A Socioecological Exploration of County-Level Toddler Immunization Completion

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Abstract

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There is wide variation among county-level toddler immunization completion, which ranges from 26% to more than 90%. The cause of this variation is unclear and reflects our limited understanding of the factors that affect toddler immunization. **Aims.** 1) Identify a theoretical framework to support the multifaceted nature of toddler immunization completion research. 2) Describe the characteristics of counties with high and low toddler immunization completion. 3) Explore relationships between county-level toddler immunization completion and immunization-related state policies. **Methods.** Theoretical arguments proposed by Rose (1985) were used to adapt the ecological systems theory for populations instead of individuals. A cross-sectional sample of 624 counties from 10 states was then used in a secondary data analysis exploring county-characteristics associated with toddler immunization completion. The same sample was then used to explore the association between county-level toddler immunization coverage and state policies. **Results.** 1) A socioecological framework was identified and modified. 2) There are county characteristics positively and negatively associated with county-level toddler immunization completion. 3) Counties in states that expanded Medicaid or had Democratic legislatures had lower toddler immunization completion. **Conclusion.** Complex, local-level characteristics have a relationship with variation in county-level toddler immunization completion. Understanding these relationships can help researchers, policy makers, and public health professionals take important actions that can help improve immunization rates.

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Chapter 1: Introduction

A Socioecological Exploration of County-Level Toddler Immunization Completion

Vaccination is a well-established, critical public health intervention that prevents the transmission of infectious diseases and protects against associated morbidity and mortality. Throughout the early 21st century, however, cases of vaccine-preventable diseases have slowly been increasing (Centers for Disease Control and Prevention, 2018a, 2019a; World Health Organization, 2019). Vaccines appear to be a victim of their own success, and as a result, the risk-benefit balance has moved toward vaccines being considered riskier than the diseases themselves (Cooper, Larson, & Katz, 2008). Because of this and many other factors, vaccination rates are declining, leading to an increase in vaccine-preventable diseases (Heininger & Zuberbuhler, 2006; Luman, Barker, Shaw, McCauley, Buehler, & Pickering, 2005; Ostroff, 2011). One of the benchmarks of Healthy People 2020 is that 80% of toddlers aged 19 to 35 months complete the recommended immunizations on time. However, toddler immunization completion varies widely among counties in the U.S. (Public Health Activities and Services Tracking, 2017), indicating that some communities are more at risk than others for outbreaks of vaccine-preventable diseases. Therefore, the overall objective of this dissertation is to explore toddler immunization completion at the county level.

Background

Despite advances in vaccine technology, some members of the public are concerned about the safety, effectiveness, and necessity of vaccination (Cooper et al., 2008; Poland, 2011). According to the World Health Organization (WHO), the reluctance or refusal to vaccinate despite the availability of vaccines is one of the top ten global public health concerns of 2019 (WHO, 2019). Although delaying or avoiding vaccination threatens the success of immunizations, individual choice is not solely responsible for lowered immunization rates

(Dube, Laberge, Guay, Bramadat, Roy, & Bettinger, 2013). In fact, vaccination rates may also be influenced by factors at the local, state, and federal levels, including inadequate access to services, negative health staff attitudes, social norms, culture, values, and education (Favin, Steinglass, Fields, Banerjee, & Sawhney, 2012). Although there is a great deal of vaccine literature, vaccine research lacks a consistent theoretical framework, making it challenging to scrutinize the literature, identify gaps, and address lowered immunization rates holistically (Peretti-Watel, Larson, Ward, Schulz, & Verger, 2015).

Theoretical Framework

Socioecological frameworks demonstrate the multifaceted and interrelated effects of personal and environmental factors that influence health behavior and have been used to understand complex issues, such as human development (Bronfenbrenner, 1979) and inter-personal violence (Violence Prevention Alliance, 2019). It is apparent that individual, local, state, and federal factors all influence vaccination rates, yet only two studies were identified that addressed the multilayered nature of vaccine research (Kumar, Quinn, Kim, Musa, Hilyard, & Freimuth, 2012; Nyambe, Van Hal, & Kampen, 2016). Most studies are focused on individual or federal factors, ignoring local-level factors that may be associated with immunization rates. By presenting a framework within which various aspects of vaccine research can fit, this study brings clarity to the field and allows for easier identification of gaps in the literature and making clearer connections among existing studies.

Kumar and colleagues (2012) found that factors at every socioecological level were associated with the intent to vaccinate and vaccine uptake. Together, all socioecological levels explained 65% of the variance in H1N1 influenza vaccine uptake, indicating that targeting multiple levels would be more effective than only targeting one. However, few studies are

focused on local-level factors. Two studies identified explored the clustering of school vaccine exemptions (Omer et al, 2008) and the geographic proximity of un- and under-immunized toddlers (Lieu, Ray, Klein, Chung, & Kulldorff, 2015). The dearth of local-level research on toddler immunization completion makes it difficult to design interventions that target all socioecological levels.

County

There is wide variation in toddler immunization completion at the county-level that is masked when looking more broadly at state and national rates. For example, in Washington State in 2016, county-level toddler immunization completion varied from as low as 26% to as high as 77% (PHAST, 2017), but the state average demonstrated that 59% of Washington toddlers had completed their recommended vaccinations (Washington State Department of Health, 2016). In addition to the wide variation among counties, toddlers are often not the primary focus of state legislation because it is easier to reach school-aged children through school attendance. For example, Washington State passed House Bill 1638 in May 2019, which removes the personal belief exemption for the measles-mumps-rubella (MMR) vaccine, but only for school age children (Harris et al., 2019). This proposal would mean that healthy children with no medical contradictions to the vaccine have to receive the MMR vaccine but not until they enter kindergarten around the age of 5 years. The delay of toddler vaccinations not only puts them at risk, but their families and communities as well. Counties with lower toddler immunization completion are associated with outbreaks of vaccine-preventable diseases (Lieu et al., 2015). By exploring toddler immunization at the local level, the variation in toddler immunization completion could be addressed and community health prioritized.

Interaction between County and State

From a socioecological perspective, the interaction between levels is considered essential in understanding behavior (Bronfenbrenner, 1979), yet only one study identified explored the interaction between any of the socioecological levels in regard to immunization (Kumar et al., 2012). Immunization legislation is generally implemented at the state level, but the wide variation in county-level toddler immunization completion both within and across states indicates that some counties benefit more from state policies than others. Such policies include whether the state expanded Medicaid, as well as laws regarding permitted immunization exemptions for school or daycare attendance. By exploring the relationship between county-level toddler immunization completion and immunization-related state policies, this study examines the influence of state policies on health outcomes at the county-level and is among the first of its kind in vaccine research to begin to unpack the complexity associated with county-level toddler immunization completion.

Relevance of Dissertation

In 2019, confirmed measles cases in the U.S. surpassed the highest number on record since the disease was eliminated nationwide in 2000 (CDC, 2019b). Over 200 students and faculty across two universities in California were exposed to a confirmed measles case and subsequently quarantined (Drash, 2019). Additionally, 21 children and one adult contracted measles from a contagious person attending a basketball game in the Pacific Northwest (Karimi, 2019). Measles is highly contagious, with 90% of exposed individuals contracting the disease if not already immune (CDC, 2018b). Communities rely on herd immunity, achieving appropriate immunization rates to protect at risk members of the community, to limit the spread of vaccine-preventable diseases—such as measles—but herd immunity has been seriously jeopardized due

to lowered immunization rates (Kim, Johnstone, & Loeb, 2011; Lieu et al., 2015). Aside from the impact on the exposed individuals and their families, there are economic consequences associated with vaccine-preventable disease outbreaks. In 2011 in the U.S. there were 16 measles outbreaks with a total of 107 confirmed cases (Ortega-Sanchez, Vijayaraghavan, Barskey, & Wallace, 2014) resulting in an overall estimated economic burden for local and state public health departments of between $2.7 and $5.3 million (Ortega-Sanchez et al., 2014).

Although the decision to immunize seems innately personal, the consequences of those decisions impact both population and economic health. Additionally, individual choices are not made independently, but instead are a result of the complex interplay between environment, social context, and the individual (Boerner, Keelan, Winton, Jardine, & Driedger, 2013). This study addresses the gaps in the literature concerning local-level factors associated with county-level toddler immunization completion as well as the interaction among different socioecological levels. Filling these gaps supports policy makers and public health professionals in designing and evaluating interventions that cross multiple socioecological levels, eventually leading to increased toddler immunization completion and fewer outbreaks of vaccine-preventable diseases.

Focus and Scope of Dissertation

Using a socioecological framework, this dissertation focuses on toddler immunization completion at the county-level. For most states, toddler immunization completion is defined as receiving all the vaccines recommended by the Advisory Committee on Immunization Practices (ACIP) before the age of 36 months. This research focused on county and state factors, as well as the interaction between them, to build an evidence base that encourages immunization interventions that target multiple socioecological levels.

Objective

The primary objective of this study is to explore county-level toddler immunization. There are three main aims, each represented as a scholarly paper and a chapter in this dissertation. This study intends to:

1. Identify a theoretical framework to support the multifaceted nature of toddler immunization completion research.
2. Describe the characteristics of counties with high and low toddler immunization completion.
3. Explore the relationship between county-level toddler immunization completion and immunization-related state policies.

Structure of Dissertation

This dissertation contains three main papers that aim to address each of the aforementioned objectives. The first paper is an analysis and reformulation of Bronfenbrenner's (1979) ecological systems theory. In current vaccine research, little theoretical evidence was identified to support current vaccine interventions. The goal of this theory analysis and reformulation is to provide a framework from which vaccine interventions can be based. The second paper is a secondary data analysis of county-level factors associated with toddler immunization completion. The primary purpose of this paper is to identify county characteristics associated with toddler immunization to help detect counties that could be at risk for vaccine-preventable disease outbreaks. The final paper is a secondary data analysis of the association between state policies and toddler immunization completion at the county level. The cause of the inconsistency in county-level toddler immunization completion is unclear and reflective of our limited understanding of the multiple factors that affect it. Together these papers provide a

comprehensive look at toddler immunization completion at the county level and begin to address gaps in our understanding of the multifaceted nature of immunizations.

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Chapter 2: A Model for Systems-Level Influences on Toddler Immunization Completion

Abstract

Toddler immunization completion rates vary across counties in the U.S. and may be contributing to the national rise in vaccine-preventable diseases. Yet in examining how to address toddler immunization completion, there is little theoretical support in the literature for why multiple environments should be considered influential in an individual's decision. However, as Rose (1985) argues, population characteristics are distinct from the sum of individual characteristics. Thus, a reformulation of Bronfenbrenner's (1979) ecological model, with empirical support from Rose, helps provide theoretical direction and can guide future population health research regarding system-level influences on vaccine coverage.

Keywords: county, toddler, socioecological, ecological systems theory

A Model for Systems-Level Influences on Toddler Immunization Completion

Vaccines not only protect the individuals who receive them but also the community through the benefits of herd immunity, the protection achieved when enough community members are vaccinated (Andre et al., 2008). In recent years, community health has been endangered through a decline in vaccination rates and an increase in vaccine-preventable diseases (Centers for Disease Control and Prevention, 2019; World Health Organization, 2019). The public's lack of confidence in the safety and effectiveness of vaccines is believed to be one factor associated with decreasing vaccine coverage (Dube et al., 2013), yet it is not entirely responsible. It is challenging to identify all the variables that influence vaccination because—despite the plethora of vaccine literature—there is no consistent use of a theoretical framework, making it challenging to identify gaps in the literature (Peretti-Watel, Larson, Ward, Schulz, & Verger, 2015). Therefore, the aim of this paper is to identify a theoretical framework that supports toddler immunization completion research in order to more effectively promote vaccination.

In the U.S., the goal by 2020 is that 80% of toddlers aged 19 to 35 months complete their recommended vaccinations (Healthy People 2020, 2014), but as of 2016, only 70% of toddlers nationally were up-to-date (Hill, Elam-Evans, Yankey, Singleton, & Dietz, 2016). However, this national estimate masks the variation found among toddler immunization completion at the county-level, which ranged from 26% to over 90% in 2016 (Public Health Activities and Services Tracking, 2017). Few studies examine what could be causing this local-level variation, but findings demonstrate there are factors at local, state, and federal levels that influence county immunization rates (Lieu, Ray, Klein, Chung, & Kulldorff, 2015; Olive, Hotez, Damania, & Nolan, 2018; Omer, Enger, Moulton, Halsey, Stokley, & Salmon, 2008). These studies suggest

that a multilayered framework, such as the ecological systems theory (Bronfenbrenner, 1979), could be used to explore vaccine literature, identify gaps in the science, and address lowered immunization rates holistically (Peretti-Watel et al., 2015).

Theory Analysis

The ecological systems theory was developed to understand how the interaction between the individual and their environment influences human development (Bronfenbrenner, 1979). Since vaccination is not solely an individual concern, but also a community and population health concern, the ecological systems theory is reformulated here from an individual focus to a population focus. This study first analyses Bronfenbrenner's theory to understand its concepts and allow for appropriate reformulation consistent with the purpose of the theory overall. The analysis of the ecological systems theory was guided by Walker and Avant (2011) and entailed seven steps: determining the theory's origins, meaning, logical adequacy, usefulness, generalizability, parsimony, and testability.

Origins

The origins of a theory are evaluated through a determination of why a theory was generated, whether the development was inductive or deductive, and whether empirical evidence supports the theory (Walker & Avant, 2011). In the 1970s, Bronfenbrenner (1979) noted there was a gap in the human development literature regarding the interaction between the person and their environment. He felt that human development studies at the time focused overwhelmingly on the characteristics of people and ignored the diverse context from which the person came. Additionally, the environment was generally considered static, overlooking the evolving interactive processes that influence a person's development (Bronfenbrenner, 1979). Finally, Bronfenbrenner (1979) argued that most research occurred in labs, which removed the person

from their environment, further diminishing the ability to understand the interaction between environment and the person.

According to Bronfenbrenner (1979), social psychology has theories about the influence of the environment on human behavior, but this understanding is limited to interpersonal processes and one setting because of the emphasis on scientific rigor. By limiting the setting and controlling for other variables, researchers were better able to draw causal conclusions. In contrast, anthropology addresses the environment but relies heavily on anecdotal evidence, limiting causal inferences (Bronfenbrenner, 1979). In response to these shortcomings, some researchers at the time argued that experimental methods are not suited to study behavior in natural circumstances (Bronfenbrenner, 1979; McCall, 1977). This argument was primarily based on ethical concerns about manipulating and controlling variables in a child's environment (McCall, 1977). Bronfenbrenner (1979) countered that the experimental method can be used not only to support hypotheses but also for the discovery of hypotheses—a deductive approach. He proposed that understanding human development requires more than direct observation; it entails the examination of multiple settings beyond a person's immediate situation, again demonstrating a deductive approach. Using theories and hypotheses from multiple fields, Bronfenbrenner (1979) deduced the ecological systems theory (Figure 1).

Meaning

The meaning of a theory consists of the concepts' definitions and the relationships among those concepts (Walker & Avant, 2011). Initially, the ecological systems theory had four systems: microsystem, mesosystem, exosystem, and macrosystem. Later, a fifth system, the chronosystem, was added (Figure 1; Bronfenbrenner, 1995).

The microsystem is the direct environment in which people live (Bronfenbrenner, 1979). For toddlers, this can include friends, family, preschool teachers, and pediatric healthcare providers with whom toddlers have direct contact.

The mesosystems are the relationships among the other microsystems affiliated with a child (Bronfenbrenner, 1979). An example of a mesosystem could be the interaction between a toddler's parents and the toddler's health care provider, such as when vaccination is discussed.

The exosystem includes social agents with which the individual does not immediately interact but that have a large impact on the individual (Bronfenbrenner, 1979). For example, the continuing education opportunities available to pediatric providers about the safety and efficacy of new vaccines may influence whether the provider decides to administer the vaccine or whether the provider has enough knowledge to educate parents or parental exposure to vaccine information through social media.

The macrosystem is the largest and most remote set of social agents that still influences the individual (Bronfenbrenner, 1979). Examples of macrosystem social agents often include social norms, cultural values, the economy, and government.

The chronosystem includes the transitions in an individual's life (Bronfenbrenner, 1995). These might include the social and historical context that may influence a child, such as being born during an economic depression, growing up during a war, or experiencing parents divorcing in an area where divorce is not common.

The ecological systems theory asserts that human development is influenced by these different systems (Bronfenbrenner, 1979 & 1995). It is graphically depicted as concentric circles with the innermost circle representing the individual and each subsequent circle representing a different system, from the microsystem encircling the individual to the macrosystem, which is

generally depicted as the outermost circle (Figure 1). In some models, the chronosystem is the outermost circle or an arrow traveling from left to right, above the concentric circles.

This theory was originally published in 1979, and it has influenced many social scientists' understanding of the interaction between a person and their environment. However, the initial theory was criticized for not emphasizing the importance of the individual in their own development (Eriksson, Ghazinour, & Hammarstrom, 2018). Thus, the theory underwent several reformulations, and most recently is represented by the Process-Person-Context-Time (PPCT) model that introduced the chronosystem (Eriksson et al., 2018).

Logical Adequacy

Logical adequacy is the logic embedded in the theory that allows for it to be confirmed or refuted (Bacharach, 1989; Walker & Avant, 2011). The goal of logical adequacy is to understand the structure of the theory, not the content (Walker & Avant, 2011), which is why it is necessary to understand if the theory was developed deductively or inductively. If a theory was developed deductively, as the ecological systems theory was, all the arguments must be true for the conclusion to be true.

Bronfenbrenner (1979) does not explicitly state the premises of his argument, but the arguments can be inferred.

Premise 1: Human development occurs.

Premise 2: Humans experience multiple environments.

Conclusion: "In ecological research, the properties of the person, the environment, the structure of environmental settings, and the processes taking place within and between them must be viewed as interdependent and analyzed in systems terms" (Bronfenbrenner, 1979, p. 41).

The field of developmental psychology is the study of how and why humans change over their life course, and developmental biology is the process by which organisms grow and develop. If human development did not occur, neither of these scientific fields would exist, which supports the truth of premise one. The truth of premise two is supported anecdotally by observing humans in our daily lives, but also by the existence of the field of sociology, which is the study of human social relationships and institutions. Because both premises are true, the conclusion that Bronfenbrenner draws is also true.

Usefulness

A useful theory provides insights into a phenomenon, aids with understanding it, or helps make predictions (Walker & Avant, 2011). The usefulness of Bronfenbrenner's ecological systems approach for toddler vaccination is promising but is dependent upon which version of the ecological systems theory is used (Eriksson et al., 2018). The PPCT version of the model focuses on proximal or immediate processes instead of the more distal environmental factors (Eriksson et al., 2018). Therefore, any policy implications drawn from the PPCT version would focus on the individual as opposed to the social and organizational context. This version would not be effective for a population health concern like toddler vaccination. Thus, the focus of this paper is on Bronfenbrenner's initial model developed in 1979.

There are three specific criteria to consider when determining a theory's usefulness: how much subsequent research is based on the theory, whether the theory can be associated with a clinical problem, and the influence of the theory on healthcare practice, education, administration, or research (Walker & Avant, 2011). Bronfenbrenner's ecological systems theory has been applied broadly in research. A Google Scholar search finds that his model has been cited over 35,000 times. Although not all these citations are original research (the ecological

model is often described in textbooks), these results demonstrate the widespread dissemination and use of this theory since its development in 1979.

Human development is clinically relevant for providers across the health care spectrum, including both primary and acute care settings. In particular, pediatric health care is largely influenced by developmental progression and health promotion. Understanding the influences of systems on children's development may help providers promote the health and well-being of the child.

Finally, the usefulness of the ecological systems theory in healthcare practice, administration, education, and research needs to be considered. The usefulness of the ecological systems theory in healthcare practice has already been demonstrated by human development being clinically relevant to pediatric practice, specifically the focus on attaining developmental milestones and a broader focus on the child in the context of the family. The ecological systems theory is also useful in education to help healthcare students understand the interaction between and among systems and the individual. The usefulness in research is limited because it can provide a theoretical framework for research, but the framework could be used differently across disciplines because there are no operational definitions for each system.

Generalizability

The generalizability of a theory is determined by how widely the theory can be applied (Walker & Avant, 2011). Although the ecological model was developed within the discipline of educational psychology, it has been used in many social sciences to understand how systems and the interaction among them influence an individual's behavior. However, the focus on the ecological model is the individual, as demonstrated by the graphic depiction of the individual in

the center of the four systems (Figure 1); therefore, the generalizability of the ecological model is limited to the individual rather than communities or populations.

Parsimony

A theory is considered parsimonious if it can be stated briefly, yet clearly (Walker & Avant, 2011). Generally, theories in math are the most parsimonious, with theories involving human behavior considered as the least parsimonious (Walker & Avant, 2011). The main purpose of the ecological model is to demonstrate that human development is influenced both directly and indirectly by the environment. The graphic presentation of the theory demonstrates the parsimony of the ecological model because it is simply a group of concentric circles surrounding an individual, with each circle representing a system (Bronfenbrenner, 1979).

Testability

Testability is whether the theory can be supported with empirical evidence (Walker & Avant, 2011). Bronfenbrenner developed the ecological systems theory in an attempt to drive human development experiments out of the laboratory because he believed the laboratory was too clinical and limited researchers' ability to observe the individual and their interaction with their environment (Bronfenbrenner, 1979). Measurement of these interactions with the environment present methodological challenges. Additionally, the concepts in the ecological systems theory only have descriptive definitions and not operational ones, adding to difficulties in measurement. Thus, the ecological model is not easily testable.

This theory analysis demonstrates that Bronfenbrenner wanted to include the natural environment in the study of human behavior. The clinical setting of the lab ignored environments beyond the microenvironment, and the interaction among different environments (Bronfenbrenner, 1979). Although his theory was established with the clear goal of

demonstrating the multifaceted nature of human development, it is not easily testable nor generalizable beyond the individual. Because of these limitations, the ecological systems theory was reformulated for a population level health concern such as toddler immunization completion.

Ecological Systems Theory Reformulation

According to Schwartz and Diez-Roux (2001), Rose (1985) uses a Durkheimian perspective when he argues that population characteristics may be influenced by individuals' characteristics, but this is a bidirectional relationship with the characteristics and individual's behaviors also shaped by the characteristics of the population. Emile Durkheim is considered one of the founders of modern social science and is known for the conceptualization of social facts. Social facts are values, cultural norms, and social structures that exercise social control and can interact with individual-level factors to influence health (Durkheim, 1938; Schwartz & Diez-Roux, 2001). The distinction between individual behaviors and social facts supports Rose (1985) when he argues that the causes of incidence are distinct from the causes of cases. Cases are the people within the population who become sick. In health research, we opt to look at what causes the difference between people who become cases in a population compared to those who do not; thus, we are not developing an understanding of causes of disease. Instead, we are exploring what causes variation among people who become sick and those who do not (Schwartz & Diez-Roux, 2001).

When the focus is shifted from the individual to the population, we are examining the difference in disease rates among populations. Social facts, which are coercive and can influence individual behavior, are not easily identifiable at the individual level. At the population-level, however, social facts such as customs, values, and social networks may be more readily

identified and may provide the best explanation for varying disease rates among populations (Schwartz & Diez-Roux, 2001).

Using this reasoning, the ecological systems theory is reformulated with a population in the center instead of the individual. When considering toddler immunization completion, the individual refers to the parent-toddler dyad. Instead of being the center of the concentric circles, the characteristics of the dyad became the microsystem while the mesosystem, exosystem, and macrosystem remain the same (Figure 2). This reformulation maintains the dyad because although social facts influence individual behavior, individuals can also influence social facts in the bidirectional relationship indicated by Durkheim (1938), Rose (1985), and Bronfenbrenner (1979).

Toddler immunizations is an important example of a population health concern that could benefit from this adaptation of Bronfenbrenner's ecological systems theory. Many interventions around toddler immunizations are individual interventions. In fact, much of the research and clinical focus has been on identifying vaccine hesitant parents (Martin & Petrie, 2017; Opel, Mangione-Smith, Taylor, Korfiatis, Wiese, Catz, & Martin, 2011). Despite these interventions, outbreaks of vaccine-preventable diseases are increasing. Using the adapted model, county-level toddler immunization completion is the center of the model (Figure 3). Next is the microsystem, which consists of the characteristics of the parent-toddler dyad such as race, ethnicity, education, and income. The mesosystem contains community characteristics that are a result of the relationship among individual microsystems, such as population demographics and the composition of voters in a county. The exosystem includes social agents that do not interact directly with county-level toddler immunization completion and influences it. For vaccines, this

includes policies and state government. Finally, the macrosystem includes the most distal influential factors, including social norms and cultural values.

Conclusion

In the U.S., many communities are not achieving adequate immunization rates to protect against outbreaks of vaccine-preventable diseases. This could be due in part to a disconnect between understanding what causes individual cases versus what causes incidence in the population. Expanding vaccine use research beyond the individual and their immediate environment could help identify additional interventions to improve population level vaccination rates (Kumar et al., 2012). The ecological systems theory focuses on how environments impact an individual, not a population. Therefore, the ecological system theory was adapted here using theoretical arguments from Rose (1985) and Durkheim (1938) to provide a framework for examining population health concerns, such as toddler immunization completion.

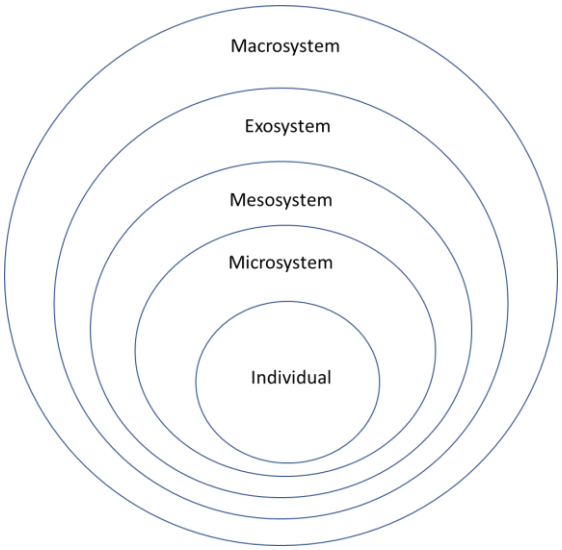

Figure 1. Bronfenbrenner's original ecological systems theory

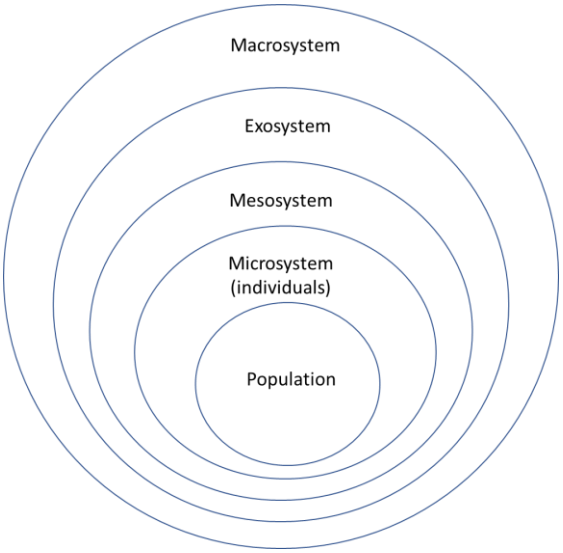

Figure 2. Reformulation of Bronfenbrenner's ecological systems theory for populations

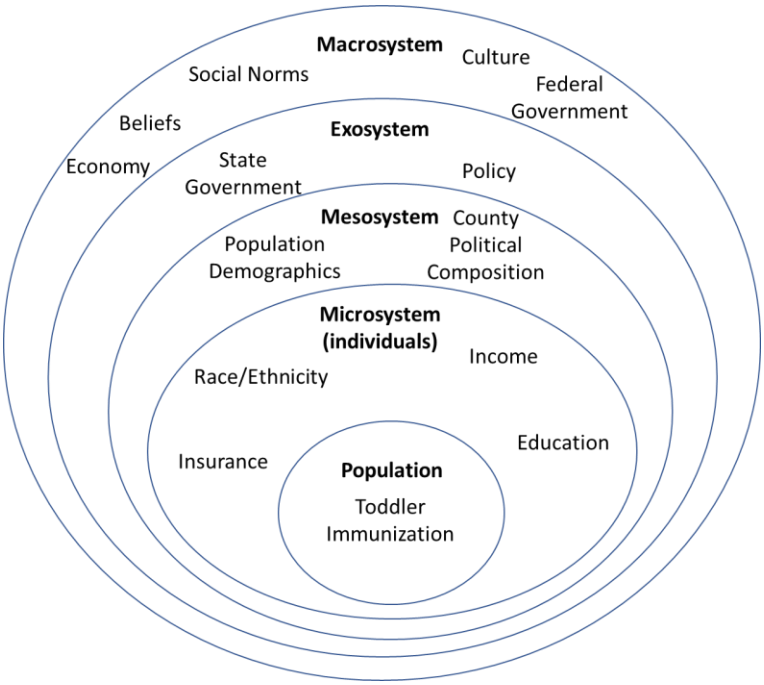

Figure 3. Using reformulated ecological system theory for toddler immunization example

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Chapter 3: Identifying County Characteristics Associated with Toddler Immunization Completion

Abstract

Clusters of un- or under-immunized children pose a public health risk. In 2019, there were two clusters of measles outbreaks, one in Clark County, Washington and the other in Rockland County and Brooklyn, New York. **Aim.** To describe the characteristics of counties with high and low toddler immunization completion. **Methods.** A cross-sectional sample of 624 counties from 10 states was used in this exploratory analysis of secondary data for toddler immunization completion. Three linear regressions were used to identify county characteristics associated with toddler immunization. **Results.** Poverty rate, percent of foreign-born residents, and percent of the population under 5 years of age were all significantly, negatively associated with county-level toddler immunization. Having a higher percentage of residents with health insurance increased toddler immunization completion, but counties with a higher percentage of children on public health insurance actually had lower toddler immunization completion. Finally, counties with local health departments (LHDs) directly administering both the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) and well-child clinics had higher toddler immunization completion than counties with LHDs that did not offer those programs. **Conclusion.** These factors can be used to identify counties at risk for lower toddler immunization completion that may need more targeted outreach, funding, or policy interventions. Being able to identify these at-risk counties could help with resource allocation and distribution, hopefully leading to the eventual increase in county-level toddler immunization and decrease of vaccine-preventable disease outbreaks.

Keywords: county-level toddler immunization, local, vaccine, local health department (LHD), access to care

Identifying County Characteristics Associated with Toddler Immunization Completion

According to the World Health Organization (WHO), there has been a 30% increase in measles cases worldwide since 2016 due to gaps in vaccine coverage (World Health Organization, 2018). The U.S. is not exempt from this increase and had several outbreaks of measles in 2019 (Centers for Disease Control and Prevention, 2019). In fact, 2019 has had the most confirmed cases of measles since measles was declared eliminated from the U.S. in 2000 (CDC, 2019). Many of these cases are clustered in the same geographic areas—specifically counties—and in young children (Lieu, Ray, Klein, Chung, & Kulldorff, 2015). However, due to lack of resources—such as funding and time—county-level toddler immunization completion is rarely studied; instead, related research has typically focused on state and national levels (Bernstein, North, Schwartz, & Niccolai, 2016; Blank, Caplan, & Constable, 2013; CDC, 2013b; Constable, Blank, & Caplan, 2014; Franco, Mazzucca, Padek, & Brownson, 2019).

The National Immunization Survey (NIS), an annual survey of vaccination coverage for both toddlers and adolescents, provides only limited immunization data for most counties in the U.S. (CDC, 2016a). Such broad national and state perspectives fail to account for the particularly wide variation in toddler immunization completion among counties. In Washington State in 2016, for example, toddler immunization completion ranged from 26% to 77% among the state's 39 counties (Public Health Activities and Services Tracking, 2017). Similar county-level variation for toddler immunization completion can be found in states across the nation (PHAST, 2017). As such, state and national toddler immunization completion may appear deceptively high or low. There is little research examining toddler immunization completion at a more granular, local-level where the influence of communities—such as community characteristics, LHDs, and

access to care—can be considered and where such an understanding could help counties and LHDs begin to plan interventions that are tailored to their communities.

Community

When there are outbreaks of vaccine-preventable diseases, the cases are clustered and often associated with unvaccinated individuals (CDC, 2019; Lieu et al., 2015). It is challenging to identify why an individual might choose not to vaccinate their child, but at the community level, it might be easier to identify and address (Rose, 1985). There are many characteristics associated with immunization including age, income, race, ethnicity, immigration status, and culture (Bahta & Ashkir, 2015; Dominguez, Parrott, Lauderdale, & Daum, 2004; Gahr et al., 2014; Gilbert, Gilmour, Wilson, & Cantin, 2017; Hambidge et al., 2006; Larson, 2014; MacDonald, 2015; Smith & Stevenson, 2008; Sugerman et al., 2010). However, studies tend to examine immunization at the individual-level and not the county-level. County-level variables—including county population size, the percent of residents under 5 years of age, employment rates, poverty rates, percent of residents on public assistance, and income inequality measured by the GINI coefficient (a statisticasl measure of income distribution; Dorfman, 1979)—that should be considered often are not.

Population size is a potentially important characteristic in examining toddler immunization completion because people in more populous counties might have more access to immunization. Similarly, the percent of county residents under the age of 5 years may also be related to toddler immunization completion because counties with more young children might have more pediatric providers and better access to care. Community factors associated with income inequality (income, poverty, public assistance, and GINI coefficient) also contribute to

which social and health programs are available in the community, which funding the community receives, and how community residents can access healthcare (McCullough & Leider, 2017).

In addition to the variables mentioned previously, there are more abstract factors that could influence toddler immunization completion at the county-level, including a county's culture, values, and norms (Franco et al., 2019). The culture of a county may be more lenient regarding vaccine policy, which could lead to differential enforcement of school immunization laws or less emphasis on immunization as a public health goal. Capturing the culture of a county is challenging, and as a result many studies examine individual attitudes and beliefs but not the aggregation of such values. Voting records can be a rough measurement of county culture, although voting decisions are complex. On a population-level, counties leaning more Democratic might be more likely to be pro-vaccine (Baumgaertner, Carlisle, & Justwan, 2018) or fund social or health programs that could improve education about vaccines or work to prevent the dissemination of incorrect information.

Access to Care

Having adequate health insurance is linked to having access to appropriate and timely administration of vaccinations (Blewett, Davidson, Bramlett, Rodin, & Messonnier, 2008). There are three federal programs or policies to help ensure that all children have access to immunizations: Vaccines for Children (VFC), Children's Health Insurance Plan (CHIP), and provisions within the Affordable Care Act (ACA).

VFC was created partially in response to the 1989 – 1991 measles epidemic that resulted in several tens of thousands of cases and hundreds of deaths (Mitchell, Philipose, & Sanford, 1993). The goal of VFC is to encourage higher immunization rates by providing vaccines to the children of parents or guardians who are unable to afford immunizations (CDC, 2016b). Children

are eligible for VFC if they are under the age of 19 years and are either Medicaid eligible, uninsured, under-insured, or are Native American or Alaska Native. To provide free vaccines to eligible children, the Centers for Disease Control and Prevention and Prevention (CDC) buys discounted vaccines and distributes them to state health departments, which then redistribute the vaccines to providers who are registered as VFC program providers (CDC, 2016b).

CHIP was created by the Clinton administration in 1997. The program is designed to cover children who are not Medicaid eligible because their parents' income is too high, but who are uninsured because private health insurance is unaffordable. The states and the federal government jointly fund CHIP, which is administered by each state following a set of federal government requirements (Centers for Medicare & Medicaid Services, 2017).

One of the many goals of the ACA was to remove patient cost-sharing for vaccines recommended by the Advisory Committee on Immunization Practice (ACIP; Kaiser Family Foundation, 2015). To incentivize states to prohibit cost-sharing for vaccines, the ACA has a provision in which states receive a 1% increase in their Federal Medical Assistance Percentages, which are used to determine the matching funds allocated to medical programs (Kaiser Family Foundation, 2015). The purpose of this provision was to decrease the cost of the vaccine for patients and make vaccines more accessible to all. Together, these three programs—VFC, CHIP, and ACA—are intended to ensure that children have access to healthcare and often include explicit provisions regarding timely access to recommended vaccine administration.

Although these three programs offer some potential consistency in immunization access, access to care varies by county in the number of primary care providers available. Some areas are designated health professional shortage areas, which are geographic areas that do not have an adequate patient-to-provider ratio (The Health Resources and Services Administration, 2016).

The American Academy of Pediatrics describes not only shortages of specialty pediatric providers, but also an uneven distribution of primary care pediatric providers. This shortage could mean that children living in rural and other underserved areas may not have easy access to adequate care, including immunizations (American Academy of Pediatrics, 2013).

Local Health Departments

LHDs have a major role and responsibility in monitoring and promoting toddler immunization completion in their jurisdictions. There are approximately 2800 LHDs in the U.S. serving mostly county jurisdictions (National Association of County and City Health Officials, 2015). They provide a wide range of services, including communicable and infectious disease surveillance and vaccine provision and distribution (NACCHO, 2015). In addition to addressing infectious diseases, LHDs monitor environmental factors that impact health, such as air and water quality (NACCHO, 2015). LHDs receive local, state, and federal funding to monitor population health and provided prevention services (Teutsch & Fiedling, 2016). Since 2008, LHDs have suffered major budget cuts (NACCHO, 2015; Office for State, 2015). As a result, many LHDs have cut clinical health services, emergency preparedness and response services, and maternal and child health (MCH) services, putting communities at risk for infectious disease outbreaks (NACCHO, 2015). In fact, the National Association of County and City Health Officials (NACCHO) Profile of Local Health Departments survey reported that 19% of LHDs made cuts to their immunization services in 2011 (NACCHO, 2017; Office of State, 2015). With widespread and lingering budget cuts, LHDs may lack the appropriate personnel to administer a vaccination program or ensure community providers are adequately fulfilling current community needs. Thus, LHDs may be influencing toddler immunization completion in their communities (Ransom, Schaff, & Kan, 2012; Rudner, 1996; Teutsch & Fiedling, 2016).

In an effort to better understand local-level variables that might be influencing the variability in county-level toddler immunization completion, this study uses county data to examine the multiple influences on immunization rates as a means to guide development of effective strategies to increase toddler immunization completion and reach national goals.

Methods

Using data from publicly available sources, a dataset was created for county-level variables, and an exploratory secondary data analysis was conducted examining toddler immunization completion for 624 counties in 10 states. Multiple linear regressions were used to analyze the association between county-level variables and county-level toddler immunization completion.

Data

Community. Most community data were compiled from the 2015 American Community Survey (ACS; United States Census Bureau, 2015). These variables include population size, percent of residents under 5 years of age, racial and ethnic composition of the county, educational attainment, employment rate, income, need for income assistance, poverty rate, and percent of residents born outside of the U.S. The GINI coefficient, also collected by the ACS, is a measure of income distribution among a county's residents (United Stated Census Bureau, 2014). A GINI coefficient of 0 indicates perfect equality, whereas, a GINI coefficient of 1 means perfect inequality, where one person has all the income and everyone else has nothing (United States Census Bureau, 2014).

County rural and urban designation data were drawn from the U.S. Department of Agriculture (Economic Research Service, 2010). The percentage of people in the county who voted Democratic or Republican in that state's most recent gubernatorial election was obtained

from each state's Secretary of State website. Gubernatorial election data were used to provide comparable proxy measures of county culture. Votes for state senators and representatives are based on legislative districts, not counties, so although legislative voting may be more representative of local beliefs, these data would not be comparable to other county-level data. The election years included in the dataset were for either 2014 (Alabama, California, Iowa, Maine, Tennessee, and Wisconsin) or 2016 (Indiana, Oregon, Washington, and West Virginia). These data were then coded into a binary variable that represented whether a county voted majority Democrat, coded as 1, or Republican, coded as 0.

Access to Care. County-level healthcare access data were also compiled from the 2015 ACS and included the proportion of county residents with health insurance, the percent of residents with public health insurance, and the number of primary care providers per 100,000 residents.

Local Health Departments. Data regarding LHDs were obtained and compiled from the NACCHO Profile of Local Health Departments survey, which is administered approximately every three years. This survey provides data about each U.S. LHD's infrastructure, finances, governance, and services provided. The 2016 NACCHO Profile survey variables used in this study included whether the LHD directly provided the following services in the previous year: immunizations, prenatal care, WIC, MCH home visits, MCH surveillance, communicable disease surveillance, and well-child clinics. These variables were included in the analysis because they could be associated with the administration of immunizations or education about immunizations.

Sample

All 624 counties from 10 states were selected for inclusion in this sample. States had to have county-level toddler immunization completion data available via the Public Health Activities Services Tracking (PHAST) immunization dashboard during the years 2015, 2016, or 2017, and similar definitions of toddler age and required vaccines (PHAST, 2017). The PHAST immunization dashboard houses a dataset specific to county-level toddler immunization completion data that are uniquely comparable and were obtained and compiled from 14 states by the PHAST study team at the University of Washington. Four states were excluded due to unreliable data and variation in how data were input into state systems. Immunization completion for the sample counties was commonly defined as finishing the vaccines recommended by the ACIP. All states in the sample except California used the 4:3:1:3:3:1:4 schedule, which includes 4 DTaP (diphtheria, tetanus, and pertussis), 3 Polio, 1 MMR (measles, mumps, ruebella), 3 HIB (Hemophilus influenzae type B), 3 Hep B (Hepatitis B), 1 Varicella (chicken pox), and 4 PCV (pneumococcal). California followed the 4:3:1:3:3:1 series, which does not include the 4 PCV. Additionally, most states defined toddler as somewhere between 19 and 35 months; California defined toddler as 24 to 59 months.

Statistical Analysis

Descriptive statistics for all variables were obtained for counties with low and high county-level toddler immunization completion. For descriptive purposes, counties were split into two groups based on the Healthy People 2020 goal of 80% of toddlers completing their immunizations on time. Low was defined as less than 80% and was comprised of 506 counties. High was defined as at least 80% and was comprised of 118 counties. Three separate linear

regressions were conducted to explore local factors theorized to contribute to county-level toddler immunization completion.

Each of the items used from the NACCHO Profile survey had between a 22% and 28% non-response rate. Chained logistic multiple imputation was used to replace the NACCHO missing data, with the imputation completed in Stata/IC 15.1 (StataCorp, 2017). The imputation was based on the following variables: percent of Democratic and Republican voters in a county, whether the state expanded Medicaid, which political party controlled the governorship, and the rural or urban designation of the county. These variables were selected because they could be theoretically associated with the services and funding of LHDs and could influence LHD responses to the items with the missing data.

Results

Descriptive Analysis

This descriptive analysis used a binary high and low county-level toddler immunization completion variable to compare a variety of county characteristics. County-level characteristics of the sample are described in Table 1 and as follows.

Community. Counties with high toddler immunization completion had on average 9% foreign-born residents, whereas counties categorized with low toddler immunization completion had on average of only 3.3% of foreign-born residents. Additionally, counties with low toddler immunization completion had a lower proportion of Hispanic residents (M= 0.05, SE = 0.003) compared to counties with high toddler immunization completion (M= 0.15, SE = 0.017). Of the 118 counties classified as high toddler immunization completion, 92 were Republican and 26 were Democratic.

Access to Care. Counties categorized as having low toddler immunization completion had a slightly lower proportion of children with health insurance (M = 0.95, SE = 0.002) compared to counties with high toddler immunization completion (M = 0.96, SE = 0.002). Counties with lower toddler immunization completion also had fewer primary care providers per capita (M = 58.6, SE = 1.42) than counties with high toddler immunization completion (M = 61.2, SE = 3.21).

Local Health Departments. Counties with low toddler immunization completion were less likely to have LHDs that offered prenatal care (M= 0.26, SE = 0.023) compared to counties with high toddler immunization completion (M = 0.32, SE = 0.048). The LHDs in counties with low toddler immunization completion were less likely to provide MCH home visits (M = 0.59, SE = 0.03) compared to LHDs in counties categorized with high toddler immunization completion (M = 0.89, SE = 0.03). Counties with low toddler immunization completion had LHDs that were less likely to offer well-child clinics (M = 0.27, SE = 0.023) compared to LHDs in counties categorized with high toddler immunization completion (M = 0.45, SE = 0.04). Counties with low toddler immunization completion were slightly more likely to have LHDs that offered immunization clinics (M = 0.92, SE = 0.01) compared to counties with high toddler immunization completion (M = 0.90, SE = 0.03). Overall, counties with low toddler immunization completion tended to have LHDs that did not offer prenatal care, MCH home visits, or well-child clinics; but interestingly, LHD immunization clinics tended to be slightly more common in low immunization completion counties.

Inferential Analysis

Community. Linear regression analyses identified several county-level community variables that were significantly associated with toddler immunization completion at the county-

level (Table 2). The variables that were significantly, positively associated included percent of Asian residents and percent of Hispanic residents. Poverty rate, percent of foreign-born residents, and the percent of the population under 5 years of age were all significantly, negatively associated with county-level toddler immunization. Finally, counties in which the majority of voters selected the Democratic gubernatorial candidate had lower county-level toddler immunization completion compared to counties where voters selected the Republican candidate.

Several other community characteristics did not achieve statistical significance in relation to county-level toddler immunization completeness. These included the total county population, the percent of county residents who identify as white or black, educational level, income, the GINI coefficient, the employment rate of county residents, the percent of residents on public assistance, and the rural or urban designation of the county.

Access to Care. When looking at access to care at the county-level, health insurance and the number of primary care providers were analyzed relative to county-level toddler immunization completion (Table 2). As the percent of residents 18 years and younger with health insurance increased, county-level toddler immunization completion increased ($\beta = 0.56$, $SE = 0.10$, $p < 0.0001$). However, counties with more children 18 years and younger on public health insurance had lower toddler immunization completion than counties with fewer toddlers on public health insurance ($\beta = -0.18$, $SE = 0.07$, $p = 0.01$). The number of primary care providers in a county (PCP per capita) was not associated with county-level toddler immunization completion.

Local Health Departments. Due to the LHD variables missing data, chained logistic multiple imputation with 10 samples was used to address the missing data for the LHD variables, F (16, 9080.2) = 39.798, $p < 0.0001$. In terms of LHD services, WIC and well-child clinics were

significantly associated with toddler immunization completion at the county-level (Table 3). Counties with LHDs that directly administered WIC programs had higher toddler immunization completion than counties with LHDs that did not directly administer WIC programs (β = 0.03, *SE* = 0.02, p = 0.02). In counties where LHDs provided well-child clinics, county-level toddler immunization completion coverage was higher compared to counties where LHDs did not provide direct well-child clinics (β = 0.028, *SE* = 0.01, p = 0.05). Counties with LHDs that participated in communicable disease surveillance had lower county-lever toddler completion than counties with LHDs that did not participate in communicable disease surveillance (β = -0.06, *SE* = 0.02, p = 0.01). For the remaining LHD variables, statistical significance was not achieved. These included variables indicating if LHDs provided services for immunizations, prenatal care, and MCH surveillance and home visits.

Discussion

Many studies, including those by the CDC, focus on adult immunizations, the influenza vaccine, or immunizations at the state level (Bernstein et al., 2016; Blank et al., 2013; CDC, 2013a; Constable et al., 2014; Franco et al., 2019; Winston, Wortley, & Lees, 2006). This study is among the first to examine how county-level characteristics potentially influence toddler immunization at the county-level and identifies several characteristics significantly associated with toddler immunization completion. An examination of these characteristics provides new insight into toddler immunization completion.

Aside from the percentage of county residents who identify as Asian, no racial category was associated with toddler immunization completion at the county-level. This could be because of the broad racial groups used in this study. There may be variation within racial sub-groups based on ethnicity or culture (Bahta & Ashkir, 2015). It is difficult to identify the influence of

racial composition is on county-level toddler immunization with the cross-sectional design of this study; therefore, racial composition may not be a reliable factor used to identify counties at risk for low toddler immunization completion.

Although the association between race and county-level toddler immunization completion is not clear, there is a clear relationship between Hispanic ethnicity and toddler immunization completion: Counties with higher toddler immunization completion have a higher proportion of Hispanic residents. This result aligns with the results reported in the CDC's health disparities and inequalities report (CDC, 2013a), as well as a study on children entering Chicago public schools (Dominguez et al., 2004).

In addition to community variables, some LHD services are significantly associated with toddler immunization completion: Specifically, if the LHD directly administers a WIC program or a well-child clinic. Interestingly, there was no difference in county-level toddler completion among counties with LHDs that provided immunization clinics and counties were LHDs did not provide this service. The combination of these results suggest that comprehensive care might play a role in how county residents use LHD services. Well-child clinics offer many benefits in one appointment, including wellness checks, child developmental screening, immunizations, and having the appropriate forms signed for daycare or preschool. LHDs that focus on single services might not be efficient enough, especially if those needs could be met elsewhere. Consequently, the presence or absence of some LHD services could be used to identify counties that are possibly at risk for low toddler immunization completion.

The final group of county characteristics is access to care, measured by the per capita number of primary care providers in a county and the proportion of residents under the age of 19 with health insurance. Counterintuitively, counties with more primary care providers had lower

toddler immunization completion than counties with fewer primary care providers. There are several possible reasons for this result. First, primary care pediatric providers and primary care family providers recommend vaccines differently (Campos-Outcalt, Jeffcott-Pera, Carter-Smith, Schoof, & Young, 2010). One study found that about 44% of children and adolescents were referred elsewhere for vaccines by family practice physicians (Campos-Outcalt et al., 2010). This may be an ineffective method of immunization, especially if they are referring children to LHDs that are facing cuts to their budgets and immunization services (NACCHO, 2015; Office of State, 2015). Another study found that pediatricians were more likely than family physicians to vaccinate during chronic illness and follow up visits and to track under-immunized children in their patient panels (Szilagyi et al., 1994). Encounters and efforts such as these might improve immunization rates and influence the association with provider density and immunization completion. The data used in this study, however, are unable to distinguish between primary care pediatricians and primary care family medicine doctors.

Limitations

Although this study is among the first of its kind to examine county-level immunization completion for toddlers, there are limitations. Primarily, this study does not account for geographic spacing due to lack of timely access to the required longitudinal and latitudinal data. Using a spatial auto-correlational tool such as Moran's I would account for correlation among counties in geographic proximity to one another (Jackson, Huang, Zie, & Tiwari, 2010). As Lieu and colleagues (2015) found, there is geographic clustering of families that are un- or under-immunized at the county-level, but their study did not identify the county-level factors associated with those clusters. Furthermore, this study does not delineate between toddlers who are completely unvaccinated from those who had received some or most of the recommended

vaccines. This will be an important consideration for future studies to help further tailor public health interventions for communities. Evidence to support such interventions would inform provider recommendations and population-level messaging to effectively educate and advise people who are hesitant but willing to consider vaccination.

Conclusion

This study underscores the complex nature of county-level toddler immunization completion coverage and the many factors that are associated with this critical public health intervention. These factors can be used to identify counties at risk for lower toddler immunization completion and in need of more targeted outreach, funding, or policy interventions. Being able to identify these at-risk counties could help with resource allocation and distribution, hopefully leading to the eventual increase in county-level toddler immunization and decrease of vaccine-preventable disease outbreaks.

Table 1

Descriptive statistics for counties with high and low toddler immunization completion

	Low M(SE)* (N = 506 counties)	High M(SE) (N = 118 counties)
Outcome variable		
% County toddler immunization completion	63.05 (0.45)	85.74 (0.45)
Community variables		
Total county population	75138.56 (6861.83)	349758.50 (98142.88)
% of population under 5 years	5.68 (0.04)	5.79 (0.10)
% White	88.77 (0.61)	83.30 (1.33)
% Black	57.69 (0.57)	50.54 (0.74)
% Asian	1.08 (0.07)	3.74 (0.60)
% Hispanic	4.96 (0.29)	15.17 (1.72)
% No high school	13.38 (0.26)	14.85 (0.64)
% High school	36.84 (0.32)	32.12 (0.84)
% Some college	30.22 (0.23)	31.04 (0.51)
% Bachelor degree	12.77 (0.22)	14.37 (0.55)
% Graduate degree	6.83 (0.15)	7.65 (0.40)
Employment rate	92.85 (0.13)	92.03 (0.30)
% Receiving public assistance	2.54 (0.06)	3.21 (0.16)
% Poverty	22.03 (0.38)	21.01 (0.78)
% Foreign-born	3.34 (0.16)	9.03 (0.94)
Rural/urban designation	4.65 (0.063)	4.19 (0.155)

Median income ($)	58331.41 (494.52)	62958.97 (1570.54)
GINI (0 – 1)**	0.44 (0.001)	0.45 (0.003)
Democratic counties	90 (14.42%)	26 (4.17%)
Republican counties	416 (66.67%)	92 (14.74%)
Access to care		
% Children under 19 with health insurance	94.60 (0.20)	95.46 (0.24)
% Public health insurance	42.19 (0.51)	42.35 (1.05)
% Private health insurance	57.63 (0.52)	58.07 (1.12)
Primary care providers (per capita)	58.61 (1.42)	61.16 (3.21)
Local health departments		
% Immunizations	91.61 (1.40)	90.32 (3.08)
% Prenatal care	26.37 (2.25)	31.58 (4.79)
% WIC	60.51 (2.46)	74.47 (4.52)
% MCH visits	58.64 (2.62)	89.01 (3.29)
% Well child clinics	26.58 (2.27)	47.87 (5.18)
% Communicable disease surveillance	93.69 (1.22)	90.53 (3.02)
% MCH surveillance	61.42 (2.49)	83.87 (3.83)

*M = mean, SE = standard error
**measure of income inequality

Table 2

Linear regression analysis for community variables on county-level toddler immunization completion (N = 624)

Community	*β*	*SE*	*Z*	*p*
Total population	4.26e-09	9.94e09	0.43	0.67
Percent of population under 5 years	-1.88	0.59	-3.17	0.002**
Race				
White	-0.18	0.59	-1.82	0.07
Black	-0.05	0.11	-0.48	0.63
Asian	0.92	0.35	2.62	0.001**
Ethnicity				
Hispanic	0.58	0.16	3.73	0.0001***
Education				
No highschool	3.12	5.16	0.60	0.55
Highschool	2.86	5.16	0.55	0.58
Some college	2.77	5.17	0.54	0.59
Bachelor degree	2.83	5.18	0.55	0.59
Graduate degree	2.75	5.15	0.53	0.59
Other				
Employment rate	0.14	0.23	0.60	0.55
Median income	1.01e-06	8.75e-07	1.15	0.25
Public assistance	-0.40	0.36	-0.95	0.34
GINI^	0.22	0.18	1.19	0.23
Poverty rate	-0.24	0.09	-2.57	0.01**
Foreign-born	-0.97	0.38	-2.54	0.01**
Rural/urban	0.004	0.004	1.10	0.27
Democratic counties	-0.05	0.01	-3.90	0.0001***
State	-0.01	0.002	-6.07	0.0001***
Year				
2016	-0.02	0.02	-0.80	0.426
2017	-0.22	0.02	-9.59	0.0001***
Toddler definition	0.04	0.01	6.05	0.0001***
Survey	0.059	0.013	4.62	0.0001***
Regression Equation Summary Measures				
AIC	-1.788			
Loglikelihood	582.827			

*p-value < 0.05, **p < 0.01, ***p < 0.001

^ Measure of income inequality scored from 0 to 1

Table 3

Linear regression analysis for access to care variables on county-level toddler immunization completion (N = 624)

Access to Care	*β*	*SE*	*Z*	*p*
Public health insurance	-0.18	0.07	-2.56	0.01**
PCP per capita	-7.24e-06	0.0001	-0.04	0.97
Year				
2016	-0.03	0.02	-1.64	0.10
2017	-0.24	0.02	-12.90	0.0001***
State	-0.01	0.002	-7.27	0.0001***
Toddler definition	0.04	0.01	6.27	0.0001***
Survey	0.07	0.01	7.05	0.0001***
Regression Equation Summary Measures				
AIC	-1.796			
Loglikelihood	561.572			

*p-value < 0.05, **p < 0.01, ***p < 0.001

Table 4

Linear regression analysis for local health department variables on county-level toddler immunization completion

	β	*SE*	*t*	*p*
Immunizations	-0.003	0.02	-0.17	0.86
Prenatal care	-0.003	0.01	-0.31	0.76
WIC	0.03	0.01	2.23	0.03*
MCH visits	0.02	0.01	1.28	0.21
Well child clinics	0.02	0.01	1.94	0.05*
Communicable disease surveillance	-0.06	0.02	-2.76	0.01**
MCH surveillance	0.001	0.01	0.09	0.93
% White	-0.02	0.04	-0.53	0.60
% Hispanic	0.20	0.05	3.77	0.0001***
Less than college education	0.24	0.08	2.75	0.01**
Median income	2.27e-06	6.00e-07	3.78	0.0001***
Survey	0.06	0.01	4.84	0.0001***
Year				
2016	-0.01	0.02	-0.36	0.72
2017	-0.20	0.02	-9.61	0.0001***
Toddler definition	0.04	0.01	7.20	0.0001***
State	-0.14	0.002	-7.84	0.0001***

*p-value < 0.05, **p < 0.01, ***p < 0.001

Note: chained logistic multiple imputation with 10 samples was used to address the missing data for the LHD variables

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Chapter 4: Exploring the Association between State Policy and County-Level Toddler Immunization

Abstract

Many states are debating how best to address the recent outbreaks of vaccine-preventable diseases. However, much of this debate focuses broadly on the state level and misses the variation among counties. Additionally, the debate often focuses on school children instead of younger children, such as toddlers. **Aim.** This paper examines the relationship between immunization-related state policies and county-level toddler immunization completion. **Methods.** A cross-sectional sample of 624 counties from 10 states was used in this exploratory analysis of secondary data for toddler immunization completion. Toddlers, aged 19 to 35 months, are considered completely immunized if they have received all the vaccines recommended by the Advisory Committee on Immunization Practices (ACIP) for their age. To examine the contribution of immunization exemption laws and Medicaid expansion on county-level toddler immunizations, a hierarchical regression was performed with state as the grouping variable. **Results.** States that expanded Medicaid had lower county-level toddler immunization completion than states that did not expand Medicaid. Compared to states that only allowed medical exemption, states that either permitted medical and religious exemptions or medical, religious, and personal belief exemptions (PBE) had lower county-level toddler immunization completion. **Conclusion.** The results indicate that state policies are important factors that influence county-level toddler immunization completion, but more local-level factors should also be considered.

Keywords: vaccination, immunization, toddler, county, immunization law, state policy

Exploring the Association between State Policy and County-level Toddler Immunization

Before the U.S. began a measles vaccination program in 1963, between 3 and 4 million Americans were diagnosed with measles annually, and of the infected individuals, approximately 500 died (Centers for Disease Control and Prevention and Prevention, 2018). Before 2016, measles vaccination rates were relatively stable in part due to the Vaccines for Children (VFC) program, which made the measles-mumps-rubella (MMR) vaccine more accessible (CDC, 2016). However, as of November 2018, the World Health Organization (WHO) reported a 30% increase of confirmed cases of measles worldwide since 2016 (World Health Organization, 2018). In fact, the U.S. has had the most confirmed cases of measles in 2019 since the disease was declared eliminated nationwide in 2000 (CDC, 2019).

Currently, the ACIP recommends two doses of the MMR vaccine, one dose at 12-15 months and the second between 4-6 years. However, toddler (age 19 – 35 months) vaccination rates vary wildly (Public Health Activities and Services Tracking, 2017a). Some counties in the U.S. report toddler immunization completion as low as 26%, while other counties report toddler immunization completion above 90% (PHAST, 2017a). Low vaccination rates are one of the underlying factors contributing to the resurgence of measles (Nathanson, 2016), and today the majority of people who contract measles in the U.S. are unvaccinated (CDC, 2019). Thus, if vaccination rates were improved, cases of measles would decrease.

Great gaps exist in the science and literature regarding how public health professionals in state and local health departments, as well as policy leaders, can more effectively change systems to improve toddler immunization completion. This gap reflects our limited understanding of the multiple factors that affect toddler immunization completion. Generally, the focus of political epidemiology—the study of how politics shapes health outcomes—has focused on self-reported

health outcomes and mortality (Smith & Dorling, 1996; Subramaniam, Huijts, & Perkins, 2009; Subramaniam & Perkins, 2010). Two epidemiological studies focusing on immunization were identified. The first study examined individual political ideology and attitudes about vaccination (Baumgaertner, Carlisle, & Justwan, 2018). The authors found that "conservative individuals" were less likely to express pro-vaccine beliefs than their more "liberal" counterparts (Baumgaertner et al., 2018). Conservative and liberal were labels developed by the authors based on self-report on a political ideology scale (Baumgaertner et al., 2018). The second study looked at the association between population-based voting trends in the 2016 presidential election and adolescent vaccination rates (Suryadevara, Bonville, Cibula, Domachowske, & Suryadevara, 2019). These authors argued that because politics play a role in the dissemination of public health information, there is an association between vaccination rates and voting patterns (Suryadevara et al., 2019). States were classified in their study as either Democratic or Republican based on which U.S. presidential candidate received the most votes in that state (Suryadevara et al., 2019). They found that human papillomavirus (HPV) vaccination rates, an adolescent immunization that protects against sexually transmitted infections, were associated with state-wide voting patterns. Republican states had significantly lower unadjusted HPV vaccines series initiation and completion rates than Democratic states, yet Republican and Democratic states had similar rates of TdaP (tetanus, diphtheria, and pertussis) and meningococcal vaccinations (Suryadevara et al., 2019).

More information about the influence of policies and political ideology on vaccination is needed, considering the amount of time and money spent on lobbying and debating vaccine policies. For example, on January 25, 2019, House Bill 1638 was introduced to the Washington State Legislature to eliminate the MMR philosophical exemption—an exemption that permits

students to attend school without a required vaccination based on personal or moral beliefs rather than medical or religious grounds (Harris et al., 2019). When HB 1638 was in committee, 700 opponents filled multiple hearing rooms to express their dissent (Sun & Young, 2019). One interviewee explained that vaccine opponents will not abide by this bill; instead, they will move out of state or "go underground" (Sun & Young, 2019). However, opinions regarding vaccines are more nuanced than initially thought (Brunson & Sobo, 2017; Carrion, 2018), and immunization policies should account for this nuance.

Affordable Care Act

Through the Affordable Care Act (ACA), nearly 30 million people across the U.S. gained health insurance as a result of tax credits, expanded Medicaid eligibility, and insurance market regulation (Blumenthal, 2017). Due to a Supreme Court ruling, Medicaid expansion was deemed optional for states (Centers for Medicare & Medicaid Services, 2018; Kaiser Family Foundation, 2012). As of 2018, 32 states and the District of Columbia had expanded Medicaid, meaning the income level at which people qualify for Medicaid increased (Kaiser Family Foundation, 2012). In addition to improving access to care through health insurance, the ACA also had a provision that eliminated cost-sharing with patients for all ACIP-recommended vaccinations (Kaiser Family Foundation, 2015). Despite this, no literature was identified examining the relationship between toddler immunization and the ACA. However, there are a few studies about the association between the HPV vaccine and the ACA (Corriero, Gay, Robb, & Stowe, 2018; Lipton & Decker, 2015). These studies found an association between HPV vaccine uptake and the implementation of the ACA (Corriero et al., 2018; Lipton & Decker, 2015).

Immunization Exemption Laws

Jacobsen v. Massachusetts (1905) is a landmark case regarding state power and personal liberties in which the Supreme Court upheld a city's authority to require vaccination during an epidemic (Mariner, Annas, & Glantz, 2005). Similarly, in *Zucht v. King* (1922) the court upheld a city ordinance that prohibited children from attending school without a certificate of smallpox immunization (Mariner & Annas, 2014). These and other cases have continued to uphold the state's power to enforce mandatory vaccines (Calandrillo, 2004). However, these laws are not truly mandatory because they allow for exemptions. All states have medical exemptions that allow students who cannot be vaccinated for medical reasons to attend school without required immunizations. All but three states (Mississippi, West Virginia, and California) permit exemptions based on religious belief, and eighteen states have a PBE that allows families to opt out for a variety of reasons (National Conferences of State Legislatures , 2017). Because not all children attend licensed daycares or preschools where vaccination is required, the legal pressure to immunize toddlers is not sufficient to assure the high vaccination rates required to prevent vaccine-preventable disease outbreaks.

State Political Composition

Vaccine policies have the possibility of unintended, negative consequences for vaccine policy decisions. For example, the removal of thimerosal from vaccines in 1999 intended to improve public confidence; instead, this decision called into question the safety of other vaccine ingredients (CDC, 2000; Opel & Marcuse, 2013). Additionally, when California eliminated non-medical exemptions for the 2016-2017 school year, the use of medical exemptions increased by about 0.4% (Delamater, Leslie, & Yang, 2017). Although a small increase, medical exemption use in California had been relatively stable for about twenty years, and these increases were

concentrated in areas with previously high uses of personal belief exemptions, indicating that the policy might be doing little to change the behavior of truly vaccine hesitant parents (Delamater et al., 2017).

The American Academy of Pediatrics, the American Medical Association, and the American College of Physicians all call for the elimination of non-medical exemptions from state school-entry immunization laws (Goldstein, Suder, & Bendistis, 2017). However, one barrier to the removal of non-medical exemptions is that the legislation must be written and voted into law (Goldstein et al., 2017). Currently in the U.S. there is strong opposition to vaccination within a small but vocal segment of the population. Many states have groups of residents that lobby to prevent the strengthening of vaccine laws (Evrony & Caplan, 2017). This is particularly challenging because state-level voting patterns have been associated with adolescent immunizations (Bernstein, North, Schwartz, & Niccolai, 2016; Suryadevara et al., 2019). Therefore, any law associated with vaccination may be subject to strong constituant backlash that may disuade legislators from proposing this type of legislation. Thus, the political composition of the state legislature may be extremely relevant in terms of when and which types of vaccine laws are introduced.

Other Factors

Unfortunately, despite a plethora of research supporting the safety, efficacy, and effectiveness of vaccines (Dales, Hammer, & Smith, 2001; DeStefano, Bhasin, Thompson, Yeargin-Allsopp, & Boyle, 2004; Gerber & Offit, 2009; Madsen et al., 2002; Parker, Schwartz, Todd, & Pickering, 2004; Taylor, Swerdfeger, & Eslick, 2014; Uno, Uchiyama, Kurosawa, Aleksic, & Ozaki, 2015), vaccines continue to remain controversial, and as a result, families may be hesitant to vaccinate their children (Poland, 2011). Lowered immunization rates or delayed

immunizations are associated with a variety of family characteristics. Although many of these characteristics cluster within populations and vary by county, the characteristics of un- or under-immunized children in the U.S. may include race and ethnicity, socioeconomic status, and parental educational attainment; but the relationship between these family characteristics and immunization rates is unclear because of inconsistent study results. Sometimes only ethnicity and not race, for example, has an effect (Hambidge et al., 2006), but other studies find that race is associated with immunization rates (Dominguez, Parrott, Lauderdale, & Daum, 2004; Smith & Stevenson, 2008). This may be because broad racial groups over-shadow subgroup differences. When ethnicity had an effect, the study results contradicted each other. One study found that Hispanic children had the highest immunization rates (Hambidge et al., 2006), whereas another study found that they had the lowest (Rosenthal et al., 2004).

Regarding socioeconomic status and parental education levels, both higher and lower levels of education and income have been found to be associated with lowered immunization rates or delayed vaccination (Larson, 2014; MacDonald, 2015). The cause of this inconsistency is unclear, but there may be some geographic variations that influence this inconsistency. For example, geographic and contextual factors such as the income range in the area, the racial-ethnic composition, and population density were associated with the initiation of the HPV vaccine (Henry, Stroup, Warner, & Kepka, 2016).

Few studies were identified that explored the influence of state policies on toddler immunization completion at the county-level. Immunization legislation is generally implemented at the state level, but the wide variation in county-level toddler immunization completion within and between states (PHAST, 2017a) indicates that some counties benefit more from state policies than others. Developing an understanding of the interaction between state and county could help

eventually clarify the variation among counties. To begin to address the interaction between states and counties, this study explores relationships among county-level toddler immunization coverage and state policies and state political composition, also taking other community and population factors into account.

Methods

This exploratory study uses cross-sectional secondary data to 1) understand the hierarchical nature of county-level toddler immunization data, and 2) explore the association between county-level toddler immunization completion and Medicaid expansion and school immunization exemption laws. A comprehensive dataset was created for this study using county-level and state-level variables from publicly available sources.

Data

County-Level Covariates

Covariates included in this analysis were obtained from the 2015 American Community Survey (ACS) and include race, ethnicity, education, and income (Table 1). These covariates were selected for inclusion at the county-level because of previous literature associating them with vaccine-hesitant families (Dominguez et al., 2004; Hambidge et al., 2006; Henry et al., 2016; Larson, 2014; MacDonald, 2015; Poland, 2011; Rosenthal et al., 2004; P. J. Smith & Stevenson, 2008).

State-Level Predictors

The two policy predictors used were Medicaid expansion and state immunization exemption laws. Medicaid expansion was established as a binary variable defined as whether each state adopted an expansion of access to health insurance after the ACA passed in 2010. Of the states that expanded Medicaid, all but one expanded in 2014; Indiana expanded Medicaid in

2015. Data regarding Medicaid expansion were obtained from the Kaiser Family Foundation (2018). School immunization exemption laws represent types of exemptions that permit children to attend daycare or school without all required vaccines: medical, religious, and PBE. Aside from California, West Virginia, and Mississippi (the only state to review medical exemptions for appropriateness), all states have a combination of either medical and religious exemptions or medical, religious, and PBE (Table 2). A categorical variable (medical exemptions, medical/religious exemptions, and medical/religious/PBE) was established using exemption law data obtained from the National Conferences of State Legislatures (NCSL 2017).

Data about state partisan composition were obtained from NCSL (2019). A categorical variable for legislative control was created with categories representing Democrat, Republican, or divided (i.e. the two legislative houses were under control of different political parties).

Outcome Variable

County-level toddler immunization completion (generally defined as children aged 19 to 36 months completing the ACIP-recommended vaccines on time) data are not typically available through any single source, but the Public Health Activities and Services Tracking (PHAST) team at the University of Washington School of Nursing obtained and compiled these data from state websites and state-level immunization staff (Table 1) who provided summaries of toddler immunization completion at the county-level either through online immunization information systems (IIS) or by random surveys of patients and/or providers (PHAST, 2017b). Most states in the PHAST dataset use IIS data (Alabama, Maine, New York, Indiana, Iowa, Kentucky, Minnesota, Oregon, Utah, Washington, and Wisconsin), but a few states (California, New Mexico, Florida, Tennessee, and West Virginia) use randomized surveys (PHAST, 2017b). In addition to how states collected toddler immunization completion data, states also varied in their

definition of toddler (PHAST, 2017b). Most states defined toddler as between 19 and 35 months, except for California, which defined toddler as a child between the ages of 24 and 59 months (Table 1). Finally, California also used a slightly different vaccine schedule to determine toddler immunization completion (Table 1); unlike the other states, California does not require 4 doses of the PCV for a child to be considered complete (PHAST, 2017b).

Sample

A cross-sectional sample of 624 countries from 10 states was selected according to the availability of toddler immunization data for the years 2015, 2016, or 2017 via the PHAST Immunization Dashboard (PHAST, 2017a). If a state in the dashboard had 2016 data, then that year was used in the statistical analysis. If the state did not have data in 2016, but had data in 2015 or 2017, data from 2017 were used. If the state only had data available in 2015, then 2015 data were used. The goal was to create a sample large enough for hierarchical regression analysis while using the most current data available.

Statistical Analysis

To explore the association between state policies, state political composition, and county-level toddler immunization completion, a mixed linear model was used to account for the possibility that counties within each state were correlated with each other. The levels were county (level 1) and state (level 2). Model fit was assessed using Likelihood Ratio Tests. The null hypothesis was that there was no relationship between state politics and policies and toddler immunization completion.

Results

Descriptive Analysis

State- and county-level characteristics are described in Table 2. The average toddler immunization completion by county varies across the 10 states (Figure 1). Among the 10 states, counties in California had the highest percent of toddlers with completed immunizations (88.3 ±0.8), but state regulations require the fewest immunization and expanded the definition of toddler to include children up to 5 years of age. Counties in Wisconsin reported the lowest percent of toddlers with completed immunizations (51.2±1.9). California, Iowa, Indiana, Oregon, Washington, and West Virginia expanded Medicaid (Table 2). West Virginia has the strictest immunization policies, only permitting medical exemptions for immunizations required for daycare and school. Maine, Oregon, Washington, and Wisconsin were the most permissive states in the sample, allowing medical, religious, and PBE (Table 2). In 2016, four states were controlled by Republican legislatures, two were controlled by Democratic legislatures, and four legislatures had divided control (Table 2).

Inferential Analysis

All analyses controlled for county and state characteristics associated with immunization rates (labeled county-level and data covariates; Table 3). First, a likelihood ratio test—used to compare the single-level model with the multilevel model—showed that the grouping according to states significantly improved the fit of the model ($\chi^2 = 58.40$, $p < 0.001$). Next, an intercept-only model was used to test for variance among states. The intra-class correlation (ICC) was 0.57, which means that 57% of the variability among counties was due to state characteristics. Next, a mixed linear model with random intercepts and fixed slopes was used to further explore the relationships between state policies, state political composition, and county-level toddler

immunization completion. This analysis resulted in an extremely low ICC (1.32e-14). The change in ICC from 0.57 in the intercept-only model to essentially zero in the full model demonstrates that the variables included in the full model are accounting for the variation seen among states. For Medicaid expansion and immunization exemption laws, the null hypothesis was rejected, demonstrating an association between county-level toddler immunization completion and state policies (Table 3). States that expanded Medicaid had lower county-level toddler immunization completion than states that did not expand Medicaid (β = -0.29, p < 0.0001). Compared to states with the most restrictive immunization exemption laws, states that permitted both medical and religious exemptions—which are considered moderately permissive—had lower county-level toddler immunization completion (β = -0.47, p < 0.001). Compared to states with restrictive immunization exemption laws, states that were most permissive (allowed medical, religious, and PBE) had lower county-level toddler immunization completion (β = -0.68, p < 0.001). For political composition, state legislatures controlled by the Republican Party (β = 0.08, p = 0.001) or with split political control (β = 0.172, p < 0.001) had higher county-level toddler immunization completion than state legislatures controlled by the Democratic Party.

Discussion

This study explored the association between state policies, state political composition, and county-level toddler immunization completion. This multilevel analysis using county and state data found the significant predictors of county-level toddler immunization completion were Medicaid expansion, school immunization exemption laws, and state political composition represented by political party in control of the state legislature.

The results indicate that states that expanded Medicaid had lower average county-level toddler immunization completion than states that did not expand Medicaid. This finding would seem counterintuitive given the expectation that Medicaid expansion would increase access to care, which would theoretically result in improved immunization rates. However, this could be due to the cross-sectional nature of this study; it cannot be determined if states expanded Medicaid because of already existing concerns regarding low toddler immunization completion. Furthermore, Medicaid expansion was implemented starting in 2014; there simply may not have been enough time to measure an effect. Additionally, there were already two federal programs in place to improve access to immunizations: VFC and the Children's Health Insurance Program (CHIP). These programs were intended to address economic barriers to accessing healthcare and prevention services (Joyce & Racine, 2003; Lykens & Jargowsky, 2002; Wolfe & Scrivner, 2005).

VFC became operational in 1994 and was created partially in response to the 1989 – 1991 measles epidemic that resulted in several tens of thousands of cases and hundreds of deaths (Mitchell, Philipose, & Sanford, 1993). The goal of VFC is to encourage higher immunization rates by providing vaccines to the children of parents or guardians who are unable to afford immunizations (CDC, 2016). Children are eligible for VFC if they are under the age of 19 years and are Medicaid eligible, uninsured, Native American or Alaska Native, or underinsured (only eligible to receive VFC vaccines through Federally Qualified Health Centers or Rural Health clinics). To provide free vaccines to eligible children, the CDC buys discounted vaccines and distributes them to state health departments, which then redistribute the vaccines to providers who are registered as VFC program providers (CDC, 2016).

CHIP was created by the Clinton administration in 1997 (Centers for Medicare & Medicaid Services, 2017). The program is designed to cover children who are not Medicaid eligible because their parents' income is too high, but who are uninsured because private health insurance is unaffordable. The states and the federal government jointly fund CHIP, which is administered by each state following a set of federal government requirements (Centers for Medicare & Medicaid Services, 2017). The combination of these existing programs prior to Medicaid expansion may have already made immunizations widely-accessible such that Medicaid expansion did not have a positive impact on immunization rates.

Although state policies and political composition influence county-level toddler immunization completion, the 43% of the variability among counties in this study is not fully accounted for by state characteristics. Instead, there may be many other factors that affect county-level toddler immunization completion. Toddler immunization completion thus remains a multifaceted issue that needs further research to consider the complexity of the state politics and county characteristics that may be barriers or mitigators. County-specific interventions are likely required to address county-level toddler immunization completion. Thus, knowing the location and characteristics of low immunization clusters could help with the design, implementation, and evaluation of public health interventions. Further understanding these issues is critical to effectively increasing toddler immunization completion and eliminating the growing number of vaccine-preventable outbreaks in the U.S.

Limitations

Although this study is among the first of its kind to examine county-level immunization completion for toddlers, there are limitations. This study does not delineate between toddlers who are completely unvaccinated and those who have received some of the recommended

vaccines. This is an important consideration for future studies to help further tailor community public health interventions. Such evidence would support provider recommendations and population-level messaging to effectively educate and advise people who are hesitant but willing to consider vaccination.

Additionally, there are variations in the methods states U.S. for data collection, the definition of toddler, and required vaccines. Although statistical analysis can account for these variations, it should be noted that this makes comparison across states challenging. However, now that all 50 states have online immunization systems (New Hampshire Department of Health and Human Services, 2016) some of this variation may be reduced in future studies.

Conclusions

With outbreaks of vaccine-preventable diseases on the rise, the complex nature of the factors affecting toddler immunization completion needs to be further examined to improve immunization rates. Although state policies are important and appear to account for some of the variation among county-level toddler immunization, these policies are not the whole picture. In fact, future research should include multilevel studies, further acknowledging the interaction between state policies and state characteristics. Researchers, policy makers, and public health professionals need to better understand the complexities and variation of local-level characteristics in county-level toddler immunization completion to increase the immunization coverage and prevent costly, deadly outbreaks.

Table 1

Difference in county-level toddler immunization data sources and definitions by state

State	Data collection	Toddler definition	Immunization series*	Year
Alabama	IIS	19-35 months	4:3:1:3:3:1:4	2017
California	Survey	24-59 months	4:3:1:3:3:1	2015
Iowa	IIS	24 months	4:3:1:3:3:1:4	2016
Indiana	IIS	19-35 months	4:3:1:3:3:1:4	2016
Maine	IIS	24 months	4:3:1:3:3:1:4	2016
Oregon	IIS	24 months	4:3:1:3:3:1:4	2015
Tennessee	Survey	24 months	4:3:1:3:3:1:4	2016
Washington	IIS	19-35 months	4:3:1:3:3:1:4	2016
Wisconsin	IIS	24 months	4:3:1:3:3:1:4	2016
West Virginia	Survey	24-35 months	4:3:1:3:3:1:4	2017

*4:3:1:3:3:1 is 4 DTaP: 3 Polio: 1 MMR: 3 Hib: 3 HepB: 1 VZV. 4:3:1:3:3:1:4 adds 4 PCV to the series

Table 2

Description of state-level and county-level characteristics by state

	AL M (SE) [n*=67]	CA M (SE) [n=58]	IA M (SE) [n=99]	IN M (SE) [n=92]	ME M (SE) [n=16]	OR M (SE) [n=36]	TN M (SE) [n=95]	WA M (SE) [n=39]	WI M (SE) [n=72]	WV M (SE) [n=55]
Outcome variable										
% complete for toddlers in county	52.4 (1.5)	88.3 (0.8)	64.0 (0.9)	70.5 (0.9)	74.9 (2.4)	68.9 (1.2)	75.9 (0.7)	54.7 (1.9)	51.2 (1.9)	69.9 (0.9)
State Explanatory variables										
Medicaid Expansion (year of expansion)	No	Yes (2014)	Yes (2014)	Yes (2015)	No	Yes (2014)	No	Yes (2014)	No	Yes (2014)
Immunization Exemption Law** (2016)	R+M	R+M	R+M	R+M	P+R+M	P+R+M	R+M	P+R+M	P+R+M	M
Legislative Control (2016)	Republican	Democrat	Divided	Republican	Divided	Democrat	Republican	Divided	Republican	Divided
County Covariates										
% White	67.4 (2.7)	74.8 (1.7)	93.5 (0.6)	94.8 (0.4)	95.4 (0.4)	88.9(0.93)	88.9 (1.2)	84.6 (1.2)	95.4 (0.4)	91.8 (1.3)
% Black	28.7 (2.9)	3.2 (0.4)	2.6 (0.4)	1.4 (0.1)	0.8 (0.1)	0.8 (0.2)	7.3 (1.1)	1.5 (0.3)	2.4 (0.3)	1.6 (0.4)
% Hispanic	3.2 (0.4)	30.1 (2.4)	3.7 (0.4)	4.4 (0.4)	1.4 (0.1)	11.9 (1.5)	3.3 (0.2)	13.7 (2.3)	1.2 (0.1)	3.5 (0.3)
% Low Education	83.1 (0.1)	74.1 (1.5)	81.5 (0.8)	79.3 (0.6)	73.9 (1.9)	76.9 (1.6)	83.7 (0.7)	75.5 (1.4)	84.1 (0.8)	77.9 (0.8)
% High Education	16.9 (0.9)	25.9 (1.5)	18.5 (0.8)	20.7 (0.7)	26.1 (1.9)	23.1 (1.6)	16.3 (0.8)	24.5 (1.4)	15.9 (0.8)	22.2 (0.9)
Median Income ($)	50068.4 (1215.23)	69379.49 (2537.28)	60934.69 (957.59)	65134.90 (779.59)	60188.81 (2236.16)	57857.91 (1669.45)	50844.72 (1059.29)	63347 (1704.92)	51433.31 (1149.16)	64482.19 (1215.19)
Democratic Counties	12	28	1	11	1	13	0	9	16	25
Republican Counties	55	29	98	79	15	21	95	30	56	30

*number of counties in each state

**M = medical exemption, R = religious exemption, P = philosophical or personal belief

Table 3

Fixed effect results of linear mixed model analysis on county-level toddler immunization completion

	β	*SE*	*Z*	*p*
State covariates				
Legislative control				
GOP	0.08	0.02	3.30	0.001***
Split	0.17	0.03	5.07	0.0001***
Medicaid expansion	-0.29	0.04	-6.60	0.0001***
Immunization exemption				
Religious & medical	-0.47	0.11	-4.42	0.0001***
Religious, medical, and PBE	-0.68	0.13	-5.15	0.0001***
County covariates				
% White residents	-0.002	0.04	-0.05	0.958
% Hispanic residents	0.25	0.03	4.87	0.0001***
% Below college education	-0.16	0.08	-2.01	0.04*
Median income	2.16e-06	5.5e-07	3.92	0.0001***
Democratic counties	-0.03	0.01	-3.01	0.003**
Data covariates				
Survey	-0.12	0.03	-3.80	0.0001***
Year of data collection	-0.39	0.05	-7.82	0.0001***
Definition of toddler	-0.02	0.01	-1.79	0.074

*p-value < 0.05, **p < 0.01, ***p < 0.001

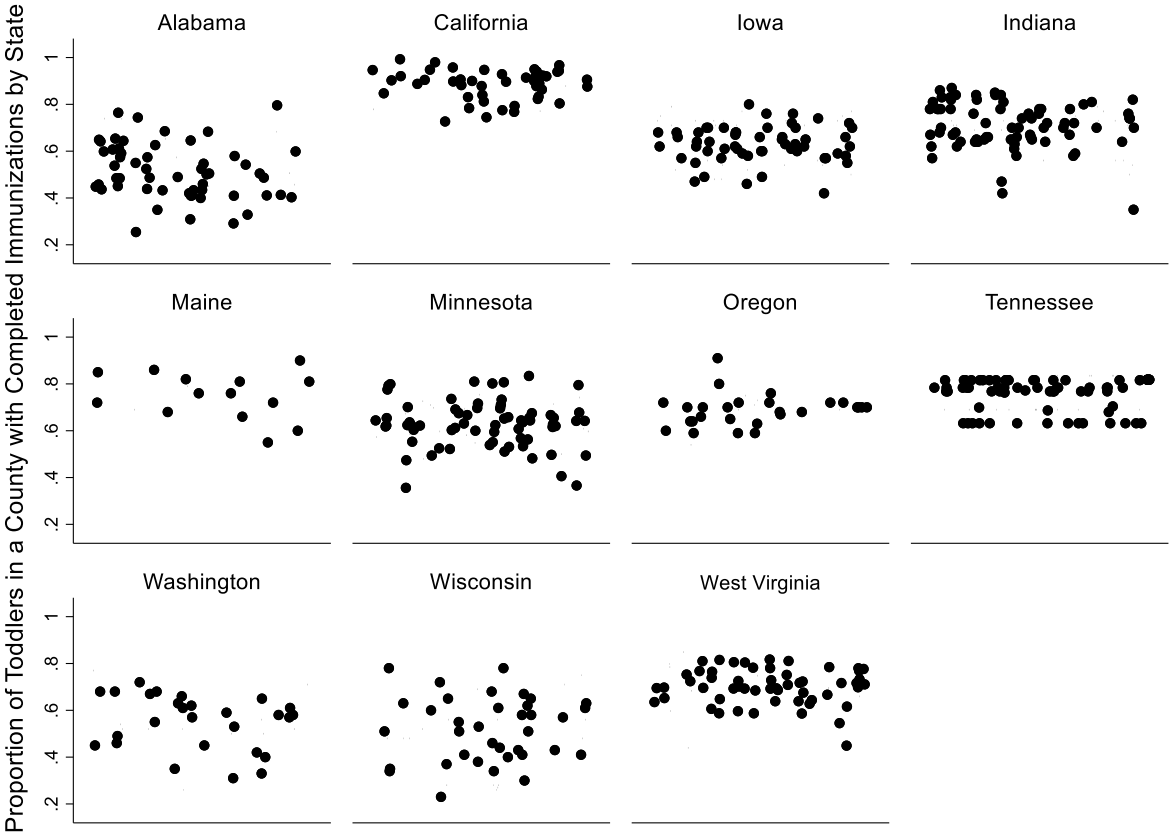

Figure 1. Variation of county-level toddler immunization completion by state
Note: California defines toddler (19 to 59 months) differently than the other states and requires fewer immunizations for toddlers to achieve completeness.

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Chapter 5: Conclusion

With the increase in vaccine-preventable disease outbreaks, addressing lowered immunization rates is essential (Centers for Disease Control and Prevention, 2018, 2019a, 2019b; World Health Organization, 2019). The overall objective of this dissertation was to examine vaccination rates through a socioecological framework that supports the development of research on the individual, county, state, and federal levels. This dissertation was particularly intended to address gaps in the literature about the poorly understood local factors associated with toddler immunization completion at the county-level and help guide practical responses to improving immunization rates. Therefore, the scope of this research included county and state data to begin to develop an evidence base to help public health professionals and policy makers identify at-risk communities and select appropriate interventions. Together these three research papers demonstrate that there are county and state factors that influence county-level toddler immunization completion, indicating that a socioecological framework for improving immunization rates is appropriate and important.

Aims

The overall objective of this dissertation was separated into three aims that were accomplished in each of the three previous papers. This study intended to:

1. Identify a theoretical framework to support the multifaceted nature of toddler immunization completion research.
2. Describe the characteristics of counties with high and low toddler immunization completion.
3. Explore the relationship between county-level toddler immunization completion and immunization-related state policies.

Theoretical Framework

Bronfenbrenner (1979) developed the ecological systems theory to understand human development in the context of environment. The ecological systems theory (Bronfenbrenner, 1979) was identified and reformulated for toddler immunization completion using work from Rose (1985). The reformulation was required because Bronfenbrenner (1979) focuses on the individual rather than a population health concern such as immunization. This reformulation served two purposes for vaccine research. First, it demonstrated the multilayered nature of vaccination. Second, it provided a framework in which to situate current vaccine research to better identify research gaps.

County

One of the gaps in vaccine literature is a thorough understanding how local factors influence county-level toddler immunization completion. This gap is partly because the wide variation among county-level toddler immunization completion is often masked using federal or state data. However, cases of vaccine-preventable diseases are often clustered geographically (Lieu, Ray, Klein, Chung, & Kulldorff, 2015), and there are communities where non-medical exemptions are used more frequently (Omer, Enger, Moulton, Halsey, Stokley, & Salmon, 2008). In this study, the county characteristics that were positively associated with county-level toddler immunization completion included the percent of county residents with health insurance, and whether local health departments (LHDs) directly provided The Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) and well child clinics. County characteristics negatively associated with toddler immunization included the percent of county residents under the age of 5 years, who were living in poverty, were foreign born, or had public health insurance, whether the LHD directly provided communicable disease surveillance, and if a

county had more Democratic than Republic voters in the most recent gubernatorial election. These findings demonstrate that there are county characteristics associated with toddler immunization completion, thus beginning to fill the gap in the science. By understanding the characteristics of counties with high and low toddler immunizations, communities may be identified before outbreaks occur. It is very costly and traumatic to a community to contain an outbreak of a vaccine-preventable disease; thus, preventing outbreaks by focusing on immunization promotion efforts is preferable.

Interaction between County and State

Very few studies about vaccines use a socioecological approach. This study is among the first of its kind to explore the interaction between two socioecological levels: the association between state legislature political composition and immunization-related state policies with county-level toddler immunization completion. This study found that state policies were associated with toddler immunization completion at the county-level, but it did not explain all the variation among counties. This finding suggests that, although state immunization policies are important, they cannot be the only way to address low toddler immunization completion. This result further supports the importance of a socioecological perspective, addressing toddler immunization completion at all levels.

Limitations

States collect county-level toddler immunization completion data differently, including the age range of toddlers included and which vaccines are required. Although statistical analysis can control for these variations, it should be noted that this makes comparison across states challenging. Now that all 50 states have online immunization systems (New Hampshire

Department of Health and Human Services, 2016), some of this variation may be reduced in future studies.

From a socioecological perspective, culture, norms, and values could have a great deal of influence on immunization rates. Counties in geographic proximity could have more similar values than counties that are more distant. Geography would be especially important to consider for counties on state borders. Including a measure of spatial autocorrelation would be important for future research.

Conclusion

Using a socioecological framework is an innovative way of addressing immunization concerns. This study used rare toddler immunization data to highlight and examine the variation across counties. The data compiled and the socioecological framework established supported a unique and critical examination of the growing problem of under-immunization among young children. These dissertation findings revealed that public health and policy leaders can potentially predict and meaningfully focus their prevention and vaccine promotion efforts by working with communities at particularly high risk. State policies related to immunization, such as Medicaid expansion and immunization exemption laws, were also found to be an important part of addressing low immunization rates, but these policies are insufficient to address the problem of low toddler immunization completion. The overall implications for practice are that local-level county and state characteristics have a relationship with the variation in county-level toddler immunization completion. Understanding these relationships can help researchers, policy makers, and public health professionals take important actions that can help improve immunization rates.

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