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Geographic variation in influenza vaccination among U.S. nursing home residents: A national study

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Abstract

Objectives: Estimates of influenza vaccine use are not available at the county level for U.S. nursing home (NH) residents but are critically necessary to guide the implementation of quality improvement programs aimed at increasing vaccination. Furthermore, estimates that account for differences in resident characteristics between counties are unavailable. We estimated risk-standardized vaccination rates (RSVRs) among short- and long-stay NH residents by U.S. county and identified drivers of geographic variation.

Methods: We conducted a retrospective cohort study utilizing 100% of 2013–2015 fee-for-service Medicare claims, Minimum Data Set assessments, Certification and Survey Provider Enhanced Reports, and Long-Term Care: Facts on Care in the U.S. We separately evaluated short-stay (<100 days) and long-stay (≥100 days) residents aged 65 and older across the 2013–2014 and 2014–2015 influenza seasons. We estimated RSVRs via hierarchical logistic regression adjusting for 32 resident-level covariates. We then used multivariable linear regression models to assess associations between county-level NHs predictors and RSVRs.

Results: The study cohort consisted of 2,817,217 residents in 14,658 NHs across 2798 counties. Short-stay residents had lower RSVRs than long-stay residents (2013–2014: median [interquartile range], 69.6% [62.8–74.5] vs 84.0% [80.8–86.4]), and there was wide variation within each population (range, 11.4–89.8 vs 49.1–92.6). Several modifiable facility-level characteristics were associated with increased RSVRs, including higher registered nurse to total nurse ratio and higher total staffing for licensed practical nurses, speech-language pathologists, and social workers. Characteristics associated with lower RSVRs included higher percentage of residents restrained, with a pressure ulcer, and NH-level hospitalizations per resident-year.

Conclusions: Substantial county-level variation in influenza vaccine use exists among short- and long-stay NH residents. Quality improvement interventions to improve vaccination rates can leverage these results to target NHs located in counties with lower risk-standardized vaccine use.

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KEYWORDS
infections, influenza, long-term care, quality of health care, vaccination

INTRODUCTION

Older adults residing in nursing homes (NHs) are at high risk for respiratory infections, including influenza.[1–3] Between 70% and 85% of influenza-related deaths occur in people aged 65 and older.[4] Influenza vaccination decreases the risk and severity of infection and, in doing so, also decreases the risk of subsequent adverse outcomes such as hospitalization and mortality.[5] However, influenza vaccination rates among U.S. NH residents did not meet the Healthy People 2020 goal of 90%.[6,7] While this goal was not carried forward and included in Healthy People 2030, implementing quality improvement initiatives aimed at increasing influenza vaccine use in NHs and consistently achieving a 90% vaccination goal in each influenza season remains an important objective. To do so, it is critical to first understand how influenza vaccination rates differ across the country and to identify areas with the lowest vaccine uptake.

While influenza incidence rates are known to vary widely by U.S. county after adjusting for differences in NH residents between counties,[8] the small-area geographic patterns of influenza vaccination among NH residents remain unknown. National data reporting geographic information for NH resident vaccination have provided national- or state-level estimates, but these mask variations in smaller areas, such as counties, and have other important limitations.[9,10] Prior studies that have reported on person- or NH-level predictors of vaccination did not use risk-standardization when estimating influenza vaccination rates.[11–14] Utilizing risk-standardization is critical as NH resident characteristics are known to vary by geography and without accounting for these differences it is extremely difficult to validly compare county-level vaccination rates or ascribe any observed differences to local policies and practices. Prior studies also have not analyzed short-stay (post-acute care) and long-stay (long-term care) residents as two distinct groups despite the two subpopulations' markedly different care needs and profiles.[11–15]

Quantifying county-level vaccination rates is vital for stakeholders responsible for making decisions to prevent and control infections in NHs. These stakeholders could include state, county, and local health departments, local boards of health, policymakers, and public health officials. County-level estimates are useful especially if local stakeholders are organized into informal networks, such as through local chapters of professional organizations like The Society for Post-Acute and Long-Term Care Medicine, the Association of State and Territorial Health Officials, and the National Association of County and City Health Officials. Absent such information, these stakeholders cannot allocate finite resources appropriately or focus quality improvement or other interventions on areas and specific NHs with the lowest vaccination rates. Failure to allocate resources and intervene effectively is likely to perpetuate any ongoing geographic inequalities in vaccine use among NH residents.

Key Points

- Significant geographic variation in vaccine use exists among nursing home residents.
- Several facility-level predictors were associated with increased vaccination rates.
- Geographic variation was consistent across seasons.

Why Does this Paper Matter?

County-level vaccination rates are needed to guide quality improvement interventions.

Accordingly, our objectives were to (1) estimate how risk-standardized influenza vaccination rates (RSVRs) among short- and long-stay NH residents varied across U.S. counties after adjusting for NH resident characteristics to ensure consistent and comparable estimates, and (2) identify potential drivers of observed small-area geographic variation. We hypothesized that wide variation in vaccination rates would exist across counties for both the short-stay and long-stay populations despite risk-standardization. We also hypothesized that modifiable NH-level predictors related to variety of staffing, direct care hours, and quality measures would be associated with increases in county-level RSVRs.

METHODS

Study design and data source

This retrospective cohort study included fee-for-service Medicare beneficiaries who resided in U.S. NHs between January 1, 2013 and December 31, 2015. Data were derived from 100% samples of Medicare Parts A and B claims, Minimum Data Set (MDS) version 3.0 assessments, Certification and Survey Provider Enhanced Reports (CASPER), and Long-Term Care: Facts on Care in the U.S. (LTCFocUS). After linking MDS to Medicare claims, we employed a previously validated residential history file algorithm to track NH residents' timing and location of health service utilization.[16] We then linked this information to NH-level data using CASPER and LTCFocUS. CASPER data are collected by state survey agencies during NH inspections. LTCFocUS is a product of the Shaping Long-Term Care in America Project at the Brown University Center for Gerontology & Healthcare Research.[17,18] NHs and their residents were assigned to counties based on the zip code of the NH, which were then aggregated up to the level of Federal Information Processing Standards county codes.

The Brown University Institutional Review Board approved the study protocol.

Study population

We included beneficiaries aged 65 and older on their index date (defined below) residing in free-standing (i.e., not hospital-based) NHs between January 1, 2013 and December 31, 2015 who had at least one MDS assessment. We also required that residents' NH be identifiable and the corresponding NH-level data be available in CASPER and LTCFocUS. Residents with less than 6 months of continuous enrollment in both Medicare Parts A and B or health maintenance organizations (i.e., Medicare Advantage) were excluded as were those with missing data on any person-level covariates necessary for risk-standardization (process described below in Statistical Analyses).

NH residents were divided into four subcohorts according to their short-stay/long-stay status and influenza season of stay (2013–2014 and 2014–2015). We stratified our analyses by season as we believed a priori that there may be unmeasured predictors of influenza vaccination at the county level that change between seasons (i.e., facility infection control practices and localized seasonal influenza activity were not measured). First, residents were designated as either short-stay (SS) or long-stay (LS) based on length of residency in the NH. Short-stay residents were those with <100 days in the same NH and were assigned an index date of entry. Those designated as long-stay had ≥100 consecutive days with no more than 10 days outside of the NH and an index date assigned as day 100 of their stay. Stays that occurred between October 1, 2013 and March 31, 2014 were included in the 2013–2014 season, while those that occurred from October 1, 2014 to March 31, 2015 were included in the 2014–2015 season. These dates were selected because influenza activity is empirically highest and the majority of vaccination takes place during this period. Centers for Medicare & Medicaid Services (CMS) quality measures are defined using these dates, and prior studies have often used them which allowed us to facilitate comparability. Only residents' first stay identified during a particular season was included, however residents could be represented in both seasons if they survived to the second and remained in the same NH.

Resident characteristics for risk adjustment

We selected 32 covariates encoding information about resident demographic information and comorbidities that were likely to be associated with receiving influenza vaccine.[2,19–21] We obtained age, sex, and race from the Medicare enrollment file, and we derived all remaining demographic covariates and comorbidities from MDS assessments (Table S1). For long-stay residents, covariates were derived from MDS assessments in the 100 days before their index date as well as all assessments after the index date during a given season. For short-stay residents, covariates were derived from all MDS assessments available from the time of admission to the NH to the time of discharge. Since risk-standardization requires complete resident-level data and the MDS Active Diagnoses Section I variables are not measured in every MDS assessment, this approach to MDS covariate ascertainment minimized missing data.

Vaccination status

Influenza vaccination status was ascertained from the immunization supplement on MDS resident assessments between October 1 and June 30. We emulated a previously described algorithm to leverage responses from multiple MDS assessments and classify residents as vaccinated based two questions about influenza vaccination.[7,19]

NH-level and county-level predictors for examining determinants of vaccination

We ascertained 28 potential NH-level predictors of influenza vaccination from CASPER and LTCFocUS that have been previously described (Table 1 and Text S1).[2,8,22,23] We used LTCFocUS data to capture NH-level information, including aggregate NH-level resident demographics and potentially non-modifiable structural NH predictors.

TABLE 1 County-level NH predictors for short-stay and long-stay residents, stratified by influenza season, $N = 2798$ counties

	2013–2014 season		2014–2015 season	
Predictor	**Short-stay ($N = 2740$)**	**Long-stay ($N = 2786$)**	**Short-stay ($N = 2758$)**	**Long-stay ($N = 2781$)**
Aggregate resident predictors				
Age at index date, years	79.8 ± 2.8	83.9 ± 2.1	80.3 ± 2.8	83.8 ± 2.1
% female (all admissions)	69.1 ± 7.2	68.6 ± 7.3	68.9 ± 7.5	68.5 ± 7.4
% white (all admissions)	86.1 ± 16.9	85.3 ± 17.2	86.1 ± 17.0	85.3 ± 17.3
% black (all admissions)	7.8 ± 13.0	8.0 ± 13.2	7.9 ± 13.1	8.0 ± 13.2
% Hispanic (all admissions)	2.6 ± 9.5	2.6 ± 8.9	2.6 ± 9.4	2.6 ± 8.9
ADL[a]	16.1 ± 6.3	16.2 ± 6.5	16.1 ± 6.3	16.2 ± 6.4
Non-modifiable NH predictors				
Average daily census	76.8 ± 30.6	75.6 ± 30.5	76.4 ± 30.5	75.5 ± 30.3
Occupancy rate	80.5 ± 12.3	80.2 ± 12.7	80.5 ± 12.3	80.4 ± 12.5
Total beds	97.0 ± 34.0	96.0 ± 34.0	97.0 ± 34.0	96.0 ± 34.0
% Medicare	13.1 ± 7.3	12.8 ± 7.2	12.8 ± 7.1	12.5 ± 6.9
% Medicaid	63.5 ± 13.1	63.4 ± 13.4	63.9 ± 12.9	63.9 ± 13.2
% pay other	23.4 ± 12.8	23.8 ± 13.0	23.4 ± 12.8	23.7 ± 12.9
Admissions per bed	1.6 ± 1.1	1.6 ± 0.8	1.5 ± 1.1	1.5 ± 0.8
Average acuity index	11.9 ± 1.1	12.0 ± 1.0	11.9 ± 1.2	12.0 ± 1.0
% for profit	71.5 ± 34.4	70.8 ± 34.9	71.3 ± 34.6	70.7 ± 34.8
% multi-facility corporation	58.4 ± 37.1	57.6 ± 37.0	59.0 ± 37.1	58.3 ± 37.1
% urban	1039 (38.0%)	1042 (37.4%)	1040 (37.7%)	1041 (37.4%)
Modifiable NH predictors				
CNA to nurse ratio	2.1 ± 0.5	2.0 ± 0.5	2.1 ± 0.5	2.0 ± 0.5
RN to total nurse ratio	0.3 ± 0.2	0.3 ± 0.2	0.3 ± 0.2	0.3 ± 0.2
Total nursing hours per resident day	3.9 ± 1.8	3.8 ± 1.4	3.8 ± 1.8	3.8 ± 1.3
Hospitalizations per resident year	1.0 ± 0.5	1.0 ± 0.5	1.0 ± 0.5	1.0 ± 0.5
CNA hours per resident day	2.3 ± 0.5	2.3 ± 0.5	2.3 ± 0.5	2.3 ± 0.5
LPN hours per resident day	0.8 ± 0.3	0.8 ± 0.3	0.8 ± 0.3	0.8 ± 0.3
Total physician extender FTEs/100 beds	0.1 ± 0.2	0.1 ± 0.2	0.1 ± 0.2	0.1 ± 0.02
SLP total staff FTE	335.0 ± 748.4	318.0 ± 667.9	343.8 ± 760.0	323.1 ± 669.3
Social worker on staff/100 beds	1.0 ± 0.8	1.0 ± 0.9	1.0 ± 0.8	1.0 ± 0.09
Pressure ulcers	5.7 ± 3.1	5.8 ± 3.2	5.7 ± 3.1	5.7 ± 3.2
Restraints	2.6 ± 5.0	2.1 ± 4.1	2.7 ± 5.2	2.1 ± 4.0

Note: The data are presented as either mean (standard deviation) or count (%).

Abbreviations: ADL, activities of daily living; CNA, certified nursing assistant; FTE, full-time equivalent; LPN, licensed practical nurse; NH, nursing home; RN, registered nurse; SD, standard deviation.

[a]Functional status was assessed by calculating the 28-point Morris Activities of Daily Living Scale.[34]

We use the term "structural" to refer to characteristics of facilities that relate to the basic physical existence and organization of the facilities, such as ownership, size, and rurality. We used CASPER data to capture potentially modifiable NH predictors (i.e., staffing information and quality-of-care deficiencies).

Statistical analyses

Analyses were conducted at the county level. We selected the county as the geographic unit of analysis because beneficiaries' choice of NH does not typically extend beyond that of the county in which they reside before

NH entry, and it is most likely to be the smallest geographic unit with policy implications. Also, while many individuals may wish to select a NH in the neighborhood, town, or city in which they resided before requiring NH care, most neighborhoods, towns, and cities do not have a NH, whereas most counties do, so the decision about which NH to go to is effectively made at the county level. It is also likely that highly successful quality improvement interventions aiming to improve vaccination rates may need to be implemented at the county level to maximize effectiveness.

We calculated crude vaccination rates and RSVRs for each county. Adapting from CMS methodology for risk-standardization, county-level RSVRs were calculated by multiplying the ratio of predicted to expected influenza vaccinations by the crude influenza vaccinations for each subcohort.[8,22,24] Hierarchical logistic regression models adjusted for 32 resident-level covariates were fit for each of the four subcohorts in the study (short-stay 2013–2014, long-stay 2013–2014, short-stay 2014–2015, long-stay 2014–2015) to estimate predicted and expected influenza vaccinations with a county-specific intercept and an *average* county-specific intercept based on all counties within in each subcohort.

Geospatial analyses were then conducted to explore the geographic patterns of crude vaccination rates and RSVRs. Choropleth maps were generated to plot crude vaccination rates and RSVR quintiles. Analyses were separated by subcohort, therefore the cut-points for quintiles represented on maps were not the same across seasons or short-stay and long-stay populations.

Finally, multivariable linear regression models using ordinary least squares were used to evaluate the associations between county-level RSVRs and county-level predictors. The models provided percent differences in vaccination rates and 95% confidence intervals for each of the four subcohorts. For continuous predictors, counties were grouped into tertiles with inferences made based on the percent differences in RSVRs among counties grouped in the highest tertile of a specific predictor compared counties in the lowest tertile. Predictors were classified as associated with increases or decreases in RSVRs if the direction of association was present in at least three of the four subcohorts.

Stability analyses

We evaluated alternative approaches to determine the impact of including counties with few NH residents on the stability of the main county-level RSVR estimates. We excluded all counties with fewer than five total NH residents and then again with fewer than seven. This was analogous to making a trade-off between precision and generalizability since estimates from counties with more NH residents were expected to be more precise, but potentially less generalizable to the target population of all counties with NHs. In our multivariable linear regression models, we also evaluated the impact of using Huber–White standard errors on the inferences drawn.

Software

We conducted analyses using SAS Enterprise Guide 8.1 (SAS Institute, Cary, NC), R version 3.6.1 (R Foundation for Statistical Computing, Vienna, Austria), and ArcMap 10.8 (ESRI, Redlands, CA) software.

RESULTS

Study cohort and vaccination rates

The overall study cohort consisted of 2,817,217 NH residents in 14,658 NHs across 2798 counties. During the 2013–2014 season, there were 524,739 short-stay residents in 14,059 NHs across 2740 counties, and 851,869 long-stay residents in 14,494 NHs across 2789 counties (Table 1 and Figure S1). The subcohorts for the 2014–2015 season consisted of 689,061 short-stay residents in 14,150 NHs across 2758 counties, and 881,264 long-stay residents in 14,463 NHs across 2781 counties (Table 1 and Figure S1).

The median county-level crude vaccination rate among short-stay residents during the 2013–2014 season was 73.2% (interquartile range [IQR] 61.3–81.8; range, 11.4–89.8) and 72.7% (IQR, 60.9–81.2; range, 12.0–90.8) during the 2014–2015 season. For long-stay residents, the median county-level crude vaccination rate was 86.8% (IQR, 82.0–90.5; range, 49.1–92.6) during the 2013–2014 season and 85.7% (IQR, 81.0–93.0; range, 44.6–92.2) during the 2014–2015 season (Table 2). After risk adjustment, the median county-level RSVR among short-stay residents in 2013–2014 was 69.6% (IQR, 62.8–74.5) and 69.1% (IQR, 62.0–74.1) in 2014–2015. Across long-stay residents, the median county-level RSVR in 2013–2014 was 84.0% (IQR, 80.8–86.4) and 83.1% (IQR, 79.7–85.7) in 2014–2015 (Table 2).

Geospatial analysis

Wide geographic variation was observed for both crude and RSVR across both the short- and long-stay populations and both influenza seasons (Figures 1 and 2). While

TABLE 2 Crude and risk-standardized county-level influenza vaccination rates of short-stay and long-stay residents, stratified by season, $N = 2798$ counties

	2013–2014 season		2014–2015 season	
	Short-stay ($N = 2740$)	**Long-stay ($N = 2786$)**	**Short-stay ($N = 2758$)**	**Long-stay ($N = 2781$)**
Crude assessed and provided[a]	92.0 (84.6, 97.2)	97.6 (95.7, 99.1)	91.4 (83.5, 96.2)	97.3 (95.2, 98.9)
Crude declined	13.9 (7.0, 22.2)	9.1 (6.3, 12.8)	14.0 (7.7, 22.1)	9.6 (6.6, 13.5)
Crude contraindicated	0 (0, 1.3)	0.8 (0, 1.5)	0.0 (0, 1.3)	0.8 (0, 1.5)
Crude did not offer	0 (0, 3.1)	0 (0, 1.0)	0.3 (0, 3.1)	0 (0, 1.1)
Crude vaccinated	73.2 (61.3, 81.8)	86.8 (82.0, 90.5)	72.7 (60.9, 81.2)	85.7 (81.0, 93.0)
Risk-standardized vaccinated	69.6 (62.8, 74.5)	84.0 (80.8, 86.4)	69.1 (62.0, 74.1)	83.1 (79.7, 85.7)

Note: The data are presented as median (interquartile range).

[a]Assessed and provided is an additive measure that takes into account those who were vaccinated, declined vaccination, or who had a contraindication to receiving the vaccine.

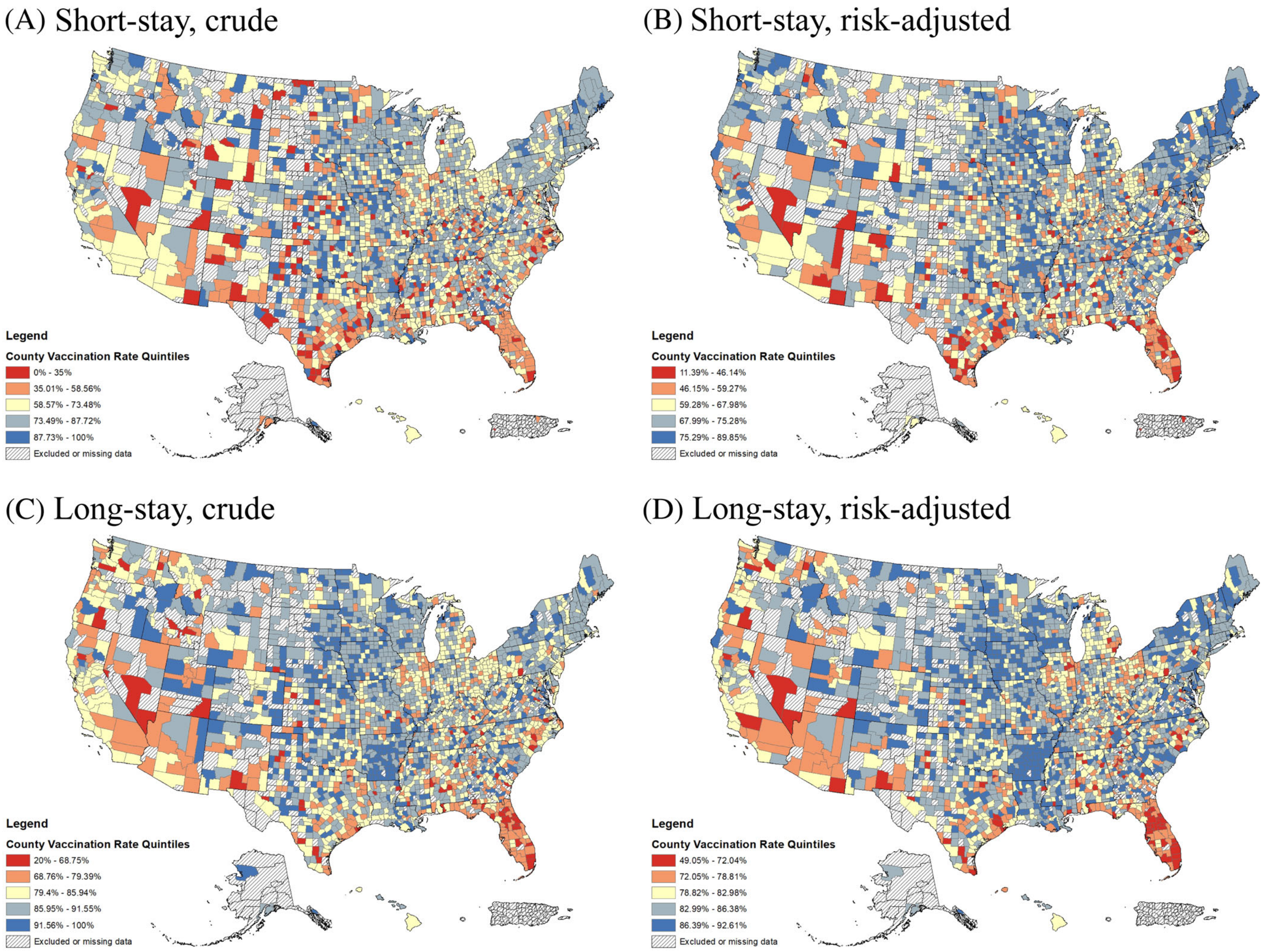

FIGURE 1 Crude and risk-standardized county-level vaccination rates among short-stay and long-stay nursing home residents during 2013–2014 influenza season, $N = 2788$ counties

observed patterns were consistent between crude and risk-standardized choropleth maps for subcohorts, 65.80% of counties ($n = 1841$) experienced one change in vaccination rate quintile (to an adjacent quintile) after risk-standardization in at least one subcohort. A change of at least two vaccination rate quintiles (to a non-adjacent

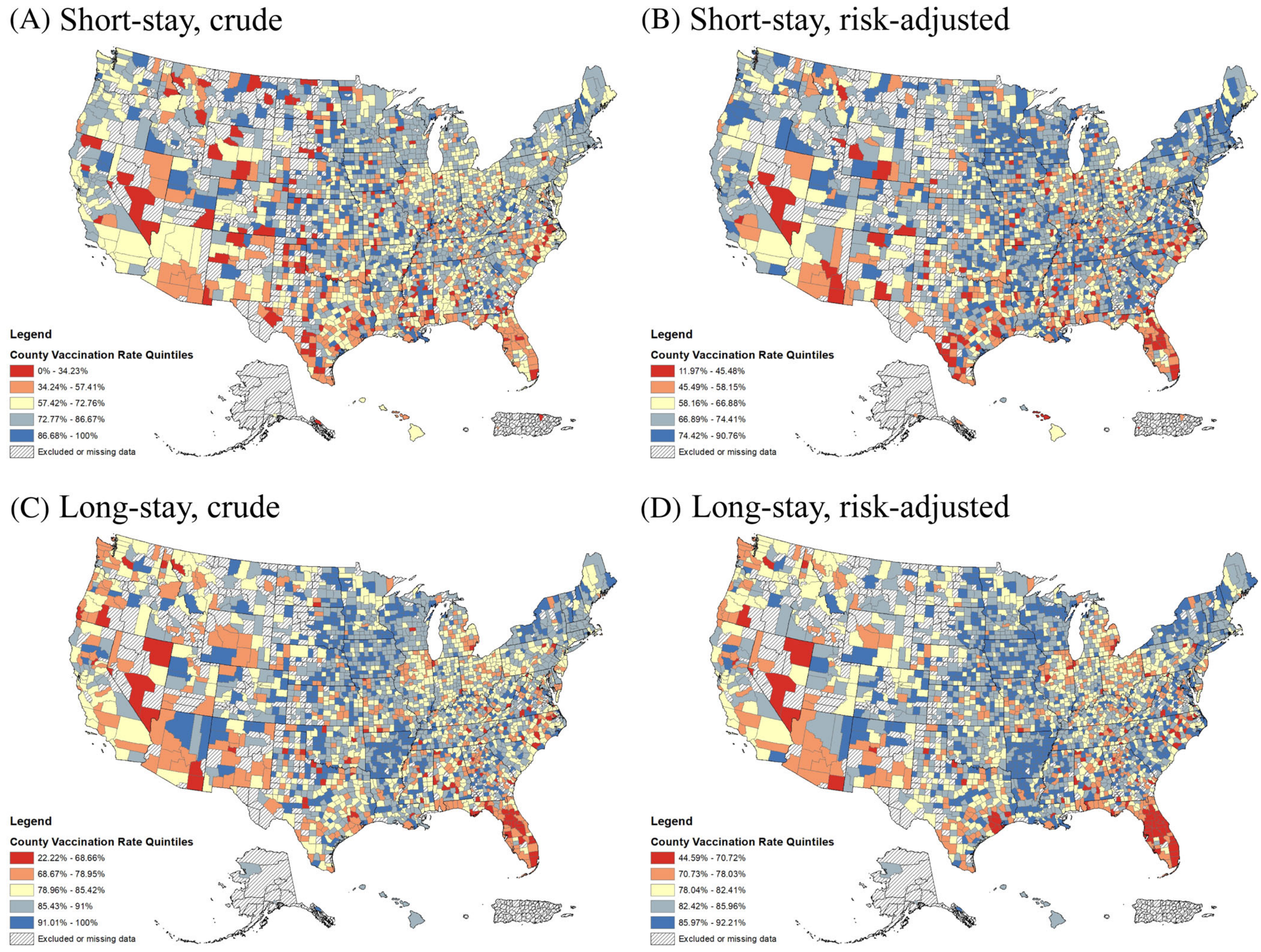

FIGURE 2 Crude and risk-standardized county-level vaccination rates among short-stay and long-stay nursing home residents during 2014–2015 influenza season, $N = 2783$ counties

quintile) for a given subcohort was observed in 112 counties, which were found primarily in a band stretching from northern Texas through counties in Oklahoma, Kansas, South Dakota, and North Dakota. Two counties, Jefferson county, Mississippi and Gadsden county, Florida, shifted three vaccination rate quintiles through risk-standardization for the long-stay population in the 2014–2015 influenza season.

Counties with the highest RSVRs were located predominately in the Midwest (central Iowa, southern Minnesota, western Wisconsin), the South (central Arkansas, Louisiana, Georgia, and Virginia), and parts of the Northeast (counties in Finger Lakes and Central regions of New York) (Figures 1 and 2). Counties with the lowest RSVRs were particularly concentrated in counties in the South, including a band stretching from Houston, Texas through much of Florida, and another along the Inner Coastal Plain of North Carolina (Figures 1 and 2). Counties with low vaccination rates were also located throughout Tennessee, Kentucky, Georgia, and Virginia as well as urban counties surrounding Las Vegas, Nevada; Phoenix, Arizona; Los Angeles, California; and Chicago, Illinois.

Multivariable analyses

Among aggregate NH resident-level predictors, higher average age at index, higher proportion of black resident admissions, and higher percentage of female resident admissions were associated with increases in RSVRs among all subcohorts (Tables 3 and S2). Higher percentage of Hispanic resident admissions was associated with decreased RSVRs in all subcohorts (SS13-14: −2.07%, SS14-15: −1.95%, LS13-14: −1.41%, LS14-15: −1.36%).

Non-modifiable NH-level predictors that were associated with increases in RSVRs included higher percentage of Medicaid residents (SS13-14: 0.19%, SS14-15: −0.87%, LS13-14: 1.11%, LS14-15: 1.73%), higher percentage of

TABLE 3 Multivariable linear regression analyses to identify factors associated with county-level risk-standardized influenza vaccination rates (RSVRs) among short-stay and long-stay NH residents, stratified by season, $N = 2798$ counties

	2013–2014 season		2014–2015 season	
	Short-stay ($N = 2740$)	Long-stay ($N = 2786$)	Short-stay ($N = 2758$)	Long-stay ($N = 2781$)
Predictors	**Percentage point difference (95% confidence interval)**		**Percentage point difference (95% confidence interval)**	
Aggregate resident characteristics				
Age at index date, years	1.05% (−0.011 to 2.10)	1.51% (0.92 to 2.10)	1.05% (−0.13 to 2.20)	1.89% (1.20 to 2.50)
% female	0.46% (−0.59 to 1.50)	0.47% (−0.02 to 0.96)	0.14% (−0.99 to 1.30)	0.36% (−0.19 to 0.90)
% white (all admits)	1.86% (0.36 to 3.40)	−0.25% (−0.91 to 0.41)	2.96% (1.30 to 4.60)	−0.13% (−0.85 to 0.58)
% black (all admits)	1.61% (0.09 to 3.10)	0.37% (−0.32 to 1.10)	1.95% (0.36 to 3.60)	0.62% (−0.12 to 1.40)
% Hispanic (all admits)	−2.07% (−3.10 to −1.00)	−1.41% (−1.90 to −0.93)	−1.95% (−3.10 to −0.80)	−1.36% (−1.90 to −0.83)
ADL	−1.01% (−2.00 to −0.03)	0.05% (−0.39 to 0.49)	−0.23% (−1.30 to 0.82)	0.04% (−0.44 to 0.53)
Non-modifiable NH characteristics				
Average daily census	0.12% (−1.80 to 2.10)	0.02% (−0.84 to 0.89)	−0.38% (−2.50 to 1.70)	0.57% (−0.38 to 1.50)
Occupancy rate	−0.77% (−2.00 to 0.46)	−0.28% (−0.84 to 0.29)	−0.22% (−1.50 to 1.10)	0.08% (−0.53 to 0.69)
Total beds	0.35% (−1.50 to 2.20)	−0.51% (−1.30 to 0.31)	0.65% (−1.30 to 2.60)	−0.94% (−1.80 to −0.04)
% Medicare	−0.17% (−1.60 to 1.30)	−0.40% (−1.10 to 0.24)	−1.64% (−3.20 to −0.09)	−0.14% (−0.85 to 0.56)
% Medicaid	0.19% (−1.70 to 2.00)	1.11% (0.25 to 2.00)	−0.87% (−2.90 to 1.10)	1.73% (0.78 to 2.70)
% pay other	0.29% (−1.60 to 2.10)	0.70% (−0.16 to 1.60)	−0.86% (−2.90 to 1.12)	1.11% (0.17 to 2.10)
Admissions per bed	−0.90% (−2.40 to 0.61)	−1.72% (−2.40 to −1.00)	0.54% (−1.10 to 2.20)	−1.87% (−2.60 to −1.10)
Average acuity index	−0.86% (−2.10 to 0.35)	−0.41% (−0.97 to 0.14)	−0.53% (−1.80 to 0.78)	−0.24% (−0.86 to 0.37)
% for profit	−1.15% (−2.20 to −0.08)	−1.10% (−1.60 to −0.62)	−0.67% (−1.80 to 0.47)	−0.68% (−1.20 to −0.16)
% multi-facility corporation	−0.82% (−1.91 to −0.28)	−0.80% (−1.30 to −0.31)	−2.11% (−3.30 to −0.94)	−0.94% (−1.5 to −0.40)
Rural counties	0.53% (−0.41 to 1.50)	0.12% (−0.31 to 0.55)	−0.24% (−1.30 to 0.78)	0.25% (−0.22 to −0.73)
Modifiable NH characteristics				
CNA to nurse ratio	−0.14% (−1.50 to 1.20)	0.05% (−0.57 to 0.67)	−0.74% (−2.20 to 0.72)	−0.21% (−0.89 to 0.47)
RN to total nurse ratio	3.05% (1.50 to 4.60)	0.04% (−0.68 to 0.76)	2.20% (0.50 to 3.90)	−0.30% (−1.10 to 0.48)
Total nursing hours per resident day	0.95% (−1.00 to 2.90)	−0.54% (−1.40 to 0.32)	−1.32% (−3.40 to 0.78)	0.31% (−0.64 to 1.30)
Hospitalizations, per resident, per year	−1.59% (−2.80 to 0.42)	0.04% (−0.50 to 0.57)	−1.35% (−2.60 to −0.10)	−0.08% (−0.66 to 0.50)
CNA hours per resident day	−0.09% (−2.10 to 1.90)	−0.08% (−0.93 to 0.78)	1.82% (−0.30 to 3.90)	−0.15% (−1.10 to 0.80)
LPN hours per resident day	0.18% (−1.60 to 1.90)	0.26% (−0.53 to 1.00)	0.28% (−1.60 to 2.10)	−0.32% (−1.20 to 0.55)
Total physician extender FTEs/100 beds	−0.40% (−1.50 to 0.69)	0.12% (−0.38 to 0.61)	−1.01% (−2.20 to 0.15)	−0.24% (−0.79 to 0.31)

(Continues)

TABLE 3 (Continued)

Predictors	2013–2014 season		2014–2015 season	
	Short-stay ($N = 2740$)	Long-stay ($N = 2786$)	Short-stay ($N = 2758$)	Long-stay ($N = 2781$)
	Percentage point difference (95% confidence interval)		Percentage point difference (95% confidence interval)	
SLP total staff FTE	1.67% (0.58 to 2.80)	0.70% (0.20 to 1.20)	1.45% (0.27 to 2.60)	0.98% (0.43 to 1.50)
Social worker on staff/100 beds	0.93% (−0.16 to 2.00)	0.83% (0.33 to 1.30)	0.99% (−0.19 to 2.20)	0.44% (−0.10 to 0.98)
Pressure ulcers	−0.28% (−1.40 to 0.82)	−0.69% (−1.20 to −0.20)	−1.43% (−2.60 to −0.26)	−0.64% (−1.20 to −0.10)
Restraints	−0.67% (−1.70 to 0.36)	−0.35% (−0.81 to 0.12)	−0.74% (−1.80 to 0.35)	−0.13% (−0.64 to 0.38)

Note: Values represent percent differences in RSVRs among counties grouped in the highest tertile of a specific predictor compared counties in the lowest tertile. Reference for all comparisons is the lowest tertile of each potential predictor.

Abbreviations: ADL, activities of daily living; CNA, certified nursing assistant; FTE, full-time equivalent; LPN, licensed practical nurse; NH, nursing home; RN, registered nurse.

other non-Medicare non-Medicaid payer residents, higher average daily census counts, and counties classified as rural settings. Non-modifiable NH-level predictors associated with decreases in RSVRs included higher percentage of NHs part of multi-facility corporations within the county sample (SS13-14: −0.82%, SS14-15: −2.11%, LS13-14: −0.80%, LS14-15: −0.94%), higher occupancy rates, higher percentage of Medicare residents, higher admissions per bed, higher average acuity index, and higher percentage of for-profit NHs within the county.

Modifiable NH-level predictors that were associated with higher RSVRs included higher RN to total nurse ratio (SS13-14: 3.05%, SS14-15: 2.20%, LS13-14: 0.04%, LS14-15: −0.30%), higher total LPN hours, higher total SLP FTEs, and higher total social worker FTEs/100 beds. Decreases in RSVRs were found to be associated with higher average rate of hospitalizations per resident-year (SS13-14: −1.59%, SS14-15: −1.35%, LS13-14: 0.04%, LS14-15: −0.08%), higher percentage of NH residents who had a pressure ulcer, higher percentage of NH residents who were restrained, higher total CNA hours, higher CNA to total nurse ratio, and higher total physician extender FTE/100 beds.

Stability analysis

The stability analysis (Table S3) produced results that were consistent with the main findings. While excluded counties were predominately excluded in analyses of the short-stay subcohorts, there was no significant difference in the median RSVR or geographic variation across counties. Our findings were also consistent when using Huber–White standard errors for our multivariable linear regression models.

DISCUSSION

In this large national retrospective cohort study of NH residents from 2013 to 2015, we found notable geographic variation in vaccination rates for both the short- and long-stay populations. The foundational evidence we provide can inform strategic efforts at the state- and county-levels to improve the health outcomes of NH residents by increasing influenza vaccination. Our findings also reveal that crude estimates of vaccination rates were often higher than RSVRs, an attenuation resulting from lower vaccine use among a larger number of counties with sicker NH residents. Accounting for differences in NH resident-level characteristics across counties also changed inferences about which counties might be the best targets for NH quality improvement interventions.

The geospatial variation in vaccination rates that we documented among older adults in NHs is generally consistent with previously documented state-level variation.[9,10] Our results related to the drivers of vaccination in NHs concord with prior work establishing that vaccination rates are higher in NHs with better staffing.[22,25,26] Our findings also agree with other studies of important drivers of the associations between vaccination rates and non-modifiable NH-level predictors. NHs in rural counties, NHs operated by the government or non-profit organizations, NHs not affiliated with multi-facility corporations, and NHs with fewer Medicare residents all had higher vaccination rates.[13,14]

While prior studies have described state-level NH resident vaccination rates, our findings reveal new patterns of heterogeneity in vaccination rates at the county-level. High- and low-vaccinating counties were identified in most states such that, for example, subregions of high-vaccinating counties exist in low-vaccinating states. Examples of such subregions are those surrounding Tallahassee, Florida, and counties between San Antonio and Austin, Texas. Among states in the middle distribution of state-level variation in vaccination among NH residents, more heterogeneity across counties was observed. South Carolina, ranked in the middle quintile for vaccination,[9,10] contains counties with high RSVRs in the westernmost regions of the state, and counties with lower RSVRs among coastal communities. More studies are needed to understand the determinants increased heterogeneity among vaccination rates at the county-level within states.

Limitations

The findings of this study must be interpreted in light of several limitations.

First, while observed patterns of NH geospatial vaccine use were comparable between seasons, it is unknown if these patterns have persisted. NH resident influenza vaccine use may have increased over time, but it is unclear if use has continued to increase at the same rate across states and counties.[27] Since analyses were limited to Medicare beneficiaries aged 65 and older, the results may also not generalize to younger individuals with disabilities who reside in NHs. However, individuals aged 65 and older represent the majority of NH residents.[28]

Second, some counties have a higher number of total NH residents, which influences the precision of RSVRs across counties. Our two stability analyses, which restricted to counties with a minimum of five or seven NH residents, respectively, provided evidence that this may not be a major concern because inferences were generally unaffected.

Third, we identified several county-level predictors that may drive the observed patterns of intra-state variation, however, other potential drivers such as hospital-NH relationships, county-level incidence of influenza, local attitudes toward vaccination, and county-level NH-staff vaccination rates may also influence vaccine use at the county level as opposed to the NH or state level.[8,22] Staff vaccination can not only lessen severity of illness and prevent spread through herd-immunity, but also prevent absenteeism in the presence of an outbreak.[5,29] Current CMS regulations include requirements for offering NH residents vaccination, but state public health laws also exist to ensure vaccination of both NH residents and staff.[30,31] Arkansas, a state with many high performing counties, and Florida, a state with many low performing counties, had similar influenza vaccination laws for NH residents, but Florida had no existing state law for NH staff vaccination.[31]

Finally, the associations we estimate between county-level predictors and vaccination are not estimates of causal effects and should not be interpreted as such.

CONCLUSIONS AND IMPLICATIONS

The CDC, CMS, or other national entities could use data readily accessible to them to calculate standardized vaccination rates that better enable valid comparisons of influenza vaccine use across geographic units. These estimates could then be disseminated regularly to local stakeholders and used to deploy quality improvement and other interventions to improve vaccination rates in NHs at the county level. Current interventions that might be deployed using our findings include The Immunization Champions, Advocates and Mentors Program.[32] While some successful local interventions to improve NH resident vaccination have been previously described,[33] an additional understanding of which practices work well in which settings can likely spur progress toward further reducing the disparities that exist between counties. Finally, our findings may also be relevant for guiding the distribution and uptake of COVID-19 and other vaccines should similar geographic patterns exist.

In summary, wide county-level geographic variation in influenza vaccine use among long-stay and short-stay NH residents was observed in this study. In combination with information about the geospatial variation in influenza in NHs, this information about the geospatial variation in vaccine use should be used by local public health authorities and clinicians to target interventions to improve vaccine use to counties with both high rates of infection and low rates of vaccine use in their NHs. The results can also be used to identify areas that are in need of other interventions to reduce infections, such as better infection preventionist staffing models. Additional research is warranted to further elucidate the sources of geographic variation in vaccine use and support improved health outcomes of NH residents.

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CONFLICT OF INTEREST

J.B.B.S., E.B., M.R.R., P.M., B.H.B., R.B., and A.R.Z. declare no conflicts of interest. R.V.A., M.M.L., and A.C. are employed by Sanofi Pasteur. K.W.M. reports grants from Seqirus Pharmaceuticals, Sanofi Pasteur and Pfizer related to pneumococcal pneumonia and influenza vaccination in the long-term care setting., S.G. reports grants from Seqirus Pharmaceuticals, Sanofi Pasteur; and consulting or speaker fees from Sanofi, Seqirus, Merck, Longeveron, and the Gerontological Society of America related to vaccines or nursing home care quality.

AUTHOR'S CONTRIBUTIONS

J.B.B.S. and E.B. participated in conceiving the study, data collection, data analysis, interpretation of the data, writing and critical revision of the manuscript for important intellectual content, and final approval of the manuscript submitted. S.G. and A.R.Z. participated in conceiving the study, data collection, interpretation of the data, critical revision of the manuscript for important intellectual content, and final approval of the manuscript submitted. M.R.R., K.W.M, P.M, R.V.A, B.H.B, R.B., M.M.L, and A.C. participated in interpreting results, providing critical revisions, and final approval of the manuscript submitted.

SPONSOR'S ROLE

Employees of the sponsor (R.V.A., M.M.L., and A.C.) participated in interpretation of the data, review of the manuscript, and final approval of the submitted manuscript. The study sponsor was not responsible for analyzing the data or preparing the initial manuscript draft.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

Figure S1 Consort Diagram of Study Cohort, Stratified by Influenza Season, N = 2,817,217.
Text S1. Description of Nursing Home-Level and County-Level Predictors for Examining Determinants of Vaccination.
Table S1. Covariates Included in Risk-adjustment.
Table S2. Multivariable Linear Regression Analyses to Identify Factors Associated with County-level Risk-Standardized Influenza Vaccination Rates Among Short-Stay and Long-Stay NH Residents, Stratified by Season, N = 2798 counties.
Table S3. County-Level Risk-Standardized Vaccination Rates of Long-Term Care Facility Residents Stability Analysis, by Season and Cohort.

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