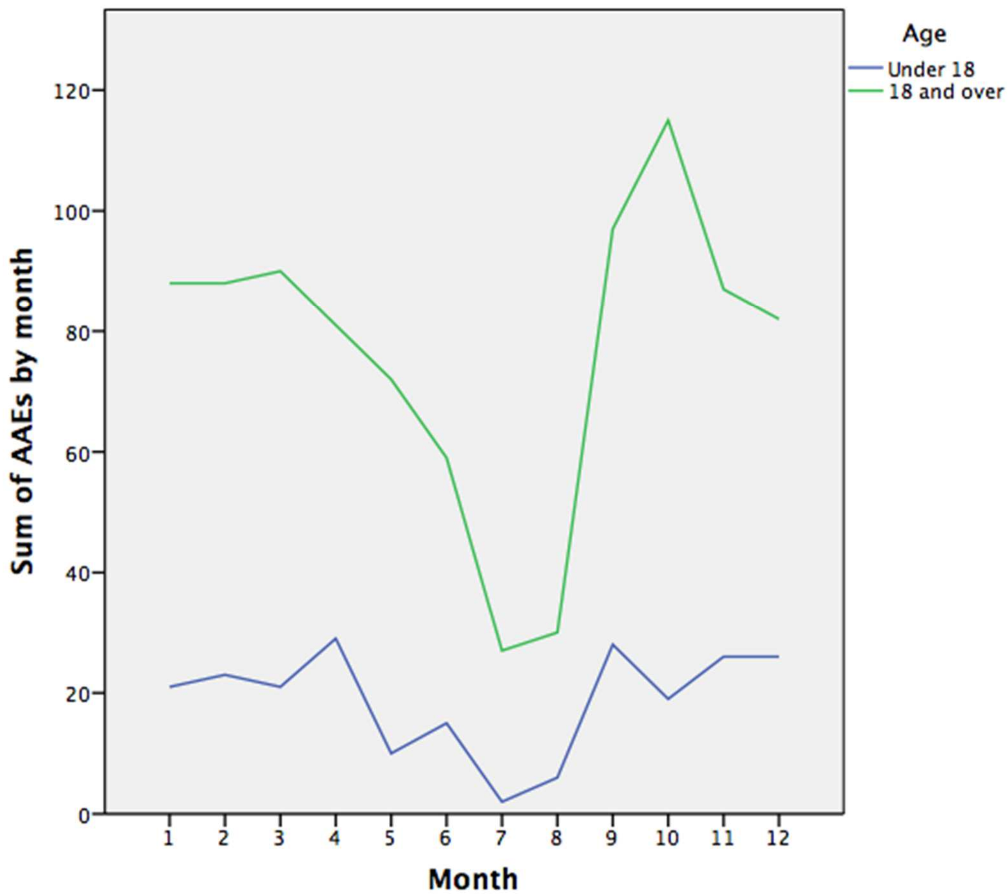

Figure 3: AAEs by age group and month

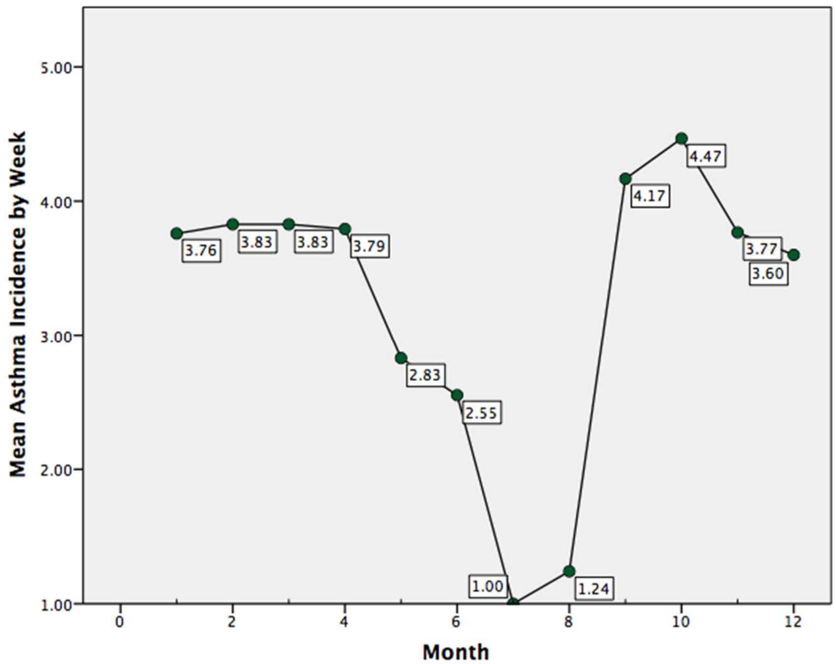

Figure 4: Mean AAE visits per week by month

AAE visits by weather and climate

Using Spearman's, analysis of colder days and AAEs (r = -0.188, p = 0.000) yielded more significant results than diurnal shifts (r -0.057, p = 0.024) or air quality (r = 0.017, p = 0.495). In accounting for lag time, both minimum temperature plus three days (r = -0.193, p = 0.000) and diurnal shift plus two days (r = -0.109, p = 0.000) had the greatest correlation coefficient for those respective categories showing a weak but very significant correlation with AAEs (Table 2). Air quality appeared to have no relationship to AAEs, but further analysis suggested that air quality has a weak but very significant relationship to minimum temperatures (r = -0.341, p = 0.000).

As a model of logarithmic probability, the Poisson's analysis showed only minimum temperatures were significantly associated with AAEs (B = -0.014, p = 0.000,

Table 2: Spearman's rho by weekly mean of AAEs

			AAE incidence
Spearman's rho	Min temp	Correlation Coefficient	-.188**
		Sig. (2-tailed)	.000
		N	1551
	Diurnal shift	Correlation Coefficient	-.057*
		Sig. (2-tailed)	.024
		N	1551
	Min temp, one day lag	Correlation Coefficient	-.186**
		Sig. (2-tailed)	.000
		N	1551
	Min temp, two day lag	Correlation Coefficient	-.188**
		Sig. (2-tailed)	.000
		N	1550
	Min temp, three day lag	Correlation Coefficient	***-.193*****
		Sig. (2-tailed)	.000
		N	1550
	Diurnal shift, one day lag	Correlation Coefficient	-.076**
		Sig. (2-tailed)	.003
		N	1551
	Diurnal shift, two day lag	Correlation Coefficient	***-.109*****
		Sig. (2-tailed)	.000
		N	1550
	Diurnal shift, three day lag	Correlation Coefficient	-.089**
		Sig. (2-tailed)	.000
		N	1550
	Daily mean PM2.5 concentration	Correlation Coefficient	.017
		Sig. (2-tailed)	.499
		N	1526
	Daily mean AQI value	Correlation Coefficient	.017
		Sig. (2-tailed)	.495
		N	1526

Correlation is significant at the 0.01 level (2-tailed).**
Correlation is significant at the 0.05 level (2-tailed).*

CI: -0.17, -0.10) given the rest of the variables in the model (Table 3). Meaning, that for every 1 ° F change, the difference in the logs of asthma-related primary care visits are excepted to change by the respective coefficient (B). Other independent factors including air quality and diurnal shift were not significant in association with AAEs.

Table 3: Poisson's model by weekly mean AAEs

			95% Wald Confidence Interval		Hypothesis Test		
Parameter	B	Std. Error	Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	-87.277	35.7285	-157.303	-17.250	5.967	1	.015
Week (1-53)	.002	.0020	-.002	.006	.696	1	.404
Mean min temp F[a]	**-.014**	**.0020**	**-.017**	**-.010**	**46.205**	**1**	**.000**
Mean diurnal shift	-.002	.0057	-.013	.009	.166	1	.683
Daily Mean PM2.5	-.050	.0339	-.117	.016	2.198	1	.138
Daily AQI Value mean	.012	.0116	-.011	.034	1.010	1	.315
(Scale)	1[a]						

Dependent Variable: AAEs
Model: (Intercept), week, mean minimum temperature Fahrenheit, mean diurnal shift, daily mean PM2.5, daily mean AQI
Boldface indicates statistically significant ($P \leq 0.05$).
a. For every 1 ° F change, the difference in the logs of asthma-related primary care visits are excepted to change by the respective coefficient.

Discussion

Principal findings

In this study, I examined the potential relationship between visits to primary care clinics for asthma exacerbations with local weather and climate. When assessed individually, it appears that colder temperatures and greater diurnal shifts show a weak but significant correlation to visits for AAEs. For example, an increase in visits for September and October is observed when there is greater change in minimum temperatures, but not diurnal shifts (Figure 4). And, in the spring the under-18 age group has a spike in visits when the overall temperatures are warming, but there is a wider diurnal shift (Figure 5). This is possibly attributable to these independent variables exerting influence differently across the lifespan. Other studies corroborate the autumn peak in AAE incidence, but it has been widely attributed to upper respiratory infections when children return to school (Cohen et al. 2014). However, this does less to account for the significant increase in AAEs among adults in September and October. In other research, asthma exacerbation in adults reaches the highest annual levels around Christmas, which parallels the timing of peak hospitalizations for respiratory tract infection in all age groups (Johnston 2007). All variables being equal, it appears that increased AAE visits are attributable to colder weeks in the NEK.

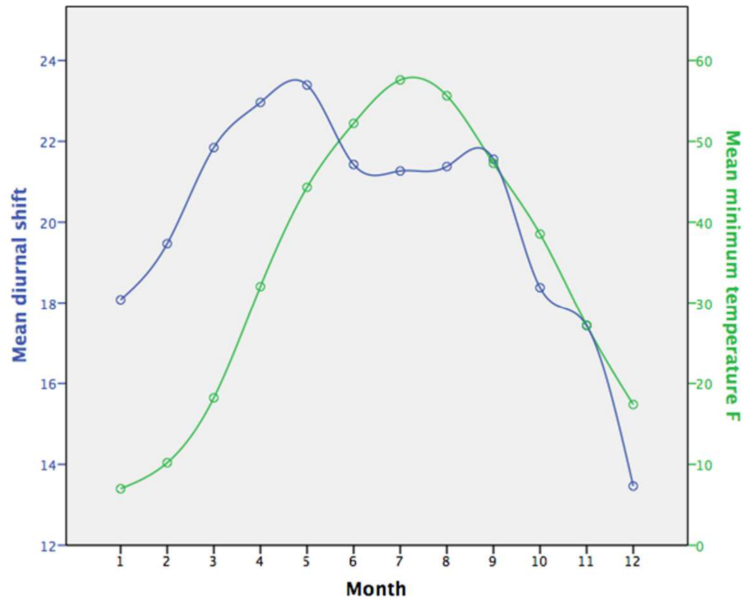

Figure 5: Mean diurnal shift and minimum temperature by month

While there was not a significant correlation noted, the effect of AQI on AAEs is an area of great potential for future research. The lack of correlation between air quality and AAEs is perhaps not surprising, considering the AQI data is from another area of the state. It may be that the use of analogous southern Vermont data—although similar in topography—to examine the relationship between NEK variables is not appropriate. What is interesting is the significant negative correlation between AQI (higher numbers indicating poorer air quality) and colder temperatures, which would indicate either the effect of a capping inversion causing pollutants to settle or an increase in the use of woodstoves, or both.

Implications for future research

Future research should be able to compare the AAE visits in primary care included for this review against visits to urgent care or emergency departments (ED) in the health service area in the same time period. One of the questions remaining from this study is the frequency and severity (mild, sub-acute or acute) of AAE visits to primary care compared to the ED, as influenced by climate factors.

To forward the Nurse Practitioner core competency of scientific foundations, further advanced practice nursing student research could focus on a quality improvement project in primary care to increase the number of patients screened to receive an Asthma Action Plan or other asthma education.

One of the chief missing pieces of the seasonal asthma puzzle in this study is the lack of local AQI monitoring the in NEK. Future research might focus on tracking both air quality data in these counties as well as seasonal woodstove use among persons with asthma.

Implications for practice

The trends in AAE incidence described here could help health care clinics and primary care providers in the NEK design and implement better prevention strategies. Nurse practitioners at the NCHC clinics are well positioned to be the hub of collaboration, reaching across the several disciplines including the educators and social workers needed to implement such prevention, thereby forwarding the NONPF core competency of leadership.

This research is appropriate in the context of the SEM by connecting people and healthcare within an environmental context. For example, the specific seasonal triggers for AAEs in the NEK would suggest that routine quarterly or semi-annual visits for asthma, including interventions such as an Asthma Action Plan should be a priority for adult patients. Pediatric patients in particular should be recalled to the clinic in August before returning to school for prescription refills and education on appropriate use of asthma maintenance medications. However, adult patients compose 70% of the visits for AAE, and therefore, a majority of the clinical care burden, which is compounded by an increased likelihood for co-morbid disease and smoking among adults which increases the risk for exacerbations (Sears 2008).

Furthermore, a public health campaign might highlight the expectation for all patients with asthma to ask for an Asthma Action Plan and to receive education on strategies in avoiding seasonal exacerbations.

Limitations

There are a several limitations to this research. Most importantly, the sampling and analysis does not control for potential confounders such as smoking status or pets in the house, as well as comorbid disease, socioeconomic status and race. The significance of the results might be limited by a small sample size, as the population of the NEK is <70,000 and AAEs may only affect an estimated 1-2% of individuals annually. Most critically, the weather and climate measurements were only an analog of the local climate, and furthermore, do not account for microclimate variations that may affect AAEs. Moreover, the data assumes patient proximity to the clinic sites, which was not verified in the study. As questioned among the implications for future research, it is also possible that the AAEs presenting to primary care or outpatient settings may be lesser in severity than those presenting to the emergency department or urgent care centers, and therefore only one segment of the population at risk has been reviewed.

Conclusions

There is a clear but subtle association of colder temperatures and increased primary care visits for asthma exacerbations in the Northeast Kingdom of Vermont, especially among female adults. All patients with asthma should be called in for routine asthma maintenance visits at least twice a year, in the late summer and late winter, for Asthma Action Plan review and patient education on seasonal triggers. Within the framework of the Social Ecological Model, future research should focus on the possible influence of air quality and patient behaviors on seasonal asthma trends in the NEK.

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APPENDIX I: DEFINITIONS

Acute Asthma Exacerbation—commonly referred to as an asthma attack. The classic symptoms are shortness of breath, wheezing, and chest tightness.

Asthma Action Plan—a widely used education tool to aid patient understanding and management of asthma.

Climate—a measure of the average pattern of variation in temperature, humidity, atmospheric pressure, wind, precipitation, atmospheric particle count and other meteorological variables in a given region over long periods of time.

Particulate Matter—air pollution term for a mixture of solid particles and liquid droplets found in the air. The pollutant comes in a variety of sizes and can be composed of many types of materials and chemicals.

Weather—the state of the atmosphere at a place and time as regards heat, dryness, sunshine, wind, rain, etc.