Correlates of High Vaccination Exemption Rates Among Kindergartens

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2. Introduction

Modern vaccination programs have arguably had more impact on the health of Americans than any other public health measure, resulting in dramatic decreases in vaccine-preventable diseases (VPD) [1, 2]. Currently, all 50 states in the U.S. require vaccinations upon school entry, though all allow medical exemptions and 48 states offer exemptions for either religious or personal beliefs. Historically, children who did not receive vaccinations were more likely to be part of an underserved population [3-6]. However, parental refusal to vaccinate is emerging as a major contributor to undervaccination [7-10]. In Arizona, the procedure to opt out of vaccination is relatively simple [10]; pre-printed forms are available online or at the school health office and parents need only sign the form to exempt their child from some or all of the vaccination requirements. Over the past decade, personal belief exemptions (PBE) have risen steadily in Arizona; rates in the 2010-2011 school year for exemptions were 14% higher than in 2009-2010, 78% higher than 2005-2006 and 129% higher than in 2000-2001 [11].

The reasons behind vaccination exemptions likely fall into two broad categories: 1) convenience; and 2) parental beliefs regarding perceived susceptibility to VPD and concerns about vaccine safety [12-23]. In states such as Arizona, where the exemption process is straightforward, it may be simpler for parents to sign a waiver than to obtain records or updated vaccinations from their physician. In the other category, parents who intentionally choose not to vaccinate their children have supplied various reasons for doing so. These include concerns that children receive too many vaccines [23, 24], or that they are at risk for adverse events from vaccines [12, 18, 21, 22]. Parents may also question the importance of the vaccines themselves [21, 23], and/or believe VPD can be prevented through "natural" lifestyles, thus precluding the need for immunizations [9, 21]. Previous work has indicated that there may be clusters of individuals that adhere to these beliefs or others and thus refuse to vaccinate [7, 9, 25, 26], making regional differences in vaccine coverage a major public health concern.

Determining the location of exemption clusters and characterizing the populations in which they occur is critical for public health planning. While national surveys have been carried out to characterize individual parents who have concerns over vaccinations [27], there is a dearth of data describing characteristics of higher-risk schools. Like most settings in which groups congregate, schools act as transmission units of infectious disease [9, 28]. The objective of the current work was therefore to evaluate the characteristics of Arizona schools associated with the proportion of kindergarteners with permanent personal belief exemptions at those schools.

2. Methods

2.1. Data sources

Personal belief exemption rates.

Data for PBE were obtained from Arizona's 2010-2011 kindergarten Immunization Data Report (IDR). In Arizona, schools are required to submit an annual IDR for students enrolled in preschool, pre-kindergarten, kindergarten, sixth grade, and tenth grade to monitor compliance with immunization requirements for specific grade entry. The IDR includes kindergarten enrollment, counts of students with permanent PBE, temporary PBE, medical exemptions, and vaccine-specific exemptions for each school. From these data, we derived the permanent PBE rate for kindergarteners in the reporting Arizona schools by dividing the number with permanent exemptions by the total kindergarten enrollment.

Defining school characteristics

Data for school characteristics were collected from publicly-available query data on the National Center of Education Statistics (NCES) website, which includes an overview of all data and its components [29, 30]. For the current work, the following information was collected from NCES: reported enrollment for school; latitude and longitude of school; race/ethnicity of students; district type; classification of urban, suburban, town and rural; and proportion of students who receive free or reduced lunch (FRL). Race/ethnicity was reported by parents and for the current analysis was restricted to white or Hispanic due to small proportions of other reported categories. District types were classified using NCES categories. A traditional public school was defined as a local school district that is not a component of a supervisory union. Charter schools were defined as a school providing free public elementary and/or secondary education to eligible students under a specific charter granted by the state legislature or other appropriate authority, and designated by such authority to be a charter school. Urban/rural classifications were derived by NCES from 2000 U.S Census data[30]. The categories employed for the current analyses were city, suburb, town and rural. Cities were defined as territory inside an urbanized area; while suburbs were territories outside a principal city. Towns were defined as territories inside an urban cluster; and rural territories were defined as being at least 5 miles from a city and at least 2.5 miles from a town. Free and reduced lunch data were available as the count of students school-wide on free or reduced lunch; data for FRL by individual grade were not available. Proportion of students on free or reduced lunch was calculated using school-wide enrollment. FRL data were not calculated if the school did not report either the count of students utilizing free lunches or the count of students enrolled in the reduced lunch program. NCES data were also used to map school location for further analysis in ArcGIS. Regional analyses were conducted by aggregating counties into regions; Central (Gila, Maricopa and Pinal counties), North (Apache, Coconino, Navajo, and Yavapai counties), South (Pima, Santa Cruz, Cochise, Greenlee, and Graham counties) and West (La Paz, Mohave, and Yuma counties).

2.2. Linking processes

Data for the 2010-2011 IDR were obtained from Arizona Department of Health Services. In August 2011, we accessed National Center of Education Statistics (NCES) data for demographic information on public schools with kindergarten enrollment for the most recent school year for which data were available (2009-2010). IDR data were linked to the NCES database through address, phone number, and school name. The scheme of the data merge is shown in Figure 1. The IDR had submissions for 1264 schools with kindergartens, including private and public schools.

2.3. Statistical analysis

Frequencies of permanent personal belief exemptions were calculated and stratified by each explanatory variable. To characterize the Arizona schools with high rates of permanent PBE among kindergarteners, we employed negative binomial regression to account for the distribution of the outcome. Bivariate associations were first calculated between each exposure and outcome. Collinearity was assessed among covariates using a correlation matrix (which did not detect any). The potential for effect modification was explored based on the effects of stratifying the final model and determined by including an interaction terms in the model alongside the other covariates and then comparing the full model to the reduced using the log-likelihood ratio test. The IRR represented the relative increase or decrease in the number of permanent PBE per enrolled kindergartener. All statistical analyses were carried out using SAS 9.2 (Cary, NC) and STATA 12.0 (College Station, TX).

For geospatial analysis and geographical presentation, ArcMap version 10.0 (Redlands, CA) was used. The referencing map for Arizona was the current TIGER/Line® data available through the U.S. Census, which was last updated in 2009 [31]. The geospatial analysis was conducted using Getis-Ord Gi* statistic in ArcMap 10. Getis-Ord Gi* identifies pockets of high and low clusters (or hot spots) by comparing a school's rate to neighboring rates [32]. This statistic was calculated for the state overall, then separately by region to examine localized hot spots that the statewide analysis could not detect. All analysis described in this paper was deemed exempt from human subjects review by the Internal Review Board at the Mel and Enid Zuckerman College of Public Health because the data used were publically available and non-identifiable.

3. Results

Overall, 1025 direct matches between the IDR and the NCES databases were identified, leaving 222 unmatched schools and 7 with unknown PBE information, resulting in the successful linking of 80.5% of Arizona schools to the NCES data. A total of 2,050 (2.7%) of 75,788 kindergarteners in Arizona had a permanent PBE; these students were enrolled in 1,018 kindergartens across the state. Table 1 presents the characteristics of the kindergartens included in the analysis. The PBE rate ranged from 0% to 68% with a median of 1.4%. Of our sample, 215 schools (21%) had PBE rates > 5%, 77 schools (8%) had PBE rates > 10% and 30 schools (3%) had PBE rates >20%. Of the unmatched schools, 198 had permanent PBE information. The PBE rate was 3.2% across the unmatched schools (165 permanent exemptions / 5087 students in the IDR).

To assess the unmatched observations in the IDR we ran the Mann-Whitney U- test on the PBE rate and found no difference (p= 0.2535). Additionally, there were 163 schools in the NCES dataset that were unmatched. We ran Mann-Whitney U-test and χ^2 where appropriate and found a difference between these unmatched schools and matched on the basis of region (p=.042), white proportion (0.02) and agency type (<0.0001). Our population saw more matching in central Arizona, and less in northern Arizona and less charter schools. Furthermore, the unmatched schools had lower rates of white students. Because there was no difference in the PBE rate of the unmatched to matched kindergarten we believe this would have only slightly biased the results towards the null.

The crude and adjusted relationships between demographic characteristics and count of permanent PBE are reported in Table 2. In the fully adjusted model, kindergartens in towns had a 29% lower rate of PBE (95% confidence interval (CI) =0.52, 0.95) compared to cities. The schools with the highest proportion of students reporting white race/ethnicity were over 14 times more likely than those with the lowest proportion to have permanent PBE (IRR=14.11; 95% CI=9.47, 21.03). Charter schools had a significantly greater rate of vaccine exemptions compared to public schools, with over a 2-fold increase (IRR=2.04; 95% CI=1.68, 2.48). Comparing schools with over 75% of students enrolled in FRL to those with under 25% FRL, a 32% decrease in PBE was observed (IRR=0.68 ; 95% CI=0.46-0.84). The study was unable to identify any interaction between proportion of white students and agency type (table not shown, p= 0.63).

The result for the statewide Getis-Ord Gi* statistic is presented in Figure 2, and the result for the same statistic calculated per region is presented in Figure 3. Statewide, 77 of 1,018 schools (7.5%) were included in statistically significant clusters of high PBE rates and 210

(20.6%) were included in statistically significant clusters of low PBE rates. There appeared to be a geographical gradient throughout the state, with PBE rates decreasing from north to south. The identification of PBE clusters by region was somewhat limited in northern Arizona, because PBE rates were relatively uniformly high throughout the region. However, clusters of high PBE rates were detected in the area of Northeast Yavapai County, the city of Sedona, and in Colorado City. In Central Arizona, a pattern was identified in the regional analysis, where PBE clusters occurred more often in the east than the west.

4. Discussion

The results of the current work demonstrate that in Arizona, the highest PBE rates were associated with schools having the greatest proportions of white students and students who do not qualify for free and reduced lunch. Charter schools also exhibited comparatively high PBE rates, while schools in towns had lower rates compared to those in urban environments. Finally, clusters of high PBE in specific geographic regions were identified across the state.

The variable most strongly associated with higher PBE in the present study was the racial/ethnic composition of the school. Schools with the highest proportion of white students had PBE rates 14 times higher than those with the lowest proportion of white students. Our findings support prior studies showing that parents reporting white race have more doubts concerning vaccines [14] and are in general less likely to follow vaccine requirements for school entry [33, 34]. This, coupled with the inverse association between free and reduced lunch and vaccine exemptions, presents a profile in Arizona of PBE rates being more common among white, higher income families. This observation is likely due to a number of factors related to health care and parenting choices. Several physicians and celebrities have advocated for reductions in the number of vaccinations administered, or an alteration of the vaccination schedule [35, 36], and it is possible that the popularity of PBE has been heightened by its wide coverage in popular media [19].

Historically, lower vaccination rates were more often observed in lower-income families who lacked access to care [37, 38]. The present study demonstrates that this group is less likely to actively seek vaccination exemptions in Arizona; rather, schools with higher proportions of students on FRL exhibited a lower rate of PBE. This may be the result intensive efforts by public health agencies to grant families access to affordable vaccines through the Vaccines for Children Program [39, 40]. Our finding of higher PBE rates among higher-income schools is in agreement with other studies that had identified associations between higher income socioeconomic groups and higher rates of children who were unvaccinated [33], had lower vaccine completion rates [34], or selectively vaccination [34]. In contrast, a study conducted in Oregon found that parents obtaining vaccination exemptions were more likely to be living below the poverty line and more likely to be unemployed or looking for work [24]. A national survey has also indicated that parents of lower socioeconomic status may have greater concerns with mandatory vaccination [23], but parental concerns may not translate directly into refusal of vaccines. Therefore, it appears that the characteristics associated with vaccine exemptions may vary by region.

After adjustment, charter schools were associated with higher PBE rates. Per capita, Arizona has the highest number of charter schools in the country [41], and previous work has shown that kindergartners attending charter schools throughout Phoenix, Arizona were over 27 times more likely to be under vaccinated than students in public schools [42]. Although the current work revealed less extreme differences between charter and public schools statewide, it confirms the overall pattern that charter schools have significantly greater proportions of PBE. The higher rate of PBE in charter schools could indicate that parents with alternate beliefs about healthcare are more likely to enroll their children into charter schools. Another possibility relates to the availability of school nurses, who are generally responsible for maintaining vaccination records [43]. Higher PBE rates in charter schools may be a result of fewer resources for full-time school nurses. Schools where nurses are employed, particularly when these nurses strongly support vaccination, are less likely to have high PBE rates [44]. Charter schools have been implicated in measles outbreaks in the past; for example, the index patient for a 2008 measles outbreak in San Diego was an unvaccinated child attending a charter school [9]. Measles transmission first occurred in siblings within the household, then spread to classmates within the school, which had an 11% PBE rate. The outbreak concluded with a total of 48 cases throughout San Diego [9].

In addition to PBE rates varying by the characteristics mentioned above, rates of PBE are highly spatially aggregated in Arizona. As indicated by statewide analysis, the primary cluster of higher PBE rates is in the north central of Arizona. Nonetheless, high PBE rates exist in areas of the broader community as well. Regional analyses identified a notable gradient across the Phoenix metropolitan area, with lower than average PBE rates in the west and higher than average rates in the east. The underlying reasons for higher PBE rates in eastern Phoenix may be different from those in northern Arizona. The demographics in this region mirror what is associated with high school-level rates of PBE, and is likely a good starting point for understanding differences in spatial distribution of PBEs.

High vaccine exemption rates clustered in smaller geographic areas are of great concern for public health officials, as they may be a catalyst for a VPD outbreak[7]. In 2010, a large pertussis outbreak in California resulted in 9154 cases, with a rate of 23.4 per 100,000 persons [45]. In this outbreak, California counties that had higher vaccine exemption rates also had higher pertussis rates. For example, Marin county, with a PBE rate of 7.1% [25], and San Luis Obispo county, with exemptions among 5.2% of children [46], had pertussis rates far higher than California overall, at 138.36 and 137.51 per 100,000,respectively [45]. These pockets must be targeted by local and state officials to either improve vaccination uptake or to employ careful monitoring to identify outbreaks at their onset. While many individuals who choose PBEs perceive their risk of VPD as low, there is likely little knowledge that the community in which they reside may be at great risk of an outbreak due to coverage that falls below required community immunity levels.

The current study is both strengthened and limited by its use of secondary data for the analysis. While a richer survey-based dataset administered to parents can provide more in- depth information, the response rates can be low. Using available school-level exemption data, we were able to accurately capture the reported PBE rates for nearly all public and charter schools in Arizona. What is unique about the present research is that it is the first to examine vaccine exemptions in Arizona and the distinction AZDHS uses in tracking permanent PBE aims to minimize the bias of the population opting out of vaccinations strictly from convenience. Furthermore, because of the large number of charter schools, it is critical to evaluate school clustering patterns and not just neighborhood clustering patterns. However, it must be noted that school level data were aggregated, and as such no conclusions about causality can be drawn, nor can the actual vaccination status be verified. In addition, due to NCES data collection methods, we were required to employ school-based demographics matched to PBE data from kindergartners only. While in general school demographics do not shift a great deal from year to year [29], it is possible that the school-level characteristics do not fully represent the entering kindergarten class. Furthermore, the unmatched schools may introduce bias, as they had a higher average exemption rate than the rest of the state. The unmatched schools are most likely private schools, newly established public schools, or self-reported a different name and address information than what existed in the NCES database.

5. Conclusion

In Arizona, the profile of a high PBE school is that of a charter school attended by predominantly white, higher-income students. In addition, schools with higher PBE are more likely to occur in some geographic areas than others. The highly aggregated nature of these schools warrants close observation and intervention from public health officials at both state and county levels. Research has suggested policy could reduce PBE rates through better enforcement of the school-entry requirements and the inclusion of a physician visit prior to obtaining an exemption [47, 48]. Prevention of VPD outbreaks far outweighs treating and managing even a relatively small outbreak, as these have serious health impacts and strain resources [49]. Reducing the growing PBE rate requires a multi-faceted approach that calls upon all healthcare professionals. This data gives state and county public health officials information on school and geographic locations on which to focus educational interventions and surveillance.

References

[1] Bloch AB, Orenstein WA, Stetler HC, Wassilak SG, Amler RW, Bart KJ, et al. Health impact of measles vaccination in the United States. Pediatrics 1985;76(4):524-32.
[2] Bonanni P. Demographic impact of vaccination: a review. Vaccine 1999;17:S120-S5.
[3] Luman ET, McCauley MM, Shefer A, Chu SY. Maternal characteristics associated with vaccination of young children. Pediatrics 2003 May;111(5 Part 2):1215-8.

[4] Herrera GA, Zhao Z, Klevens RM. Variation in vaccination coverage among children of Hispanic ancestry. American journal of preventive medicine 2001 May;20(4 Suppl):69-74.
[5] Klevens RM, Luman ET. U.S. children living in and near poverty: risk of vaccine-preventable diseases. American journal of preventive medicine 2001 May;20(4 Suppl):41-6.
[6] Kenyon TA, Matuck MA, Stroh G. Persistent low immunization coverage among inner-city preschool children despite access to free vaccine. Pediatrics 1998 Apr;101(4 Pt 1):612-6.
[7] Omer SB, Enger KS, Moulton LH, Halsey NA, Stokley S, Salmon DA. Geographic clustering of nonmedical exemptions to school immunization requirements and associations with geographic clustering of pertussis. American journal of epidemiology 2008 Dec 15;168(12):1389-96.
[8] Thompson JW, Tyson S, Card-Higginson P, Jacobs RF, Wheeler JG, Simpson P, et al. Impact of addition of philosophical exemptions on childhood immunization rates. American journal of preventive medicine 2007 Mar;32(3):194-201.
[9] Sugerman DE, Barskey AE, Delea MG, Ortega-Sanchez IR, Bi D, Ralston KJ, et al. Measles outbreak in a highly vaccinated population, San Diego, 2008: role of the intentionally undervaccinated. Pediatrics 2010 Apr;125(4):747-55.
[10] Omer SB, Pan WKY, Halsey NA, Stokley S, Moulton LH, Navar M, et al. Nonmedical exemptions to school immunization requirements: Secular trends and association of state policies with pertussis incidence. JAMA, the journal of the American Medical Association 2006;296(14):1757-63.
[11] Arizona Immunization Exemption Rates by Facility/Grade. ADHS Immunization Program Office: Arizona Department of Health Services, 2011: 2.
[12] Luthy KE, Beckstrand RL, Callister LC. Parental hesitation in immunizing children in Utah. Public Health Nurs 2010 Jan-Feb;27(1):25-31.
[13] Gust DA, Strine TW, Maurice E, Smith P, Yusuf H, Wilkinson M, et al. Underimmunization among children: effects of vaccine safety concerns on immunization status. Pediatrics 2004 Jul;114(1):e16-22.
[14] Gust DA, Darling N, Kennedy A, Schwartz B. Parents with doubts about vaccines: which vaccines and reasons why. Pediatrics 2008 Oct;122(4):718-25.
[15] Gellin BG, Maibach EW, Marcuse EK. Do parents understand immunizations? A national telephone survey. Pediatrics 2000 Nov;106(5):1097-102.
[16] Gaudino JA, Robison S. Risk factors associated with parents claiming personal-belief exemptions to school immunization requirements: community and other influences on more skeptical parents in Oregon, 2006. Vaccine 2012 Feb 1;30(6):1132-42.
[17] Flanagan-Klygis EA, Sharp L, Frader JE. Dismissing the family who refuses vaccines: a study of pediatrician attitudes. Archives of pediatrics & adolescent medicine 2005 Oct;159(10):929-34.
[18] Salmon DA, Moulton LH, Omer SB, DeHart MP, Stokley S, Halsey NA. Factors associated with refusal of childhood vaccines among parents of school-aged children: a case-control study. Archives of pediatrics & adolescent medicine 2005 May;159(5):470-6.
[19] Hussain H, Omer SB, Manganello JA, Kromm EE, Carter TC, Kan L, et al. Immunization safety in US print media, 1995-2005. Pediatrics 2011 May;127 Suppl 1:S100-6.
[20] Vannice KS, Salmon DA, Shui I, Omer SB, Kissner J, Edwards KM, et al. Attitudes and beliefs of parents concerned about vaccines: impact of timing of immunization information. Pediatrics 2011 May;127 Suppl 1:S120-6.
[21] Luthy KE, Beckstrand RL, Callister LC, Cahoon S. Reasons parents exempt children from receiving immunizations. The Journal of school nursing : the official publication of the National Association of School Nurses 2012 Apr;28(2):153-60.
[22] Offit PA, Hackett CJ. Addressing parents' concerns: do vaccines cause allergic or autoimmune diseases? Pediatrics 2003 Mar;111(3):653-9.
[23] Kennedy AM, Brown CJ, Gust DA. Vaccine beliefs of parents who oppose compulsory vaccination. Public Health Rep 2005 May-Jun;120(3):252-8.

[24] Gaudino JA, Robison S. Risk factors associated with parents claiming personal-belief exemptions to school immunization requirements: Community and other influences on more skeptical parents in Oregon, 2006. Vaccine 2011 Dec 14.
[25] Meredith L. LCA. Public Health Advisory: Suspected cases of Pediatric Varicella. http://www.co.marin.ca.us/hs/PublicHealth/Documents/PHVaricellaAdvisory.pdf: County of Marin, 2012.
[26] Ehresmann KR, White KE, Hedberg CW, Anderson E, Korlath JA, Moore KA, et al. A statewide survey of immunization rates in Minnesota school age children: implications for targeted assessment and prevention strategies. The Pediatric infectious disease journal 1998;17(8):711.
[27] Kennedy A, Basket M, Sheedy K. Vaccine attitudes, concerns, and information sources reported by parents of young children: results from the 2009 HealthStyles survey. Pediatrics 2011 May;127 Suppl 1:S92-9.
[28] Khetsuriani N, Bisgard K, Prevots DR, Brennan M, Wharton M, Pandya S, et al. Pertussis outbreak in an elementary school with high vaccination coverage. The Pediatric infectious disease journal 2001 Dec;20(12):1108-12.
[29] Common Core Data (CCD): Build A Table. 2011 [cited 2011 August 15th,]; Available from: http://nces.ed.gov/ccd/bat/
[30] Sable J, and Plotts, C. Documentation to the NCES Common Core of Data Public Elementary/Secondary School Universe Survey: School Year 2008–09. 2010 [cited 2011 August 15th,]; Available from: http://nces.ed.gov/pubsearch/pubs.info.asp?pubid=2010350
[31] TIGER/Line® Shapefiles for Arizona counties. 2009 [cited 2011 October 1st,]; Available from: http://www.census.gov/geo/www/tiger/tgrshp2009/tgrshp2009.html
[32] Getis A, Ord JK. The analysis of spatial association by use of distance statistics. Geographical analysis 1992;24(3):189-206.
[33] Smith PJ, Chu SY, Barker LE. Children who have received no vaccines: who are they and where do they live? Pediatrics 2004;114(1):187-95.
[34] Kim SS, Frimpong JA, Rivers PA, Kronenfeld JJ. Effects of maternal and provider characteristics on up-to-date immunization status of children aged 19 to 35 months. American journal of public health 2007 Feb;97(2):259-66.
[35] Sears R. The vaccine book : making the right decision for your child. 2nd ed. New York: Little, Brown, 2011.
[36] Jenny McCarthy's Autism Fight. CNN Larry King Live 2008 [cited 2012 May 1st,]; Available from: http://archives.cnn.com/TRANSCRIPTS/0804/02/lkl.01.html
[37] Newacheck PW, Hughes DC, Stoddard JJ. Children's access to primary care: differences by race, income, and insurance status. Pediatrics 1996;97(1):26-32.
[38] Lambrew JM, Defriese GH, Carey TS, Ricketts TC, Biddle AK. The effects of having a regular doctor on access to primary care. Medical Care 1996;34(2):138.
[39] Arizona Immunization Program Office. 2011 [cited 2011 August 15th,]; Available from: http://www.azdhs.gov/phs/immun/
[40] Vaccines for Children Program (VFC). 2011 [cited 2012 April 21st,]; Available from: http://www.cdc.gov/vaccines/programs/vfc/
[41] Hoffman L. Numbers and Types of Public Elementary and Secondary Schools From the Common Core of Data: School Year 2007-08. First Look. NCES 2010-305. National Center for Education Statistics 2009:32.
[42] Frimpong JA, Rivers PA, Bae S. Vaccination coverage among kindergarten children in Phoenix, Arizona. Health Education Journal 2008;67(1):56-63.
[43] NASN position statement: immunizations. NASN Sch Nurse 2011 Mar;26(2):121-2.

[44] Salmon DA, Moulton LH, Omer SB, Chace LM, Klassen A, Talebian P, et al. Knowledge, attitudes, and beliefs of school nurses and personnel and associations with nonmedical immunization exemptions. Pediatrics 2004 Jun;113(6):e552-9.
[45] Health CDoP. Pertussis Summary Reports. http://www.cdph.ca.gov/programs/immunize/Pages/PertussisSummaryReports.aspx: California Department of Public Health, Immunization Branch, 2012: 3.
[46] Lee T, Mehra R. 2010 Kindergarten Assessment Report. http://www.cdph.ca.gov/programs/immunize/Documents/2010KindergartenAssessmentReport.pdf: CALIFORNIA DEPARTMENT OF HEALTH SERVICES, IMMUNIZATION BRANCH, 2011.
[47] Ernst K, Jacobs B. Implications of philosophical and personal belief exemptions on re-emergence of vaccine-preventable disease: The role of spatial clustering in under-vaccination. Human Vaccines & Immunotherapeutics 2012;8(6):0--1.
[48] Diekema DS. Improving childhood vaccination rates. The New England journal of medicine 2012 Feb 2;366(5):391-3.
[49] Chen SY, Anderson S, Kutty PK, Lugo F, McDonald M, Rota PA, et al. Health care-associated measles outbreak in the United States after an importation: challenges and economic impact. The Journal of infectious diseases 2011 Jun 1;203(11):1517-25.

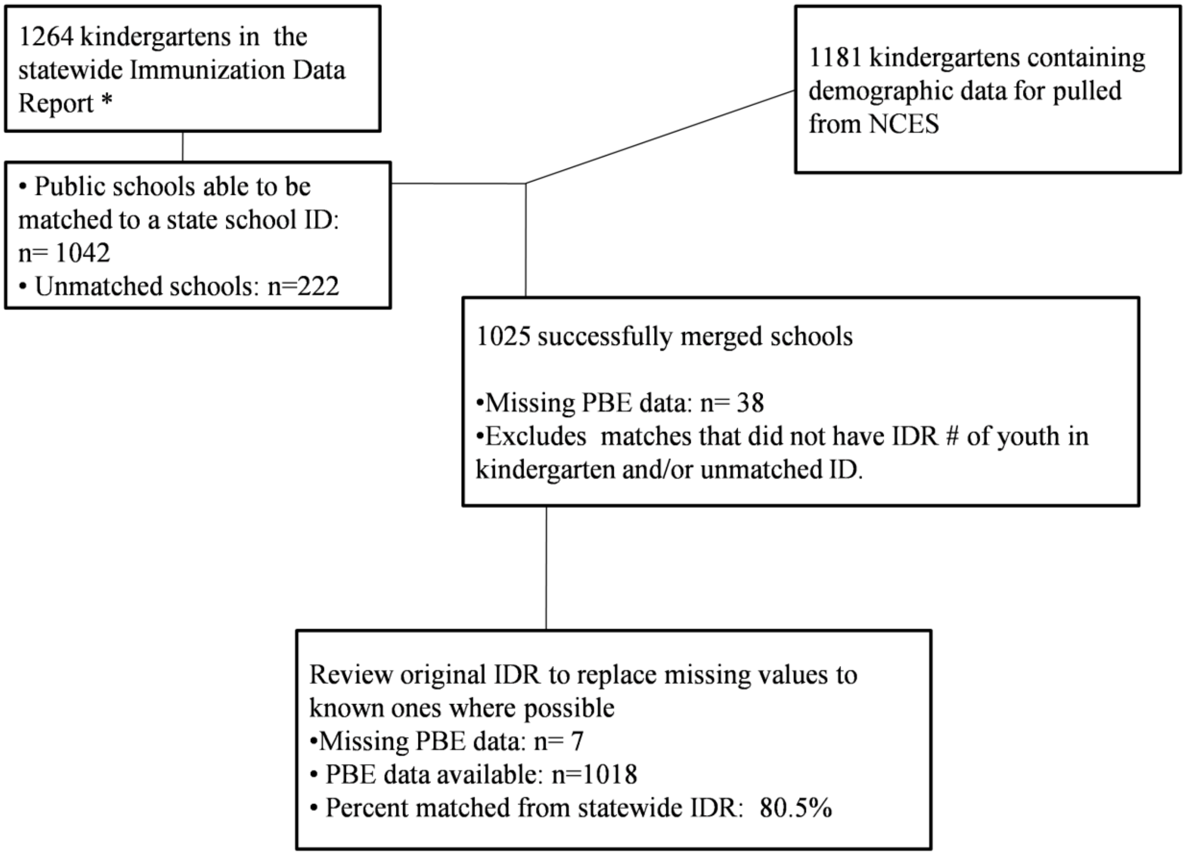

Figure 1. Scheme for linking data.

* Includes private school, which do not have a state school ID and were excluded from the study. Pima County gathers their reports separately from the state.

Table 1. Kindergarten Demographics With Permanent PBE

	No.	(%)	Permanent PBE	Count of Students	PBE per 1,000 Children
Overall	1018	(100)	2050	75788	27.05
Urban Category					
City	448	(44.0)	880	34792	25.29
Suburb	197	(19.4)	436	16211	26.90
Town	101	(9.9)	148	7588	19.50
Rural	272	(26.7)	586	17197	34.08
Statewide Region					
Central	650	(63.9)	1576	53883	29.25
North	93	(9.1)	219	4579	47.83
South	211	(20.7)	169	13003	13.00
West	64	(6.3)	86	4323	19.89
Agency Type					
Public school	838	(82.3)	1530	67206	22.77
Charter school	176	(17.3)	518	8411	61.59
Other	4	(0.4)	2	171	11.70
Free and Reduced Lunch %					
Under 25	245	(24.7)	842	20001	42.10
25-50	198	(20.0)	533	14566	36.59
50-75	265	(26.8)	432	18290	23.62
75+	282	(28.4)	147	21758	6.76
White % Quintile					
1st Quintile (0-9%)	203	(19.9)	50	17615	2.84
2nd Quintile (9-35%)	204	(20.0)	208	15568	13.36
3rd Quintile (35-59%)	204	(20.0)	376	14131	26.61
4th Quintile (59-75%)	204	(20.0)	612	15121	40.47
5th Quintile (75%+)	203	(19.9)	804	13353	60.21
PBE Rate in Ranked Groups (range)					
1st and 2nd (0%)	430	(42.2)	0	29222	0.00
3rd (0-2%)	181	(17.8)	248	17641	14.06
4th (3-5%)	204	(20.0)	576	16310	35.32
5th (5-68%)	203	(19.9)	1226	12615	97.19

Table 2. Incidence Rate Ratios of Personal Belief Exemption Among 1018 Kindergartens in Arizona

		Crude IRR	95% CI	Adjusted IRR	95% CI
Urban					
	City	Ref:	--	Ref:	--
	Suburb	0.99	0.77,1.27	0.85	0.70,1.03
	Town	0.79	0.56,1.12	0.71	0.52,0.95
	Rural	1.27	1.00,1.61	0.96	0.79,1.16
White % Quintile					
	1st Quintile (0-9%)	Ref:	--	Ref:	--
	2nd Quintile (9-35%)	4.86	3.39,6.97	4.22	2.94,6.06
	3rd Quintile (35-59%)	10.4	7.34,14.75	7.62	5.20,11.16
	4th Quintile (59-75%)	15.13	10.74,21.32	10.52	7.11,15.56
	5th Quintile (75%+)	24.97	17.74,35.14	14.11	9.47,21.03
Region					
	Center	Ref:	--	Ref:	--
	North	1.74	1.27,2.40	1.38	1.06,1.81
	South	0.46	0.36,0.61	0.64	0.51,0.80
	West	0.78	0.52,1.16	0.92	0.64,1.33
Agency Type					
	Public	Ref:	--	Ref:	--
	Charter	3.07	2.43,3.86	2.04	1.68,2.48
	Other	0.38	0.05,3.04	0.64	0.11,3.59
Free/Reduced Lunch					
	0-25%	Ref:	--	Ref:	--
	25-50%	0.87	0.69,1.11	1.05	0.85,1.30
	50-75%	0.6	0.48,0.75	1.03	0.82,1.29
	75+%	0.15	0.12,0.20	0.68	0.50,0.93

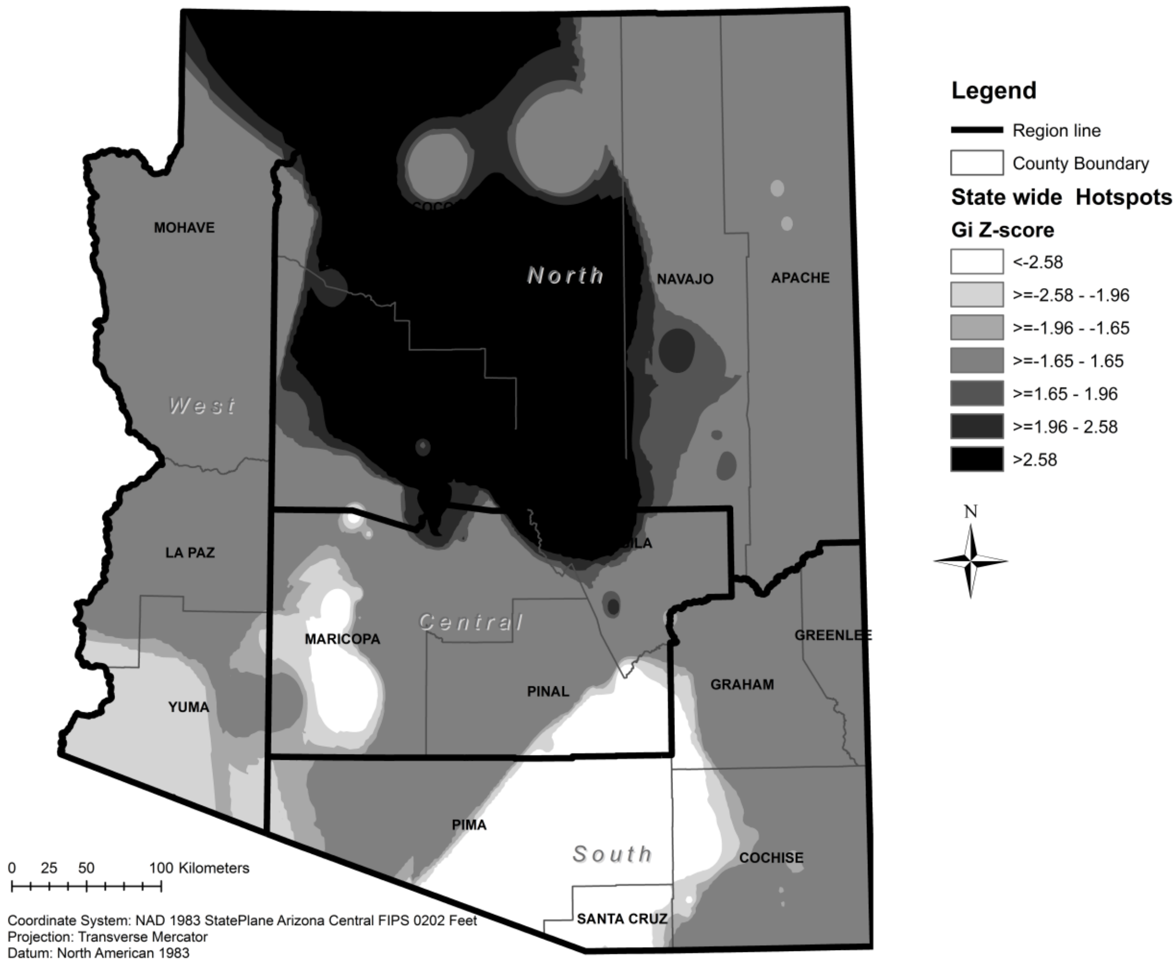

Figure 2. Cluster analysis using Getis-Ord Gi* on PBE rate throughout Arizona. Darker colors indicates clusters of schools with higher than expected rates of PBE and lighter indicates clusters of lower than expected rates of PBE.

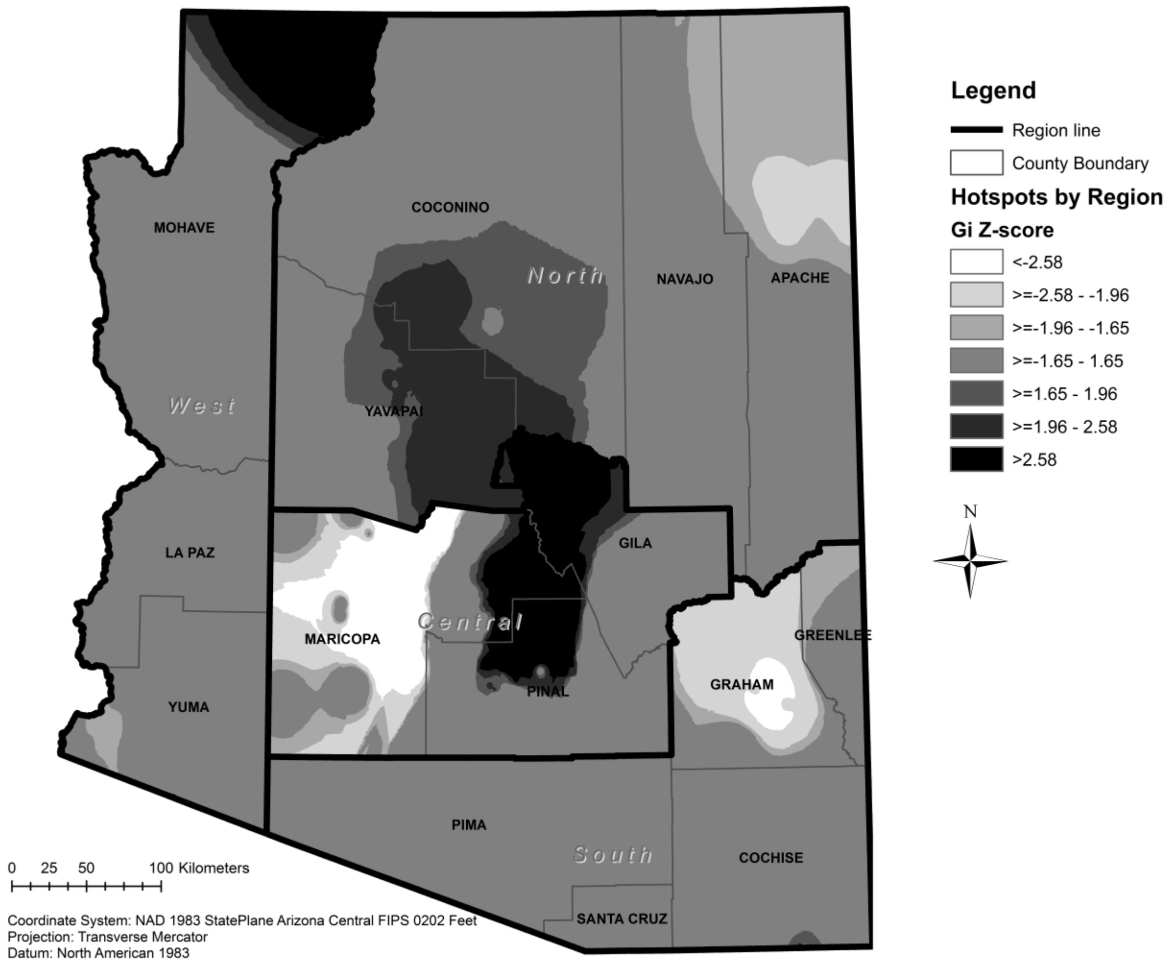

Figure 3. Cluster analysis using Getis-Ord Gi* on PBE rate by Region. Darker colors indicates clusters of schools with higher than expected rates of PBE and lighter indicates clusters of lower than expected rates of PBE.