2020

ANALYSIS OF HEALTH SURVEY DATA TO ADDRESS TOPICS IN ENVIRONMENTAL AND PUBLIC HEALTH

Nimish Valvi
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2019

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Nimish Valvi

College of Public Health

University of Kentucky

2019

ANALYSIS OF HEALTH SURVEY DATA TO ADDRESS TOPICS IN ENVIRONMENTAL AND PUBLIC HEALTH.

A Capstone project submitted in partial fulfillment of the requirements for the degree of Doctor of Public Health in the College of Public Health at the University of Kentucky

By

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Nimish Valvi

College of Public Health

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DEDICATION

To my mother. Rama Ramesh Valvi; Rest in Peace.

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I would like to express my deepest appreciation to all the members of my committee. Firstly, my committee Director, Dr. Erin Haynes, for her constant words of encouragement and profound belief in my abilities. Next I would like to thank my committee members Dr. Anna Kucharska-Newton and Dr. Steven Browning for their timely and instructive comments at every stage of this process. I greatly appreciate for taking your valuable time in guiding me throughout this path. I am eternally grateful.

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CHAPTER 1

BACKGROUND

The goal of this capstone is to highlight the use of publicly available complex sample public health data like the National Health and Nutrition Examination Survey (NHANES) and the Behavioral Risk Factor Surveillance System (BRFSS) to address relevant public health questions in the topics of environmental health and health policy using epidemiologic methods.

The role of the first paper on environmental health is to assess the role of blood manganese levels on myocardial infarction, stroke, and renal dysfunction and explore differences based on socioeconomic status. This paper will quantify the association of blood manganese levels and also provide information on individual and socioeconomic factors that are related to myocardial infarction, stroke, and renal dysfunction. Due to the lack of US studies this, the present analyses will fill some of the knowledge gaps from previous studies that were primarily conducted in Asia and Europe.

The second paper using the health policy perspective will describe the impact of the Affordable Care Act (2010) on current smoking and quit-attempts among expanded and non-expanded US states, and identify the impact among low-income individuals, and examine the state-level barriers to smoking cessation services in the expanded and non-expanded states.

The capstone will be divided into two separate papers that will include the introduction, methods, results, discussion sections of the two distinct topics of environmental health and health policy. Lastly, the conclusion will highlight the recommendations and the public health implications for the two papers.

ABSTRACT

Introduction: Manganese is an essential trace element that can cause adverse health effects with deficiency and in excess amounts. The purpose of this study is to determine the asscociation of blood manganese levels and the prevalence of myocardial infarction, stroke, and renal dysfunction in a general US population.

Methods: Data were used from the National Health and Nutritional Examination Survey (NHANES) of non-institutionalized US adults 20 years and older using the 2011-2012, 2013-2014, and 2015-2016 survey cycles (n=16629). Weighted multivariable logistic regression models adjusted for age, race/ethnicity, sex, and poverty income ratio (PIR), were used to determine the association of blood manganese levels and myocardial infarction, stroke, and renal dysfunction accounting for the complex sample survey design.

Results: The mean and standard errors (SEs) of blood manganese levels for myocardial infarction were [10.2 (0.4) µg/L], stroke [9.6 (0.2) µg/L], and renal dysfunction [9.4 (0.1) µg/L] for the combined six years. In the adjusted models, the odds of myocardial infarction [odds ratio (OR) 1.20 (95% CI: 0.76-1.90)] were highest in the highest quartile (Q4: ≥11.3 µg/L) compared to the lower quartile (Q1: ≤7.36 µg/L). There was a non-signicant 17% increased odds of stroke 1.17 (95% CI: 0.72-1.92) comparing the highest quartile (Q4) to the lowest quartile (Q1). There was a non-significant decreased odds of renal dysfunction 0.80 (95% CI: 0.62-1.05) in the highest quartile (Q4) compared to the lowest quartile (Q1).

Conclusion: The increasing odds for stroke and myocardial infarction based on the manganese quartiles, suggests that increased blood manganese levels may play an important role in the disease process.

Keywords: Manganese, myocardial infarction, stroke.

CHAPTER 2

INTRODUCTION

Metals are abundant in the environment and their presence can be measured from many body compartments like whole blood, serum, plasma, urine, hair, and toenails for epidemiological studies.[1] Most of the metals are essential but they can also give rise to adverse effects if their levels increase in the body. If they accumulate for an extended period they can be toxic to humans particularly in the young and the elderly.[2-5] One of those essential elements is manganese (Mn), which the human body is introduced via food and water consumption.[6] Additionally, Mn is involved in many cellular functions like synthesis and activation of enzymes. After it is absorbed from the gastrointestinal tract, it is transported to mitochondria rich organs like the liver, pancreas, and the pituitary gland.[7,8] Since it is important for synthesis and activation of enzymes (e.g., hyrdrolases, isomerases, ligases, lyases, oxidoreductases, and transferases), it plays a role in protection of oxidative stress and also helps in the formation of connective tissue and bone.[7] The normal range of Mn ranges between 4-15 µg/L in blood. With excess exposure it has been known to cause manganism that is manifested in neurological symptoms that are similar to Parkinson's disease.[9] In the general population, the primary pathway of exposure is through the consumption of food and water,[9] but populations can have environmental exposure if they reside closer to industries with Mn emissions.[9] Workers from the mining and welding industries have a greater risk from over exposure to Mn.[10,11]

A genetic animal study[12] found that a certain amount of Mn exposure could reduce the inflammatory response to stressful environments in rats. Mn protects cells from antioxidant processes as a cofactor for the metalloenzyme superoxide dismutase.[13] An animal study[14] by Malecki et al. (1996) demonstrated that Mn deficiency leads to reduced Mn superoxide dismutase (MnSOD) activity that caused *in vivo* oxidative stress to heart mitochondria in rats. Thus, a subclinical Mn deficiency could increase oxidative stress. However, there is limited and inconsistent information of the role of Mn from molecular biology and population-based studies. Since, Mn deficiency and excess levels are both associated with adverse neurologic and metabolic outcomes.[15,16]

Previous studies have investigated the association of Mn and myocardial infarction (MI),[17-21] stroke,[19,22] and renal dysfunction.[19] However, some of those studies used serum Mn[18,20,21] levels and one study used plasma Mn[22] levels as the exposure. A case-control study[17] found blood Mn levels were lower among those with MI and a study[20] by Manthey et al. (1981) found that plasma Mn levels were higher among those diagnosed with an MI. Two studies investigated the association of Mn with stroke—one population based cross-sectional study used blood Mn[19] and the other case-control study[22] used plasma Mn as the biomarker for exposure. However, the studies that found an association or no positive association for these chronic diseases had problems with adequate sample sizes[17,18,20] or differing exposure biomarker.[20,22] Oxidative stress and inflammation are the main pathophysiological processes underlying chronic diseases.

Prior studies have not provided sufficient evidence to support associations of blood Mn levels and the three chronic diseases. Therefore, we hypothesize that blood Mn levels could be related to the prevalence of chronic diseases. The purpose of this cross-sectional study is to describe the association of blood Mn levels with three chronic diseases (MI, stroke, and renal dysfunction).

METHODS

Data source

The United States National Health and Nutrition Examination Survey (NHANES) is a complex, stratified, multistage, probability cluster sampling design to select a representative sample of the US civilian non-institutionalized population. Our analyses were limited to survey data cycles from 2011-2012, 2013-2014, and 2015-2016 for participants 20 years and older (n=16245). The overall response rate for the survey cycles for 2011-2012, 2013-2014, and 2015-2016 were 69.5%, 68.5%, and 58.7%, respectively. The NHANES is a unique survey which collects participant information from questionnaires administered at home and standardized health examinations conducted at specialized mobile examination centers (MECs).

The NHANES used a four-stage sample design for 2011-2016. The first stage is sampled from a frame of all US counties known as the primary sampling units (PSUs). The PSUs were mostly counties but in a few instances, adjacent counties were combined to keep the PSUs above a certain minimum size. The PSUs for NHANES are chosen based on the probabilities proportional to a measure of size (PPS) which corresponds to the population count of the PSU.

The second stage consists of the selection of area segments that comprise of census blocks or a combination of blocks. The third stage consisted of the selection of dwelling units (DUs). From the selected PSU, following the selection of the segments, a list of all DUs from the sampled segments is prepared. A subsample of these DUs is carried out to in order to produce a national probability of sampled households.

The fourth stage consists of the sampling of the persons from the occupied DUs or households. From the list of all the eligible members of the household, a subsample of individuals are selected based on age, sex, race, and Hispanic origin.[23] Informed consent was obtained from all participants for the personal interview and medical examination participants. We further excluded women who were pregnant at the time of the survey because of the effect of pregnancy on blood Mn levels.

Study variables

In NHANES, a standardized questionnaire is used to collect demographic information and medical history. We defined cardiovascular disease as a self-reported history of MI and stroke. Estimated glomerular filtration rate (eGFR) was calculated using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation,[24] and renal dysfunction was defined as albumin-to-creatinine ratio ≥30 mg/g or eGFR ≤60 ml/min/1.73 m^2 using serum creatinine levels. The other demographic covariates that are used were age group (20-44, 45-54, 55-64, ≥65), sex, race, and, poverty income ratio [(PIR), the ratio of self-reported family income to the family's appropriate threshold value based on federal poverty level, grouped in quartiles].

Mn levels were measured with whole blood specimens that were frozen (–30^{o}C), stored, and shipped for analysis to the Division of Laboratory Sciences, National Center for Environmental Health (CDC). Whole blood Mn levels were measured in participants 20 years and older, using inductively coupled plasma mass spectrometry (ICP-MS).

Statistical analysis

Descriptive results are presented based on MI, stroke, and renal dysfunction. Weighted mean and standard errors were calculated for continuous variables (age and PIR), while weighted frequencies with standard errors are reported for categorical variables. We used weighted multivariable logistic regression to examine the association of blood Mn levels and MI, stroke, and renal dysfunction adjusting for demographic variables like age, race, sex, and PIR and reported odds ratios (ORs) and 95% confidence intervals (CIs). We further investigated differences in blood Mn levels by PIR. The analyses for the combined years were re-weighted to adjust for the complex sample survey design using SURVEYFREQ, SURVEYMEANS, and SURVEYLOGISTIC procedures. All comparisons were considered statistically significant with a $p < 0.05$. All analyses were conducted using SAS version 9.4 (SAS Institute, Cary, NC) using survey procedures.

RESULTS

This study included 16,229 adults aged 20 years and older from 2011-2016 NHANES surveys, we excluded women who identified as pregnant (n=136) at the time of the survey. The combined weighted prevalence of MI, stroke, and renal dysfunction was 3.3%, 2.9%, and 9.6%, respectively (data not shown). Demographic characteristics, general health conditions, health-related behaviors, and blood Mn concentration (µg/L) by MI, stroke, and renal dysfunction are presented in Table 1. The mean (SE) for blood Mn levels for MI was 10.2 µg/L, stroke (9.8 µg/L), and renal dysfunction (9.4 µg/L). The estimated blood Mn levels were lowest among those with renal dysfunction compared to those without renal dysfunction (9.7 µg/L). The distribution of blood Mn concentrations was 7.36, 9.07, and 11.29 for the 25th, 50th, and 75th percentiles, respectively (data not shown). In comparison to age, the prevalence of self-reported MI (10.3%) was highest among adults 65 years and olde, self-reported stroke (8.6%), renal dysfunction (33.8%) compared to adults younger than 65 years. Prevalence of self-reported MI (3.8%) and renal dysfunction (11.5%) was highest among Whites compared to persons Blacks, Hispanic, and other races; while, Blacks had the highest prevalence of stroke (3.7%) compared to

Whites, Hispanic, and other races . Based on poverty income ratio (PIR), participants in the low income level (1.3 to 3.49) had the highest prevalence of self-reported MI (4.5%), stroke (4.3%) compared to middle- and high-income level groups; while, renal dysfunction (10.8%) was the highest among middle income level compared to the low- and high-income levels . When compared to smoking status, the prevalence of self-reported MI was highest among former smokers (5.4%) compared to current smokers (4.5%) and never smokers (2.0%), while the prevalence of self-reported stroke was highest among former smokers (4.3%), and the prevalence of renal dysfunction was highest among former smokers (15.1%) followed by never smokers (8.7%), and current smokers (5.0%).

We performed unadjusted and adjusted weighted multivariable logistic regression models to determine the association between blood Mn, MI, stroke, and renal dysfunction with quartile 1 (≤7.36 μg/L) as the reference category (Table 2). In the unadjusted models, the odds of renal dysfunction reduced for blood Mn quartiles Q2 to Q4 with a 36% reduction for Q4 (OR: 0.64, 95% CI: 0.52-0.77) compared to participants in blood Mn Q1 quartile. There were no significant associations in the unadjusted models for MI Q2 (OR: 0.74, 95% CI: 0.53-1.03) and stroke Q3 (OR: 0.88, 95% CI: 0.54-1.44) compared to participants in blood Mn Q1. In the adjusted models controlling for age group, sex, race, and PIR there was no significant association between blood Mn Q4 (OR: 0.80, 95% CI: 0.62-1.05) and renal dysfunction compared to participants in Q1 blood Mn quartile. There were also no significant association for blood Mn Q2 (OR: 1.09, 95% CI: 0.66-1.79) for stroke and Q2 (OR: 0.88, 95% CI: 0.54-1.44) for MI compared to Q1 blood Mn quartile. We further investigated for effect measure modification of blood Mn and PIR in all the models; however, the interaction was not statistically significant.

DISCUSSION

In a nationally representative study from the US this study showed that blood Mn levels were not associated with self-reported MI, stroke, and renal dysfunction after adjusting for sociodemographic covariates. Blood Mn were lower among males compared to females and Black males had lower blood Mn levels compared to White, Hispanic, and other races. We did not find a positive association for blood Mn levels and MI, stroke, and renal dysfunction. This suggests that blood Mn might not be involved in the pathophysiological processes for MI, stroke, and renal dysfunction.

Blood Mn has been used as a biomarker in epidemiological studies, it has been used as an exposure biomarker for Mn inhalation.[13] Mn is found richly in tissues rich with mitochondria, at present there is no reliable biomarker than can measure Mn accumulation accurately, due to a discrepancy in the half-life of Mn in the tissues and blood.[19] However, Mn levels in whole blood are considered more reliable than plasma.[13] Blood Mn levels were lower in participants with renal dysfunction but not in participants with MI and stroke. Previous studies have explored the relationship of Mn and MI,[17-21] stroke,[19,22] and renal dysfunction, two of those studies for MI used blood Mn levels as the biomarker, while the other three studies used plasma Mn levels. Of the studies with blood Mn as the biomarker, one case-control study[17] found that lower blood Mn levels were associated with MI; however, the findings are questionable given the lack of adequate controls in the study. The other population-based cross-sectional study[19] from Korea found that there was no association between blood Mn and MI; although, they had a 45.0% non-significant lower odds in the highest blood Mn quartile (15.6 µg/L) compared to Q1 (≤10.5 µg/L). There were two studies for stroke and one cross-sectional study[19] used blood Mn as a biomarker that did not find an association with blood Mn levels; however, we found a similar non-significant 20% increase of the odds of stroke in the highest quartile (11.3 µg/L). The other case-control study[22] from China used plasma Mn levels and found that the highest quartile (>41.8 µg/L) had a 3-fold increased odds of stroke compared to the first quartile (<17.7 µg/L) of plasma Mn levels. There was one cross-sectional study[19] by Koh et al. (2014) on blood Mn levels and renal dysfunction that found blood Mn levels between (10.6 to 12.7 µg/L) had a 49% lower odds of renal dysfunction, while we found a 20% non-significant lower odds in blood Mn levels (>11.3 µg/L) . Although we did not find an association in the adjusted model for renal dysfunction, our adjusted model controlled for sociodemographic and socioeconomic factors, while the Koh et al. (2014) study[19] adjusted for body mass index (BMI), diabetes, and hypertension in addition to age and sex.

This is the first population-based study in the US using a nationally representative general US population that examined the association of blood Mn and MI, stroke, and renal dysfunction. Most studies have found environmental Mn toxicity to be associated with adverse outcomes compared to dietary intake and metabolism.[15,25] Mn toxicity occurs due to chronic inhalation with high concentration of Mn particles in the air.[25,26] This toxicity has been mainly observed in miners, ferroalloy workers, and battery manufacturing workers.[15,26] Since, oxidative stress plays an important role in atherosclerosis and manganese superoxide dismutase (MnSOD) is transcriptionally transported to the mitochondria, several studies[27,28] have shown that MnSOD polymorphisms induce oxidative stress and could lead to severe cardiac outcomes. In the US, Mn exposure can occur among miners, ferroalloy workers, and residents that live in close proximity to the mining industries. Mn toxicity has been known to induce tremors, rigidity, postural instability that closely resemble idiopathic Parkinson’s disease.[29] some patients exhibit neuropsychological symptoms like apathy and psychosis as it targets the dopaminergic system of the brain that mimics Parkinson's disease.[29] Although, we did not find an association with renal dysfunction, one study[19] in Korea did find a statistically significant association with lower blood Mn levels. Nevertheless, this association needs to be examined further to verify this hypothesis.

This study had some important limitations. First, we used a cross-sectional study design, and therefore, we cannot make any temporal associations with the simultaneous assessment of or outcomes and exposure. Therefore, we could not assess the changes in blood Mn levels over time to establish a causal association. Some of the outcomes were based on self-reports by the participants, thus we could underestimate or overestimate our findings. Some of our adjusted models could be affected by unmeasured variables such as serum iron or albumin levels that are important proteins in Mn-binding in the blood. Although, we looked for correlations with other heavy metals in blood like lead, selenium, cadmium, and mercury, we were unable to adjust for metals that have the same valence states as Mn like copper and calcium. There is a possibility that some of the participants with chronic diseases may not have had Mn readings that could affect the lack of association in our study. Lastly, we were not able to classify participants based on their occupation due to a large percentage of missing observations. Despite these limitations, we used a nationally representative US general population using standard analytical and quality control procedures of NHANES.

In conclusion, we found blood Mn is not associated with MI, stroke, and renal dysfunction. However, further prospective cohort studies are needed to determine protective or adverse effects of Mn for renal dysfunction.

TABLES

Table 1. Participant characteristics of blood manganese (Mn) (μg/L) according to self-reported myocardial infarction, stroke, and renal dysfunction status among US adults aged 20 years and older—NHANES, 2011-2016

	Myocardial infarction				Stroke				Renal dysfunction			
	Yes		No		Yes		No		Yes		No	
Characteristics	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Age group, y												
20-44	40	0.5	6886	99.5	45	0.6	6884	99.4	56	0.8	6874	99.2
45-54	53	1.4	2723	98.6	64	1.7	2711	98.3	126	5.0	2651	95.0
55-64	155	5.1	2649	94.8	143	3.6	2661	96.4	304	10.5	2501	89.5
≥65	407	10.3	3316	89.7	356	8.6	3368	91.4	1310	33.8	2423	66.2
Sex, (male)	412	4.1	7492	95.9	294	2.7	7613	97.3	871	8.3	7042	91.8
Race												
White	338	3.8	5746	96.2	274	2.9	5813	97.1	972	11.5	5120	88.5
Black	127	2.7	3552	97.3	171	3.7	3511	96.2	381	8.0	3301	92.0
Hispanic	132	1.9	3809	98.0	108	1.8	3829	98.2	294	4.3	3650	95.7
Other	58	3.0	2467	97.0	55	3.0	2471	97.0	149	5.5	2378	94.5
PIR												
<1.3	273	4.5	4805	95.5	240	4.3	4840	95.6	565	9.5	4519	90.5
1.3-3.49	207	3.7	5123	96.3	226	3.5	5104	96.5	660	10.8	4674	89.2
≥3.5	115	2.2	4275	97.8	90	1.5	4300	98.5	412	8.5	3980	91.5
BMI, Kg/m^2												
Normal	137	2.3	4384	97.7	144	2.5	4379	97.5	361	7.4	4166	92.6
Overweight	196	3.0	4941	97.0	180	2.5	4960	97.5	611	10.2	4530	89.8
Obsese	287	4.1	5802	95.9	239	3.1	5847	96.9	759	10.5	5335	89.5
Cigarette smoker												
Current	159	4.5	3062	95.4	150	3.6	3072	96.4	213	5.0	3010	95.0
Former	261	5.4	3482	94.6	213	4.3	3530	95.7	687	15.1	3063	84.9
Never	234	2.0	9013	97.9	245	2.0	9004	98.0	894	8.7	8359	91.3
Diabetes	239	10.8	1944	89.2	202	8.4	1984	91.6	574	24.7	1613	75.3
Hypertension	509	7.5	5461	92.6	458	6.5	5513	93.5	1314	19.9	4664	80.1
Blood Mn (μg/L), mean (SE)	9.6	0.2	9.7	0.1	9.6	0.2	9.7	0.1	9.2	0.1	9.7	0.1

Abbreviations: Body mass index (BMI); normal = 18.5-24.9, overweight = 25.0-29.9, obese = 30.0 and above. PIR, (poverty income ratio); low <1.3, middle = 1.3 to 3.49, high ≥3.5.
Note: Renal dysfunction was calculated using CKD-EPI equation eGFR = 141 x min(SCr/κ, 1)α x max(SCr /κ, 1)-1.209 x 0.993age x 1.018 [if female] x 1.159 [if Black]. eGFR < 65 is defined renal dysfunction.

Table 2. Estimates of unadjusted and adjusted logistic regression analysis of blood Mn (mcg/dL) and myocardial infarction, stroke, and renal dysfunction among adults 20 years and older—NHANES, 2011-2016.						
	Myocardial infarction		**Stroke**		**Renal dysfunction**	
	OR (95% CI)		**OR (95% CI)**		**OR (95% CI)**	
Characteristics	**Unadjusted**	**Adjusted**	**Unadjusted**	**Adjusted**	**Unadjusted**	**Adjusted**
Mn quartile (µg/L)						
Q1 (≤7.36)	**Ref**	**Ref**	**Ref**	**Ref**	**Ref**	**Ref**
Q2 (7.37-9.06)	0.74 (0.53-1.03)	0.88 (0.60-1.27)	0.98 (0.62-1.56)	1.10 (0.72-1.72)	0.77 (0.62-0.95)	0.87 (0.67-1.12)
Q3 (9.07-11.29)	0.84 (0.55-1.28)	1.11 (0.68-1.81)	0.88 (0.54-1.44)	1.09 (0.66-1.79)	0.74 (0.61-0.91)	0.97 (0.75-1.24)
Q4 (≥11.3)	0.94 (0.66-1.34)	1.20 (0.76-1.90)	0.91 (0.57-1.47)	1.17 (0.72-1.92)	0.64 (0.52-0.77)	0.80 (0.62-1.05)
Age group, years						
20-44	**Ref**	**Ref**	**Ref**	**Ref**	**Ref**	**Ref**
45-54	2.80 (1.85-4.22)	3.74 (2.17-6.46)	2.90 (1.86-4.53)	4.45 (2.41-8.19)	6.52 (4.46-9.52)	6.31 (3.98-9.99)
55-64	10.86 (7.32-16.12)	13.45 (7.5-24.1)	6.14 (3.97-9.50)	7.84 (4.2-14.7)	14.65 (9.7-22.2)	15.8 (8.9-28.0)
≥65	23.1 (16.29-32.7)	27.6 (16.8-45.3)	15.6 (10.9-22.5)	20.5 (12.4-33.9)	63.9 (45.7-90.3)	62.97 (41.0-96.6)
Sex						
Female	**Ref**	**Ref**	**Ref**	**Ref**	**Ref**	**Ref**
Male	1.64 (1.34-2.01)	2.03 (1.50-2.73)	0.87 (0.70-1.10)	1.04 (0.79-1.36)	0.31 (0.02-4.25)	0.83 (0.67-1.04)
Race						
White	**Ref**	**Ref**	**Ref**	**Ref**	**Ref**	**Ref**
Black	0.70 (0.56-0.88)	0.95 (0.65-1.37)	1.31 (1.08-1.57)	1.37 (1.08-1.75)	0.67 (0.58-0.76)	0.96 (0.79-1.17)
Hispanic	0.51 (0.39-0.66)	0.71 (0.54-0.92)	0.62 (0.49-0.78)	0.8 (0.56-1.14)	0.35 (0.29-0.42)	0.61 (0.48-0.81)
Other	0.79 (0.50-1.25)	0.75 (0.45-1.27)	1.06 (0.69-1.62)	1.10 (0.62-1.97)	0.45 (0.35-0.57)	0.62 (0.47-0.81)
PIR						
<1.3	**Ref**	**Ref**	**Ref**	**Ref**	**Ref**	**Ref**
1.3-3.49	2.07 (1.50-2.86)	3.00 (1.95-4.60)	3.01 (2.16-4.19)	4.08 (2.69-6.19)	1.13 (0.92-1.39)	1.55 (1.26-1.90)
≥3.5	1.67 (1.14-2.45)	1.86 (1.09-3.17)	2.41 (1.80-3.23)	2.39 (1.66-3.42)	1.29 (1.14-1.48)	1.22 (0.98-1.53)
Abbreviations: Odds ratio (OR); confidence interval (CI). PIR [poverty income ratio; low (<1.3), middle (1.3 to 3.49), high (≥3.5)].						

FIGURES

Figure 1. Estimated blood Mn levels (μg/L) according to sex and race/ethnicity among adults 20 years and older—NHANES, 2011-2016

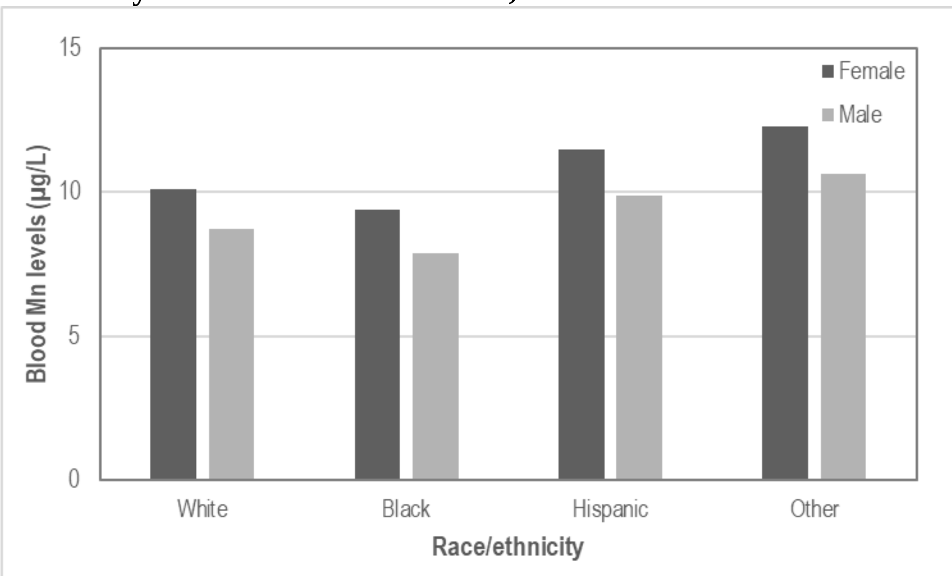
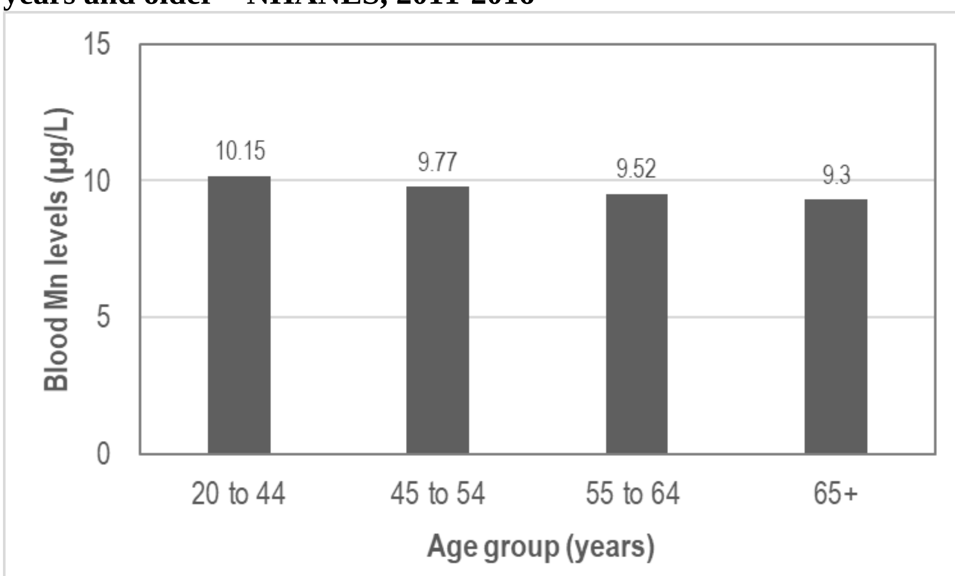


Figure 2. Estimated blood Mn levels (μg/L) by age-group (years) among adults aged 20 years and older—NHANES, 2011-2016



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ABSTRACT

Introduction: The objective of this study was to estimate the influence of the Affordable Care Act (ACA) Medicaid Expansion on current smoking and quit attempts in expanded and non-expanded states.

Methods: We analyzed data from the Behavioral Risk Factor Surveillance System (BRFSS) between 2003 through 2015 to evaluate changes in current smoking and quit attempts using multivariable logistic regression and generalized estimating equations (GEE), adjusting for socioeconomic factors. Time periods evaluated were: 2003-2009 (pre-expansion) and 2011-2015 (post-expansion), and in supplemental analysis, also 2011- 2017.

Results: Overall, smoking prevalence among adults in expanded and non-expanded states were 16% and 17% ($p < 0.001$), respectively, and quit attempt prevalence for expanded and non-expanded states were 56% and 57% ($p = 0.05$), respectively. In adjusted models comparing post- versus pre- expansion periods, current smoking declined by 6% in both expanded (RR: 0.94, 95% CI: 0.93-0.94) and non-expanded (RR: 0.94, 95% CI: 0.94-0.95) states. Quit attempts increased by 4% (RR: 1.04, 95% CI: 1.04-1.05) in expanded states, and by 3% (RR: 1.03, 95% CI: 1.02-1.03) in non-expanded states. States that imposed barriers to utilization of smoking cessation services e.g. prior authorization, saw only a 3% increase in quit attempts regardless of expansion status, while expanded states that did not impose barriers experienced a 6% (RR: 1.06, 95% CI: 1.05-1.06) increase in quit attempts.

Conclusion: Reducing administrative barriers to smoking cessation programs may enhance further declines in smoking rates among US adults.

Keywords: current smoking; quit-smoking; Medicaid expansion

CHAPTER 3

INTRODUCTION

Cigarette smoking is the leading cause of preventable morbidity and mortality in the United States and accounts for approximately 480,000 deaths each year.[1,2] There have been significant declines in cigarette smoking, from 42% in 1965 to 15% in 2015.[3] However, current smoking remains disproportionately higher among low-income (30%) and uninsured (28%) individuals.[4]

The Affordable Care Act (ACA), introduced in 2010, addressed provisions for healthcare coverage denial due to pre-existing conditions, provided tax-credits and subsidies to purchase health insurance and access to free preventive care, and expanded insurance coverage to include non-disabled single childless adults.[5-7] As part of the ACA provision, childless adults could be Medicaid eligible at or below 133 percent federal poverty level (FPL).[7] A total of 30 US states including the District of Columbia had expanded Medicaid as part of the ACA by December 31, 2015, however in March 2010, six states and jurisdictions—California, Connecticut, the District of Columbia, Minnesota, New Jersey, and Washington— enacted Medicaid expansion among low-income groups due to the provisions in the ACA.[8]

Prior to the ACA, low-income adults without Medicaid coverage had few available choices for accessing smoking cessation services and states had flexibility in types of smoking cessation services offered through Medicaid.[9] However, following the implementation of the ACA, state Medicaid programs were required to cover smoking cessation services among newly eligible adults,[10] leading to expanded coverage of evidence-based smoking cessation treatments. Previous studies have evaluated the impact of ACA expansion on quit attempts and current smoking, however prior studies have only evaluated annual trends, focused on a single or few

US states, or did not account for baseline differences in states Medicaid expansion status.[11-14] The purpose of this study is to evaluate the impact of the ACA expansion on current smoking and quit attempts among expanded and non-expanded US states, to evaluate the impact among low-income individuals, and to account for state-level barriers to smoking cessation services.

METHODS

Data source: Data were obtained from the Behavioral Risk Factor Surveillance System (BRFSS) for adults 18 years and older surveyed between 2003 and 2017.[15] The BRFSS collects nationally representative data annually on randomly selected land-line and cell-phone telephone numbers on over 400,000 adults in all 50 states, including three U.S. territories and the District of Columbia.[16] The annual telephone survey obtains information on health related risk behaviors, chronic health conditions and use of preventive services. The BRFSS median response rate over the study period ranged from 53% in 2003 to 47% in 2015.15 In the current analyses, data on socio-demographics, current smoking and quit attempts were obtained from the BRFSS, and data on Medicaid expansion status and year of expansion by state was obtained from the Kaiser Family Foundation State Health Facts.[17]

Study variables: Outcome variables of interest were current smoking and quit-attempts in the past year among smokers. Current smokers were defined as participants who indicated that they currently smoked every day or some days, or that they had smoked a cigarette within the past month. Quit-attempts among smokers was defined as having a quit-attempt in the preceding 12 months for one day or longer. Current smoking was defined using the ‘computed smoking status’ variable, while quit-attempts was defined using the variable ‘_STOPSMK2’ in the past year among current smokers. Sociodemographic characteristics, including age, sex, race/ethnicity, education, employment status, and annual household income were obtained, and data on availability of regular healthcare providers and health care coverage were included to examine access to healthcare. Age variable was classified in three groups; 18 – 49, 50 – 79, and 80+ years of age; annual household income variable was categorized into four groups- <$10,000, $10,000-<$20,000, $20,000-<$50,000, and ≥$50,000; race was identified using the five level race/ethnicity variable and classified into White, Black, Hispanic, and Other categories; education was categorized into <high school, high school graduate, and some college or higher. Healthcare coverage was ascertained as having any kind of coverage, including health insurance, prepaid plans such as Health Maintenance Organizations (HMOs), or government plans like Medicare, or Indian Health Service. To evaluate the impact of state-level barriers to utilization of smoking cessation services, data on two state-level barrier variables – prior authorization before smoking cessation treatment and copayments- were obtained from the American Lung Association for 2010, dichotomized as yes/no.[18]

Study Periods: The two study periods, pre-expansion (2003–2009) and post-expansion (2011–2015), were defined based on states' Medicaid expansion status during the study period. Five states and the District of Columbia expanded eligibility as early as 2010 by taking advantage of provisions in the ACA and Medicaid waivers,[7,8] therefore we considered the year 2010 as the washout period. By 2015, the following states had expanded Medicaid as part of the ACA; Arizona, Arkansas, California, Colorado, Connecticut, Delaware, Hawaii, Illinois, Indiana, Iowa, Kentucky, Maryland, Massachusetts, Michigan, Minnesota, Montana, Nevada, New Hampshire, New Jersey, New Mexico, New York, North Dakota, Ohio, Oregon, Pennsylvania, Rhode Island, Vermont, Washington, West Virginia, and District of Columbia. To evaluate more recent trends in current smoking and smoking cessation, we also examined BRFSS data from 2011 to 2017; comparing 2011-2013 and 2015-2017 time periods.

Statistical analysis: Weighted analyses for descriptive variables by expansion status using chi-square tests, were evaluated for current smoking and quit attempts by socio-demographic variables and expansion status. We assessed annual trends in current smoking and quit attempts by expansion status, and utilized multivariable adjusted logistic regression and generalized estimating equations (GEE) to assess current smoking and quit attempts in the past year in non-expanded versus expanded states for each time period. Due to the high prevalence of current smoking and quit attempts in the past year, we interpret estimates from GEE models as relative risks (RRs) instead of odds ratios (ORs).[19] To examine the secular time trends in the prevalence of current smoking and quit-attempt status among adults in the two time periods, we assessed for linear and quadratic changes adjusting for socio-demographic and socio-economic predictors in pre-expansion (2003–2009) and post-expansion (2011–2015) periods. Similar analyses were conducted for 2011-2013 versus 2015-2017 (supplemental tables). We also assessed for interactions between expansion status and time periods in prevalence of current smoking and quit-attempts. Furthermore, we evaluated whether the association between expansion and smoking cessation varied by state-level barriers such as prior authorization and co-payments for smoking cessation treatment. All analyses were carried out using SAS version 9.4 (SAS Institute, Inc., Cary, NC; USA) accounting for the complex sample survey design; statistical significance levels were determined based on p-values < 0.05.

RESULTS

By December 31, 2015, 30 states and DC had implemented Medicaid expansion, while 21 states had not implemented the policy. A total of 5,311,872 participants were included in this analysis, 2,289,033 (43%) were in non-expanded states and 3,022,839 (57%) were in expanded states (Table 1). Table 1 shows the baseline characteristics of the study participants overall and by Medicaid expansion status. Participants in expanded vs. non-expanded states were less likely to be Black (7% vs. 10%), more likely to be Hispanic (7% vs. 5%), have at least some college education (64% vs. 60%), have an average annual household income of >$50,000 (47% vs. 41%), more likely to have health insurance coverage (91% vs. 88%) and at least one regular healthcare provider (86% vs. 84%).

Overall, 16% of participants residing in expanded states were current smokers, compared with 17% of participants in non-expanded states (Table 2; p<0.001). The prevalence of current smoking in the expanded states declined from 23% to 14%, and in the non-expanded states reduced from 22% to 15% between 2003 and 2015 (Figure 1). For quit attempts, prevalence in expanded states increased from 53% to 57%, and in the non-expanded states it increased from 51% to 58% (Figure 2). Current smoking was lower in expanded vs. non-expanded states, especially among participants aged 18-34 (22% vs. 23%), those without health insurance coverage (31% vs. 33%), those with an annual household income less than $10,000 (31% vs. 32%) and those who were unemployed (30% vs. 34%). The prevalence of current smoking in the expanded states declined from 23% to 14%, and in the non-expanded states reduced from 22% to 15% between 2003 and 2015 (Figure 1). For quit attempts, prevalence in expanded states increased from 53% to 57%, and in the non-expanded states it increased from 51% to 58% (Figure 2).

In models adjusted for sex, race, income, education, and comparing non-expanded versus expanded states (Table 3), current smoking increased by 2% (RR: 1.02, 95% CI: 1.02-1.03) in the pre-expansion period (2003-2009), but no significant difference was found post-expansion (RR: 0.99, 95% CI: 0.99-1.00) . In addition, quit attempts declined by 2% pre-expansion (RR: 0.98, 95% CI: 0.98-0.99), and increased by 1% (RR: 1.01, 95% CI: 1.01-1.02) post-expansion. In Table 4, comparing post- versus pre- expansion periods, current smoking declined by 6% in both expanded (RR: 0.94, 95% CI: 0.93-0.94) and non-expanded (RR: 0.94, 95% CI: 0.94-0.95) states. Quit attempts increased by 4% (RR: 1.04, 95% CI: 1.04-1.05) in expanded states post- versus pre- expansion, and by 3% (RR: 1.03, 95% CI: 1.02-1.03) in non-expanded states. When focused on low income individuals (annual household income <$20,000), there was no significant change in current smoking post versus pre- expansion in either expanded or non-expanded sates, but there quit attempts increased by 5% (RR: 1.05, 95% CI: 1.05-1.06) in expanded states and by 4% (RR: 1.04, 95% CI: 1.04-1.05) in non-expanded states. More modest associations were observed in more recent BRFSS years (2011-2017); current smoking declined by 1% (RR: 0.99, 95% CI: 0.99-0.99) in 2011-2013, and increased by 1% (RR: 1.01, 95% CI: 1.01-1.01) in 2015-2017. Quit attempts increased by 0.6% (RR: 1.006, 95% CI: 1.006-1.007) in 2011-2013 period, and by 1% (RR: 1.01, 95% CI: 1.01-1.01) in 2015-2017. (Supplemental Tables 1-2).

We further examined the association between Medicaid expansion and current smoking or quit attempts varied by state-level prior authorization and co-payment barriers. Among states that required prior authorization (Table 5), quit attempts increased by 3% (RR: 1.03, 95% CI: 1.02-1.03) in the post versus pre-expansion period in both expanded and non-expanded states. However, among states that did not require prior authorization for smoking cessation, quit attempts increased by 6% (RR: 1.06, 95% CI: 1.05-1.06) in expanded states, and increased by 3% (RR: 1.03, 95% CI: 1.02-1.03) in non-expanded states. Among states that required co-payments for smoking cessation services (Table 6), quit attempts increased by 3% (RR: 1.03, 95% CI: 1.02-1.03) in expanded states, and by 2% (RR: 1.02, 95% CI: 1.02-1.03) in non-expanded states. Among states that did not require copayments, quit attempts increased by 7% (RR: 1.07, 95% CI: 1.06-1.07) in expanded states, and by 3% in non-expanded states (RR: 1.03, 95% CI: 1.03-1.04).

DISCUSSION

In a large nationally representative study population of US adults, we examined the impact of the ACA expansion on current smoking and quit attempts in pre-expansion and post-expansion time periods. Overall, current smoking was 2% higher in the non-expanded versus expanded states in the pre-expansion period, but 1% lower post-expansion. However, in both expanded and non-expanded states, there was a 6% decline in current smoking post- versus pre-expansion, and a 3-4% increase in quit attempts. There was no significant change in current smoking among participants with an annual household income of ≤$20,000, but a 4-5% increase in quit attempts was observed in this group. These results indicate that while non-expanded states had higher current smoking rates compared with expanded states pre-expansion, following implementation of the ACA Medicaid expansion policy, both expanded and non-expanded states experienced significant improvements in declining current smoking rates and higher quit attempts. However, expanded states that introduced barriers to accessing evidence based smoking cessation services, specifically prior authorization and co-payments, experienced very modest increases in quit attempts post- versus pre- expansion, compared with states that did not institute such barriers, while such barriers made no difference in non-expanded states.

Prior studies have analyzed the impact of Medicaid expansion on current smoking and quit attempt rates among US adults.[2,20-24] The majority of those studies observed that following the implementation of Medicaid expansion as part of the Affordable Care Act, current smoking rates declined modestly,[2,20,22,23] while quit attempts increased.[2,21,24] Three studies utilized data from BRFSS to evaluate differences in current smoking post- versus pre-expansion and observed declines in current smoking ranging from 15%20 and 7%22 to 0.06%.[23] Other studies have evaluated differences in prevalence of current smoking comparing trends over time,[2,20,21,23] a study using the National Health Interview Survey (NHIS) observed that current smoking prevalence was 21% in 2005 and 15% in 2015,[4] while a state-based study using the Massachusetts BRFSS observed that smoking prevalence decreased from 38% in 1999 to 28% in 2008.[20] Two studies using the BRFSS evaluated the effect of Medicaid expansion on quit attempts in the pre- versus post-expansion period, and observed that the odds of smoking cessation increased by 21% among US adults,[22] while the other study observed that non-expanded Medicaid enrollees had a 5% lower odds of quit attempts compared with enrollees.[24] Other studies have utilized data from specific states to evaluate expansion and quit attempts. For instance, a study of Medicaid enrollees in Alabama, Georgia, and Maine observed that the odds of quit attempts increased by 60% after the Medicaid expansion,[25] while a study from northern California showed a 49% increase among Medicaid enrollees compared to those on commercial insurance.[24] There are several potential reasons for the differences between these prior studies and our findings.

Compared with other studies,[2,20,22,23] we observed a more modest 6% decline in current smoking among US adults in both expanded and non-expanded states comparing post- and pre-expansion periods. That is, regardless of whether a state expanded Medicaid as part of the Affordable Care Act, current smoking declined by 6%, while quit attempts increased by 3-4%. Among low-income individuals, we did not observe a significant decline in current smoking, but did observe a 4-5% increase in quit attempts. This is similar to a 2% increase in quit attempts observed by a separate study[12] using the BRFSS dataset. Our findings of current smoking prevalence of 26% in the non-expanded and 18% in the expanded states for participants of Other races (includes multiracial, American Indian/Alaska Native, and Asians) are also comparatively lower compared to a previous study[4] using the NHIS that had a prevalence of 32% among American Indian/Alaska Natives. The lower rates could be due to the combination of racial groups i.e. American Indian/Alaska Natives and Asians with significantly different current smoking rates. Moreover, our results are based on an overall population average for 2003 to 2015, while the NHIS study reported cross-sectional results for 2015.[4]

The modest findings in our study may be explained by several possible reasons. First, in contrast to other studies, our analytic approach did not assume that states that expanded Medicaid as part of the Affordable Care Act were similar to states that did not expand at baseline. For instance, individuals in expanded states were younger, less likely to be Black, and had higher annual household incomes on average compared with individuals in states that did not expand. To account for these baseline differences, we estimated the risks of current smoking and smoking cessation in pre- versus post-expansion separately in expanded and non-expanded states, and statistically adjusted for these demographic differences.

Second, the modest declines in current smoking observed may be due to administrative and/or logistical barriers in accessing smoking cessation services that remained unaddressed or were newly implemented in some states after Medicaid expansion, a factor that was not directly considered in other studies. For instance, of the 31 states and jurisdictions that expanded Medicaid, only 19 states covered all the FDA-approved medications, while only 17 covered individual and 11 covered group counselling.[26] Furthermore, some of the expanded states established administrative barriers such as co-payments and prior authorization for available treatments, therefore limiting access for cessation programs.[27] In addition, prior to 2015, 48 states covered some cessation treatments, but by June 2017, all of the 50 states and DC covered some form of tobacco cessation treatments.[27] These may explain our observation of similar declines in current smoking and quit attempt rates between expanded and non-expanded states. That is, the added benefit of Medicaid expansion in improving access to smoking cessation services and hence reducing smoking rates may have been muted by accessibility barriers in expanded states, and provision of at least some smoking cessation services in non-expanded states. Based on our analyses, expanded states that had no barriers to smoking cessation treatments had a 7% increase in quit-attempts compared to a 3% increase among expanded states that had barriers in the post-expansion period. However, it is important to evaluate changes over time as benefits included in Medicaid coverage can change over time, for example North Dakota and Pennsylvania initially covered all cessation treatments, but no longer did so by June 2017.[27]

Third, provision of smoking cessation services without other health policies such as indoor smoking bans, cigarette excise taxes and stricter age-limits, are likely to have limited the effectiveness of Medicaid expansion on smoking cessation. As of Jan 2018, only 28 states and D.C. have instituted a statewide smoking ban policy, and 47 states have increased cigarette taxes with an average state tax of $1.69 per pack, ranging from $0.33 to $5.1.[28] A 15% decline in current smoking was reported in Massachusetts,[20] the first state to establish a Medicaid expansion program for low-income individuals. The program also provided fewer restrictions to participants, including lower administrative barriers to cessation services, and simultaneously implemented other smoking cessation policies such as indoor bans and higher excise taxes that likely contributed to its success.[20] Treatment effectiveness may also vary- one study[29] compared success rates in quitting gradually vs. abruptly found a significant quit rate (15% vs. 22%) at the end of six months in primary care clinics in England when included with behavioral support and nicotine replacement. A prior study has also reported that almost 85% of smokers quit smoking abruptly.[30] We were unable to ascertain if our rates of quit attempts were based on counseling and nicotine replacement or just quit 'cold-turkey' as the BRFSS participants were not asked regarding cessation treatments.

Fourth, Medicaid expansion was designed to increase insurance coverage for low-income individuals. Our study found no significant difference in current smoking in both the expanded and non-expanded states among low-income adults. This may be partly due to the increase in the Medicaid population over time; in 1997 low-income adults represented 8% of the US adult population, but by 2013 it had doubled almost to almost 17.[31] In addition, many low-income individuals initiate smoking due to intense exposure to advertising, and personal psychosocial factors such as stress, financial burdens, and lack of social support.[32-34] Medicaid expansion by itself is unlikely to address all these issues, and states may need to enhance tobacco cessation programs with other strategies including advertising restrictions especially for younger individuals, free or low-cost counseling and policies to further limit exposure to cigarettes. Current smoking was higher among 18-49-year olds in our study in non-expanded (21%) and expanded (20%) states compared with other age-groups evaluated, highlighting the need for greater access to comprehensive smoking cessation services with limited financial and logistical barriers to utilization among younger adults.

The strengths of our study are the use of a nationally representative non-institutionalized population of US adults across a wide range of racial, and socio-economic age groups. Our study estimates are reliable due to the large sample size across all sub-populations that provided adequate statistical power for the analysis. Also, we were able to assess study outcomes specifically among low-income individuals, since Medicaid expansion was designed to improve insurance coverage in this sub-population. There are also certain limitations relevant to our study. First, we relied on self-reported data on smoking status and quit attempts, however, self-reports of these variables have been validated previously.[35] Second, measuring the impact of a general policy on individuals is vulnerable to ecological bias. Studies of low-income individuals comparing those enrolled in Medicaid as part of the Affordable Care Act with those who remained uninsured can provide better estimates of the direct association between expansion and smoking outcomes. We did not account for the time-varying nature of state-level barriers across the study period, but obtained data on barriers for the calendar year 2010. Lastly, the weighting methodology for BRFSS changed in 2010, thus estimates after 2011 were not comparable to previous years.[36] To account for this, we examined the trends in the pre-expansion period (2003-2009) and post-expansion periods (2011-2015) by categorizing expanded and non-expanded states, and examined the trends while considering calendar year 2010 as our wash-out period.

CONCLUSION

In summary, our findings provide evidence that current smoking rates declined and quit attempts increased post-Medicaid expansion period; however, these trends were observed in both expanded and non-expanded states and were significantly influenced by state-level barriers to access smoking cessation services. Eliminating financial and logistical barriers to cessation services among Medicaid enrollees, and implementation of smoking related policies such as the indoor smoking ban and excise taxes may help to further reduce current smoking rates among US adults.

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APPENDIX

Table 1: Baseline characteristics of study population by Medicaid expansion status, BRFSS 2003-2015 (unweighted).

Characteristics	**Total (*N* = 5,311,872)**	**Expansion** Non-expanded States (21) (*N* = 2,289,033)	**Expansion** Expanded States (30) (*N* = 3,022,839)	***p* value**
Age				
18-34	796,657 (14.49)	345,041 (14.57)	451,616 (14.42)	<.0001
35-49	1,219,456 (21.20)	509,427 (20.57)	710,029 (21.70)	
50-64	1,642,264 (31.84)	701,298 (31.41)	940,966 (32.17)	
65-79	1,199,499 (24.25)	536,075 (25.0)	663,424 (23.68)	
≥ 80	403,594 (8.19)	178,504 (8.43)	225,090 (8.02)	
Sex				
Male	2,086,990 (39.98)	888,554 (39.46)	1,198,436 (40.36)	<.0001
Female	3,224,809 (60.02)	1,400,434 (60.54)	1,824,375 (59.64)	
Race				
White	4,176,702 (79.36)	1,814,675 (80.08)	2,362,027 (78.81)	<0.001
Black	429,021 (8.18)	225,859 (9.92)	203,162 (6.84)	
Other race	301,577 (5.87)	102,984 (4.56)	198,593 (6.88)	
Hispanic	336,421 (6.57)	118,687 (5.42)	217,734 (7.45)	
Education				
< High school	492,197 (8.78)	237,869 (9.80)	254328 (7.99)	<0.001
High school grad	1,576,718 (29.34)	492,197 (30.66)	710105 (28.33)	
Some college or higher	3,222,435 (61.87)	1,333,728 (59.53)	1888707 (63.66)	
Income level				
< $10,000	247,936 (5.38)	114,579 (5.73)	133,357 (5.11)	<0.001
$10,000 – < $20,000	637,669 (13.89)	299,939 (15.15)	337,730 (12.93)	
$20,000 – < $50,000	1,717,152 (36.54)	778,781 (38.59)	938,371 (34.97)	
≥ 50,000	1,947,866 (44.17)	762,843 (40.51)	1,185,023 (46.98)	
Employment				
Employed	2,296,526 (42.05)	962,264 (40.73)	1,334,262 (43.07)	<0.001
Self-employed	452,022 (8.39)	199,625 (8.63)	252,397 (8.21)	
Unemployed	257,218 (5.03)	102,243 (4.64)	154,975 (5.32)	
Student/Homemaker/Retired	1,073,783 (37.35)	843,350 (38.12)	1,073,783 (36.75)	
Unable to work	189,519 (7.16)	170,996 (7.86)	189,519 (6.62)	
Marital Status				
Married	2,878,492 (53.94)	1,273,187 (55.28)	1,605,305 (52.91)	<0.001
Divorced/Widowed/Separated	1,557,951 (29.61)	687,999 (30.28)	869,952 (29.10)	
Never married/Unmarried couple	847,402 (16.44)	317,997 (14.43)	529,405 (17.97)	
Healthcare Coverage *				
Yes	4,718,672 (89.74)	1,996,128 (88.09)	2,722,544 (91.00)	<0.001
No	576,588 (10.25)	285,477 (11.90)	291,111 (8.92)	
Healthcare Providers +				
At least one	4,523,661 (85.45)	1,925,100 (84.30)	2,598,561 (86.34)	<0.001
No	769,281 (14.54)	357,067 (15.70)	412,214 (13.65)	

() Denotes column percentage. Sample sizes are unweighted; percentages are weighted to adjust for sampling and post-stratification.
*Healthcare coverage is defined as having any kind of health care coverage, including health insurance, prepaid plans such as HMOs, or government plans such as Medicare.
+Healthcare providers is defined as personal doctor or health care provider.

Table 2: Smoking Status by study period in the expanded and non-expanded states, BRFSS 2003 – 2015 (*N* = 5,311,799).

	Smoking Status					
	Current Smoker*			Quit Attempts		
Characteristics	**Non-expanded**	**Expanded**	***p* value**	**Non-expanded**	**Expanded**	***p* value**
Overall	398,437 (16.6)	499,893 (15.90)	<.0001	219,367 (56.61)	275,150 (56.38)	0.05
Socio-Demographics						
Age						
18-34	79,937 (22.46)	100,966 (21.56)	<.0001	51,018 (65.40)	63,752 (64.19)	<.0001
35-49	113,117 (20.99)	145,667 (19.56)		62,426 (57.16)	81,325 (57.44)	
50-64	138,497 (19.45)	172,103 (18.15)		74,064 (54.76)	92,100 (54.70)	
65-79	58,565 (10.81)	69,600 (10.46)		29,223 (50.78)	34,515 (50.38)	
≥ 80	6,264 (3.46)	8,242 (3.59)		2,636 (42.73)	3,458 (42.43)	
Sex						
Male	169,434 (18.32)	213,833 (17.27)	<.0001	89,239 (53.96)	114,084 (54.54)	<.0001
Female	229,003 (15.58)	286,060 (14.98)		131,173 (58.60)	162,750 (57.84)	
Race						
White	307,000 (16.07)	384,156 (15.52)	<.0001	161,934 (53.97)	204,189 (54.01)	<.0001
Black	42,342 (18.60)	39,288 (19.40)		28,883 (69.41)	26,314 (68.15)	
Other race	27,570 (26.12)	37,223 (18.16)		16,461 (60.68)	21,917 (59.81)	
Hispanic	17,545 (14.21)	33,257 (14.95)		10,985 (64.08)	21,133 (64.63)	
Healthcare Access						
Healthcare Coverage						
Yes	303,125 (14.50)	407,772 (14.46)	<.0001	166,624 (56.20)	225,751 (56.33)	<.0001
No	94,210 (32.70)	90,653 (30.53)		53,169 (57.82)	50,266 (56.44)	
Healthcare Providers						
At least one	300,058 (14.80)	391,389 (14.31)	<.0001	169,097 (57.58)	220,773 (57.35)	<.0001
No	97,212 (26.66)	106,253 (25.26)		50,706 (53.66)	54,876 (52.73)	
Socio-economic Status						
Income level						
< $10,000	36,174 (32.02)	41,227 (31.16)	<.0001	22,212 (62.81)	24,599 (60.78)	<.0001
$10,000 - < $20,000	76,965 (25.50)	86,079 (25.47)		45,485 (60.52)	50,089 (59.40)	
$20,000 - < $50,000	151,150 (18.48)	182,850 (18.68)		82,335 (55.77)	10,611 (55.92)	
≥ $50,000	88,676 (10.75)	133,184 (10.47)		46,089 (52.77)	71,597 (54.42)	
Education						
<High school	64,218 (27.0)	67,379 (26.58)	< .0001	37,016 (59.12)	37,967 (57.37)	< .0001
High school grad	154,172 (21.12)	190,719 (21.51)		83,566 (55.53)	103,138 (54.98)	
Some college or higher	179,344 (12.70)	240,561 (12.12)		99,466 (56.63)	135,099 (57.16)	
Employment						
Employed	180,242 (17.60)	230,795 (16.26)	<.0001	97,836 (55.54)	126,946 (56.08)	<.0001
Self-Employed	32,272 (15.02)	38,167 (14.29)		16,554 (52.26)	19,985 (53.18)	
Unemployed	34,859 (33.66)	47,899 (30.40)		20,970 (61.51)	28,317 (60.07)	
Student/Homemaker/Retired	93,249 (10.60)	115,721 (10.42)		48,573 (52.84)	60,191 (52.46)	
Unable to work	56,559 (33.14)	65,265 (34.51)		35,837 (64.55)	40,344 (62.78)	

*Current smoker is defined as every day or someday smoker who smoked at least 100 cigarettes in their lifetime.
Quit attempts is defined as stopped smoking for one day or longer because of trying to quit smoking.
Expanded states include AK, AR, AZ, CA, CO, CT, DE, HI, IA, IL, IN, KY, MD, MA, MI, MN, NV, NH, NJ, NM, NY, ND, OH, OR, PA, RI, VT, WA, WV, and DC which expanded Medicaid under the ACA between 2010 and 2015
Non-Expanded states did not expand Medicaid under the ACA till the end of 2015.

Table 3: Relative risks for current smoking and quit attempts by ACA expansion status and age-group, US BRFSS 2003-2015

	Current smokers (%)		Quit Attempts (%)	
Year	**2003-2009***	**2011-2015†**	**2003-2009†**	**2011-2015†**
Overall US				
Expanded	262,751 (17.22)	200,030 (16.07)	143,057 (55.31)	113,123 (56.86)
Non-expanded	205,078 (18.28)	160,235 (15.46)	110,105 (54.59)	91,410 (57.34)
	RR = 1.02 (1.02-1.03)	**RR = 0.99 (0.99-1.00)**	**RR = 0.98 (0.98-0.99)**	**RR = 1.01 (1.01-1.02)**
18-49 years				
Expanded	142,484 (21.61)	88,645 (19.79)	81,926 (58.52)	53,845 (61.14)
Non-expanded	108,863 (23.19)	70,683 (20.84)	61,681 (57.86)	43,527 (61.98)
	RR = 1.02 (1.01-1.02)	**RR = 1.01 (1.01-1.02)**	**RR = 0.99 (0.99-1.00)**	**RR = 1.01 (1.01-1.02)**
50-79 years				
Expanded	114,680 (15.45)	106,501 (14.68)	58,669 (52.42)	57,077 (53.83)
Non-expanded	92,283 (16.45)	85,935 (15.27)	46,729 (51.76)	46,245 (54.02)
	RR = 1.02 (1.02-1.03)	**RR = 0.98 (0.98-0.99)**	**RR = 0.98 (0.98-0.99)**	**RR = 0.99 (0.99-1.00)**
>=80 years				
Expanded	3,843 (3.87)	3,613 (3.46)	1,594 (41.74)	1,538 (42.85)
Non-expanded	2,766 (3.79)	2,895 (3.37)	1,128 (41.05)	1,241 (43.04)
	RR = 0.96 (0.96-0.97)	**RR = 0.99 (0.99-1.00)**	**RR = 0.96 (0.96-0.97)**	**RR = 1.02 (1.02-1.03)**

Reference = Expanded; RR = relative risk. RRs for age categories have been adjusted for sex, race, annual household income, and educational status using Proc Genmod. Excluded 2010 data as the wash-out period.
* Linear trend $p = 0.13$; quadratic trend $p < 0.0001$
† Linear trend $p < 0.0001$

Table 4. Relative Risks for Current Smokers and Quit Attempts by Expansion and Time Period, US BRFSS 2003-2015

	Overall		Low Income (≤$20,000)$^{\Psi}$	
	Current Smoking*	**Quit Attempts***	**Current Smoking**$^{\Upsilon}$	**Quit Attempts***
	RR (95% CI)	**RR (95% CI)**	**RR (95% CI)**	**RR (95% CI)**
Expanded				
Pre-expansion (2003-2009)	**Ref**	**Ref**	**Ref**	**Ref**
Post-expansion (2011-2015)	0.94 (0.93-0.94)	1.04 (1.04-1.05)	0.99 (0.99-1.00)	1.05 (1.05-1.06)
Non-expanded				
Pre-expansion (2003-2009)	**Ref**	**Ref**	**Ref**	**Ref**
Post-expansion (2011-2015)	0.94 (0.94-0.95)	1.03 (1.02-1.03)	0.99 (0.99-1.00)	1.04 (1.04-1.05)

Note: Relative risks were adjusted for sex, race, annual household income, educational status including interaction terms for expansion status and time periods of pre-and post-expansion using Proc Genmod. Excluded 2010 data as the wash-out period.
P-value for expand x period interaction: *<0.0001; $^{\Upsilon}$ 0.0019
$^{\Psi}$Annual household income ≤ $20,000

Table 5. Relative Risks for Quit Attempts by Expansion and Time Period by Prior Authorization, US BRFSS 2003-2015			
	Quit Attempts	**Prior authorization**	
	Overall	**Yes**	**No**
Expanded	**RR (95% CI)**	**RR (95% CI)**	**RR (95% CI)**
Pre-expansion (2003-2009)	**Ref**	**Ref**	**Ref**
Post-expansion (2011-2015)	1.04 (1.04 – 1.05)	1.03 (1.02 – 1.03)	1.06 (1.05 – 1.06)
Non-expanded			
Pre-expansion (2003-2009)	**Ref**	**Ref**	**Ref**
Post-expansion (2011-2015)	1.03 (1.02 – 1.03)	1.03 (1.02 – 1.03)	1.03 (1.02 – 1.03)

Note: Relative risks were adjusted for sex, race, annual household income, educational status including interaction terms for expansion status and time periods of pre-and post-expansion using Proc Genmod. Excluded 2010 data as the wash-out period.

Prior authorization required for smoking cessation among states include: AK, AL, AR, CO, DE, HI, IA, ID, MA, ME, MI, MO, MT, ND, NE, NV, OK, RI, TN, UT, VT, WA, and WV (23 states).

Table 6. Relative Risks for Quit Attempts by Expansion and Time Period by Co-payment, US BRFSS 2003-2015			
	Quit Attempts	**Co-payments**	
	Overall	**Yes**	**No**
Expanded	**RR (95% CI)**	**RR (95% CI)**	**RR (95% CI)**
Pre-expansion (2003-2009)	**Ref**	**Ref**	**Ref**
Post-expansion (2011-2015)	1.04 (1.04 – 1.05)	1.03 (1.02 – 1.03)	1.07 (1.06 – 1.07)
Non-expanded			
Pre-expansion (2003-2009)	**Ref**	**Ref**	**Ref**
Post-expansion (2011-2015)	1.03 (1.02 – 1.03)	1.02 (1.02 – 1.03)	1.03 (1.03 – 1.04)

Note: Relative risks were adjusted for sex, race, annual household income, educational status including interaction terms for expansion status and time periods of pre-and post-expansion using Proc Genmod. Excluded 2010 data as the wash-out period.

Co-payments required for smoking cessation among states include: AK, CA, CO, DE, OA, IL, IN, KS, LA, MA, ME, MN, MS, MT, NC, ND, NE, NH, NV, OH, OK, OR, PA, SD, TX, UT, VA, VT, WI, WV, and, WY (31 states).

FIGURES

Figure 1: Prevalence of current smoking in the expanded vs. non-expanded states – BRFSS, United States, 2003-2015

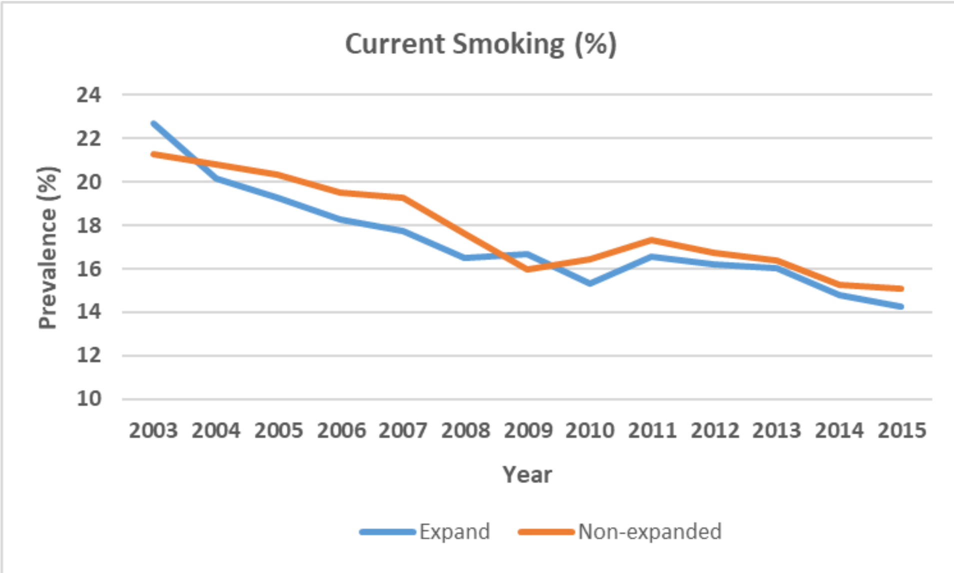
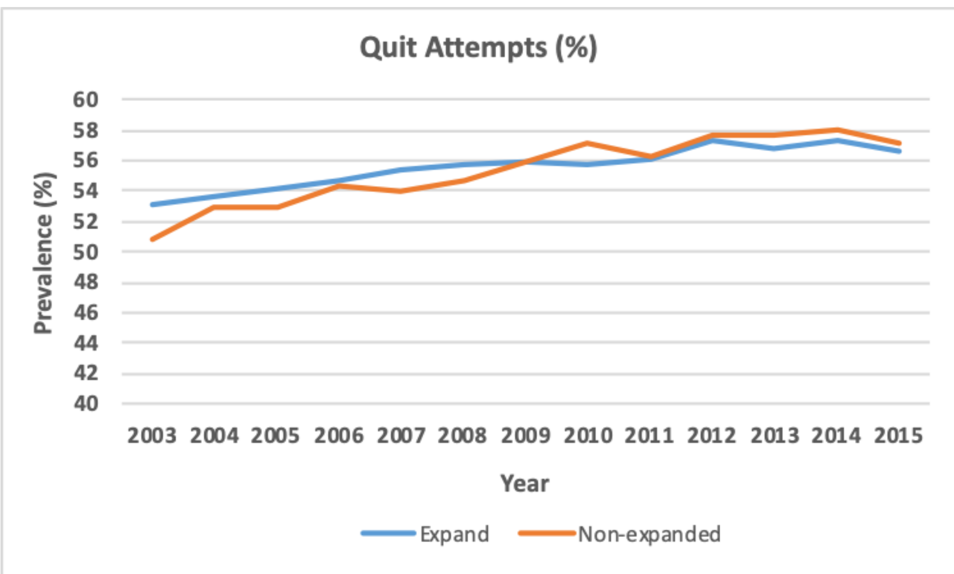


Figure 2: Prevalence of adult smokers reporting a quit attempt during the previous year in the expanded vs. non-expanded states – BRFSS, United States, 2003-2015



Supplemental Tables

Table 1: Relative Risks for Current Smoking and Quit Attempts by ACA Expansion Status by Age-Group, US BRFSS 2011-2017

	Current smokers (%)		Quit Attempts (%)	
Year	**2011-2013**	**2015-2017**	**2011-2013**	**2015-2017**
Overall US				
Expanded	128,687 (16.37)	107,521 (14.47)	72691 (57.16)	59957 (56.01)
Non-expanded	104,257 (16.84)	82846 (15.33)	59290 (57.90)	46852 (56.77)
	RR = 0.994 (0.994-0.995)	**RR = 1.016 (1.016-1.017)**	**RR = 1.006 (1.006-1.007)**	**RR = 1.011 (1.011-1.011)**
18-49 years				
Expanded	59302 (20.66)	45590 (18.10)	35801 (61.22)	27367 (60.27)
Non-expanded	46892 (21.58)	35803 (19.47)	28636 (62.37)	21983 (61.66)
	RR = 0.996 (0.996-0.997)	**RR = 1.035 (1.035-1.036)**	**RR = 1.015 (1.014-1.015)**	**RR = 1.023 (1.022-1.023)**
50-79 years				
Expanded	67045 (15.19)	59994 (13.89)	35893 (53.84)	31787 (53.20)
Non-expanded	55486 (15.81)	45477 (14.61)	29850 (54.46)	24212 (53.37)
	RR = 0.992 (0.991-0.992)	**RR = 0.997 (0.996-0.997)**	**RR = 0.997 (0.997-0.998)**	**RR = 1.0008 (1.0005-1.001)**
>=80 years				
Expanded	2340 (3.62)	1937 (3.24)	997 (42.50)	803 (41.78)
Non-expanded	1879 (3.42)	1566 (3.41)	804 (42.21)	657 (42.11)
	RR = 1.005 (1.001-1.008)	**RR = 1.006 (1.004-1.008)**	**RR = 0.968 (0.964-0.973)**	**RR = 0.995 (0.993-0.997)**

Reference = Expanded; RR = rate ratio. RRs for age categories have been adjusted for sex, race, annual household income, and education status using Proc Genmod; excluding year 2014 as the washout period.

Table 2. Relative Risks for Current Smokers and Quit Attempts by Expansion and Time Period, US BRFSS 2011-2017

	Overall		**Low Income (≤$20,000)[Ψ]**	
	Current smoking*	**Quit Attempts***	**Current Smoking***	**Quit Attempts***
	RR (95% CI)	**RR (95% CI)**	**RR (95% CI)**	**RR (95% CI)**
Expand				
Pre-expansion (2011-2013)	**Ref**	**Ref**	**Ref**	**Ref**
Post-expansion (2015-2017)	0.971 (0.971-0.972)	0.995 (0.995-0.996)	0.994 (0.9932-0.9947)	0.992 (0.991-0.993)
Non-expanded				
Pre-expansion (2011-2013)	**Ref**	**Ref**	**Ref**	**Ref**
Post-expansion (2015-2017)	0.946 (0.945-0.946)	0.991 (0.990-0.991)	0.977 (0.976-0.978)	0.982 (0.982-0.983)

Note: Rate ratios were adjusted for sex, race, annual household income, educational status including interaction terms for expansion status and time periods of pre-and post-expansion using Proc Genmod

P-value for expansion x time period interaction: *<0.0001

[Ψ]Annual household income ≤ $20,000

CHAPTER 4

CONCLUSION

This capstone attempted to address environmental health and health policy issues using publicly available nationally representative data and epidemiologic methods. The purpose of this chapter is to briefly summarize the findings from the two diverse papers, discuss the public health implications of the two studies and to briefly summarize the limitations and recommendations.

Summary of Findings

The first paper hypothesized that increasing blood Mn levels will be associated with higher prevalence of MI and stroke, while renal dysfunction prevalence will reduce with increasing blood Mn levels. In our findings, we found an increasing 10% non-significant increase of myocardial infarction and stroke. However, we did not find a significant reduction in the prevalence of renal dysfunction with increasing blood Mn levels. There were no differences in the association between blood Mn levels and myocardial infarction, stroke and renal dysfunction based on poverty income ratio.

Despite the lack of significant findings, there was a non-significant increasing trend for blood Mn levels and myocardial infarction and stroke. Due to the cross-sectional, we cannot establish a causal relationship based on our findings. However, both the outcomes and the exposure were measured using standard procedures from a nationally representative US population. This association needs to be further validated in prospective cohort studies to determine adverse effects of Mn on myocardial infarction and stroke.

The second paper focused to evaluate the impact of the Affordable Care Act (ACA) expansion on current smoking and quit-attempts in the expanded and the non-expanded US states, to evaluate the impact among low-income individuals; accounting for state-level barriers to smoking cessation services. Overall, during the pre-expansion period (2003-2009) current smoking was 2% higher in the non-expanded states compared to the expanded states, but it was lower 1% lower in the non-expanded states compared to the expanded states during the post-expansion period (2011-2015). However, there was a 6% decline in current smoking in both the expanded and non-expanded states in the post- versus the pre-expansion period and a 4% increase in the quit-attempts. Moreover, there were no significant changes in current smoking rates among individuals with annual household incomes ≤$20,000; however, there was 4-5% increase in the quit-attempts in the post-expansion period compared to the pre-expansion period. Thus, following the ACA there were declines in current smoking rates both in the expanded and non-expanded states.

The analyses from these two papers are beneficial to public health practitioners as they both attempt to find environmental and health policies that can reduce the burden of chronic diseases in the US.

Implications for Public Health

The role of public health is to protect and improve the health of the general population by health promotion, policy development, and disease prevention. Therefore, public health professionals aim to identify populations that are the most vulnerable. Since, clinical professions like doctors and nurses focus primarily on treating illnesses on individuals, public health works to reduce health disparities in the population. Thus, public health incorporates all aspects of an individual's well-being like social and physical environment, availability of health services, health behavior, and biology to address health issues in the population.

This capstone has attempted to identify the vulnerable and disparate populations using epidemiologic methods to assess biology, environmental, and health policy on the prevalence of chronic diseases and their risk factors. As practicing epidemiologists, it is our role to identify the primary risk factors and initiate the necessary health policies that can influence the health of a community and the general population. As we did find that certain policies help to reduce health disparities, we need to better on reducing barriers and administrative costs for the vulnerable populations that prevent access to timely preventive care.

The analyses of the two papers is timely as they address the environmental, biological, and health policy impact on risk factors that are associated with the onset of chronic diseases. Future research needs to evaluate implementation of policy and studies to prospectively assess the biomarkers that can reduce the cost of chronic diseases in the United States.