

Supplementary Appendix

Supplement to: McGarry BE, Barnett ML, Grabowski DC, Gandhi AD. Nursing home staff vaccination and Covid-19 outcomes. N Engl J Med. DOI: 10.1056/NEJMc2115674

This appendix has been provided by the authors to give readers additional information about the work.

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METHODS

DATA

Data for this study primarily come from the Centers for Medicare and Medicaid Services (CMS) COVID-19 Nursing Home Data database. These publicly available data provide information submitted on a weekly basis, by skilled nursing facilities (SNFs) to the CDC's National Healthcare Safety Network Long-term Care Facility COVID-19 Module.¹ Questions included in the module cover a number of topics, including the weekly counts of COVID-19 cases among staff and residents, shortages of staff and PPE, the use of on-site COVID-19 antigen testing, and turnaround time for results of lab-based PCR testing. Response rates to this survey are consistently high (~98% of eligible U.S. nursing homes).

In May of 2021, CMS began requiring nursing homes to report resident and staff vaccination rates on a weekly basis with penalties imposed on facilities that were not in compliance by the week ending June 18, 2021.² Facilities report the percent of residents (who stayed at least 24 hours in the nursing home during the week of data collection) who received completed doses of an authorized COVID-19 vaccine (i.e, 2 doses of Moderna or Pfizer-BioNTech, 1 dose of Janssen), and the percent of all healthcare personnel (eligible to work at least a portion of 1 day during the week of data collection [including staff who are on temporary leave]) who received completed doses of an authorized COVID-19 vaccine.

We obtained information about nursing homes, including overall quality ratings, profit status, and bed size from the 2021 Nursing Home Compare Provider Information dataset.³ Additional information about nursing homes, including the racial/ethnic composition of residents, the share of residents with Medicaid, and chain affiliation were obtained from the 2017 Certification and Survey Provider Enhancement Reports (CASPER) system and 2017 Minimum Data Set (MDS) assessments, both through the National Institute on Aging-funded LTCFocus.org website.⁴ Staff information was obtained from individual-level staffing records

submitted by nursing homes during the second quarter of 2021 as part of CMS's mandatory payroll-based journal (PBJ) electronic staffing reporting system.^{5,6} Information on weekly county COVID-19 case rates were obtained from the NYTimes database.⁷

VARIABLE CONSTRUCTION

Outcomes

Outcome variables were the weekly cumulative number of confirmed COVID-19 cases among residents and staff and the number of COVID-19 deaths among residents. Outcomes were operationalized as rates per 100 nursing home beds.

Independent Variables

The primary independent variable was the percent of healthcare staff with a completed COVID-19 vaccine as of the week ending June 13, 2021. This week was the first in which more than 75% of nursing homes reported staff vaccination rates, likely in anticipation of CMS penalties for non-compliance in the following week. Nursing homes were classified into quartiles of staff vaccine coverage using reported rates in this week. In using quartiles, we allow for non-linear relationships between levels of staff vaccination coverage and the outcomes of interest while facilitating a meaningful comparison between facilities with "high" and "low" baseline staff vaccination rates. In a sensitivity analysis, we show the robustness of our findings to using continuous specification for staff vaccine coverage that include a second-degree polynomial to allow for non-linear relationships.

County COVID-19 prevalence was defined as the cumulative rate (per 100,000 population) of new COVID-19 cases for the weeks ending June 13, 2021 through August 22, 2021. Counties were classified into quartiles of COVID-19 prevalence using this measure.

Covariates

Covariates included the following facility characteristics: profit status (including for-profit, non-profit, and government owned), overall 5-star quality ratings, the percent of nursing home

residents who were non-white race (categorized into quartiles), the percent of nursing home residents with Medicaid (categorized into quartiles), facility size (categorized as 1-50 beds, 51-100 beds, 101-150 beds, 151-200 beds, and 200+ beds), overall staff size (defined as the average number of unique employees who worked in a nursing home per week, categorized into quartiles), part-time staff size (defined as the average number of unique employees who worked less than 35 total hours in a facility per week, categorized into quartiles), direct care staffing levels (defined as the number of direct care hours per resident day, categorized into quartiles), and direct care skill mix (defined as registered nurse hours per resident day, categorized into quartiles).

We also constructed two measures that capture nursing homes' prior experience with COVID-19 and the level of naturally acquired immunity among residents and staff. Specifically, we measured the cumulative COVID-19 case rate resident and staff between June 7, 2020 and May 30, 2021. Both measures were categorized into quartiles.

Finally, we account for time-variant community incidence of COVID-19 cases with a weekly measure of new COVID-19 cases per 100,000 population at the county level.

In a sensitivity analysis, we show the robustness of our findings to using continuous covariate controls rather than categorical measures reflecting quartiles. In these specifications, we utilize second-degree polynomials in each control to allow for non-linear relationships. Additionally, we winsorize these continuous measures at the 1st and 99th percentile to address outliers. See results in Table S3.

SAMPLE

Among the 15,171 nursing homes in the NHSN data, we restricted the sample to those who reported staff vaccine coverage for the week ending June 13, 2021 and who reported COVID-19 outcomes in each week of the study period. These restrictions result in a final sample of 12,364 nursing homes (81% of total).

We followed outcomes through the week ending August 22, 2021 to avoid confounding due to the Biden Administration announcing plans for a federal vaccine mandate and several large nursing home chains introducing staff vaccine mandates in late August.

ANALYSIS

To estimate the association between baseline staff vaccination rates and weekly COVID-19 outcomes, we fit linear regression models. The key independent variable of interest was an interaction term between staff vaccine coverage quartiles and county COVID-19 prevalence. This term allows for the comparison of outcomes between nursing homes with differing levels of staff vaccine coverage given different levels of community spread. This interaction term was further interacted with indicators for the 11 weeks in our study window, allowing us to flexibly model the relationship of between staff vaccine coverage (for a given level of community COVID-19 prevalence) and outcomes over time. Models included the covariates described previously, as well as county fixed effects which restrict comparisons to nursing homes located within the same county. Robust standard errors were clustered at the facility level. Our approach is summarized in Equation 1.

$$Y_{i,t,c} = \beta_c + \beta_1(T_t * S_i * C_c) + \beta_2 T_t * C_c + \beta_3 X_i + \beta_3 R_{t,c} + \varepsilon_{i,t,c} \quad \text{Eq. 1}$$

$Y_{i,t,c}$ represents the COVID-19 outcome of interest for facility i located in county c in week t . T_t represents a vector of indicators for each week in our study sample, S_i is a set of indicators for quartiles of baseline staff COVID-19 vaccine coverage, and C_c is a set of indicators for quartiles of county COVID-19 prevalence. X_i is a vector of time-invariant facility-level controls and $R_{t,c}$ represent the county COVID-19 new case rate in county c in week t , and β_c is a county fixed effect term. In a sensitivity analysis, we replace the county fixed effect with a county-level random effect. See table S3 for results. We use heteroscedasticity-robust standard errors clustered at the facility level. $\varepsilon_{i,t,c}$ is an error term that is allowed to be heteroscedastic, as well

as correlated for observations within the facility. In other words, we use heteroscedasticity-robust standard errors that are clustered at the facility level.

We used our fitted model to produce the weekly adjusted estimates and 95% confidence bands presented in the manuscript Figure. To estimate the number of preventable cases and deaths, we again used the fitted model to predict the outcomes using facilities' observed levels of staff vaccine coverage and compared these estimates to predicted outcomes under the condition of all nursing homes being the top category of staff vaccine coverage.

ADDITIONAL RESULTS

Table S1. Sample Description

		Staff COVID-19 Vaccine Coverage				P-value
		Quartile 1 (lowest)	Quartile 2	Quartile 3	Quartile 4 (highest)	
N		3034	3058	3076	3196	
Staff vaccine coverage at baseline (%), mean (SD)		31.0 (9.1)	49.7 (4.1)	63.6 (4.2)	82.7 (8.1)	<0.001
Resident vaccine coverage at baseline (%), mean (SD)		71.4 (16.4)	78.8 (13.8)	82.5 (13.4)	85.9 (12.6)	<0.001
Resident COVID-19 Cases per 100 beds June 1, 2020-May 30, 2021, mean (SD)		39.6 (25.4)	37.8 (26.5)	33.3 (26.3)	31.2 (27.1)	<0.001
Staff COVID-19 Cases per 100 beds June 1, 2020-May 30, 2021, mean (SD)		36.4 (19.9)	36.3 (20.8)	34.7 (21.7)	32.9 (21.8)	<0.001
County COVID-19 prevalence (per 100,000 population) during study window , mean (SD)		1701.0 (1145.7)	1359.7 (1023.9)	1103.4 (831.9)	1061.6 (729.5)	<0.001
Facility bed size	1-50	221 (7.3%)	301 (9.8%)	341 (11.1%)	525 (16.4%)	<0.001
	51-100	1127 (37.1%)	1099 (35.9%)	1130 (36.7%)	1256 (39.3%)	
	101-150	1190 (39.2%)	1157 (37.8%)	1002 (32.6%)	894 (28.0%)	
	151-200	354 (11.7%)	335 (11.0%)	376 (12.2%)	323 (10.1%)	
	201+	142 (4.7%)	166 (5.4%)	227 (7.4%)	198 (6.2%)	
Profit Status	Non-Profit	413 (13.6%)	719 (23.5%)	857 (27.9%)	829 (25.9%)	<0.001
	Government Owned	149 (4.9%)	194 (6.3%)	178 (5.8%)	140 (4.4%)	
	For Profit	2472 (81.5%)	2145 (70.1%)	2041 (66.4%)	2227 (69.7%)	
Percent of residents with Medicaid (quartiles)	1 (lowest)	451 (14.9%)	647 (21.2%)	797 (25.9%)	949 (29.7%)	<0.001
	2	702 (23.1%)	761 (24.9%)	722 (23.5%)	721 (22.6%)	
	3	813 (26.8%)	778 (25.4%)	731 (23.8%)	645 (20.2%)	
	4 (Highest)	853 (28.1%)	674 (22.0%)	649 (21.1%)	716 (22.4%)	
Percent of resident who are non-white race (quartiles)	1 (lowest)	504 (16.6%)	676 (22.1%)	741 (24.1%)	603 (18.9%)	<0.001
	2	647 (21.3%)	753 (24.6%)	769 (25.0%)	653 (20.4%)	
	3	809 (26.7%)	743 (24.3%)	707 (23.0%)	642 (20.1%)	
	4 (Highest)	795 (26.2%)	629 (20.6%)	598 (19.4%)	958 (30.0%)	
Overall 5-star quality rating, mean (SD)		2.8 (1.4)	3.1 (1.4)	3.3 (1.4)	3.6 (1.4)	<0.001
Total resident COVID-19 cases (per 100 beds) during study window, mean (SD)		6.1 (19.2)	4.5 (19.3)	3.8 (17.7)	2.7 (11.5)	<0.001
Total staff COVID-19 cases (per 100 beds) during study window, mean (SD)		9.9 (15.9)	8.0 (15.5)	7.0 (18.7)	4.8 (10.3)	<0.001
Total resident COVID-19 deaths (per 100 beds) during study window, mean (SD)		0.7 (4.8)	0.6 (4.9)	0.4 (2.7)	0.3 (2.2)	<0.001

Table S2. County COVID-19 Case Rates by Quartiles of County COVID-19 Prevalence

	County COVID-19 Prevalence June 13, 2021 - August 22, 2021				P-Value
	Quartile 1 (Lowest)	Quartile 2	Quartile 3	Quartile 4 (Highest)	
County COVID-19 prevalence (per 100,000 population) during study window , mean (SD)	446.1 (88.0)	738.5 (132.9)	1344.8 (167.5)	2697.9 (879.2)	<0.001

Figure S1. Cumulative Unadjusted COVID-19 Outcomes by Nursing Home Staff Vaccination and County COVID-19 Prevalence, Weeks Ending June 13, 2021 to August 22, 2021

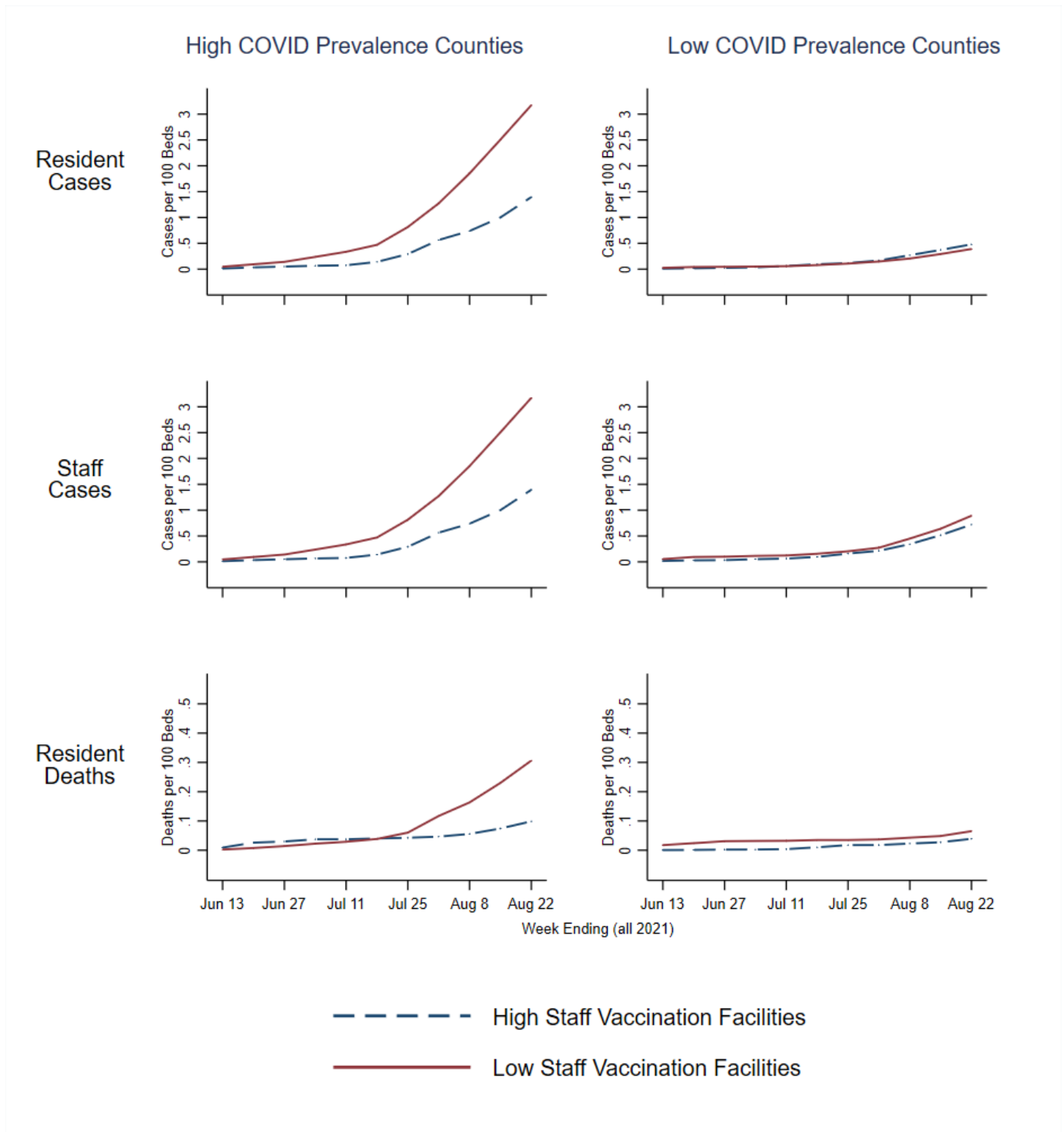
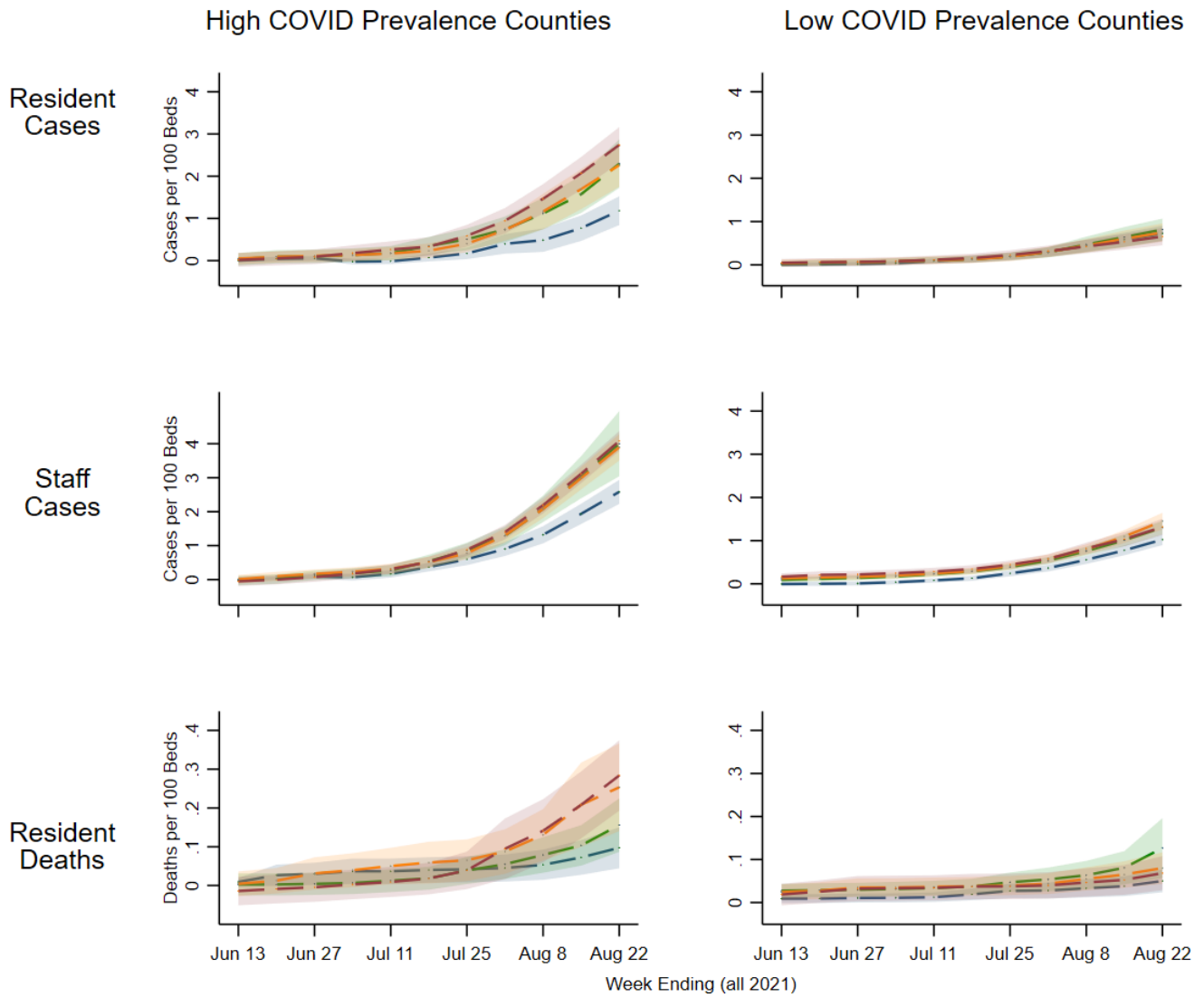
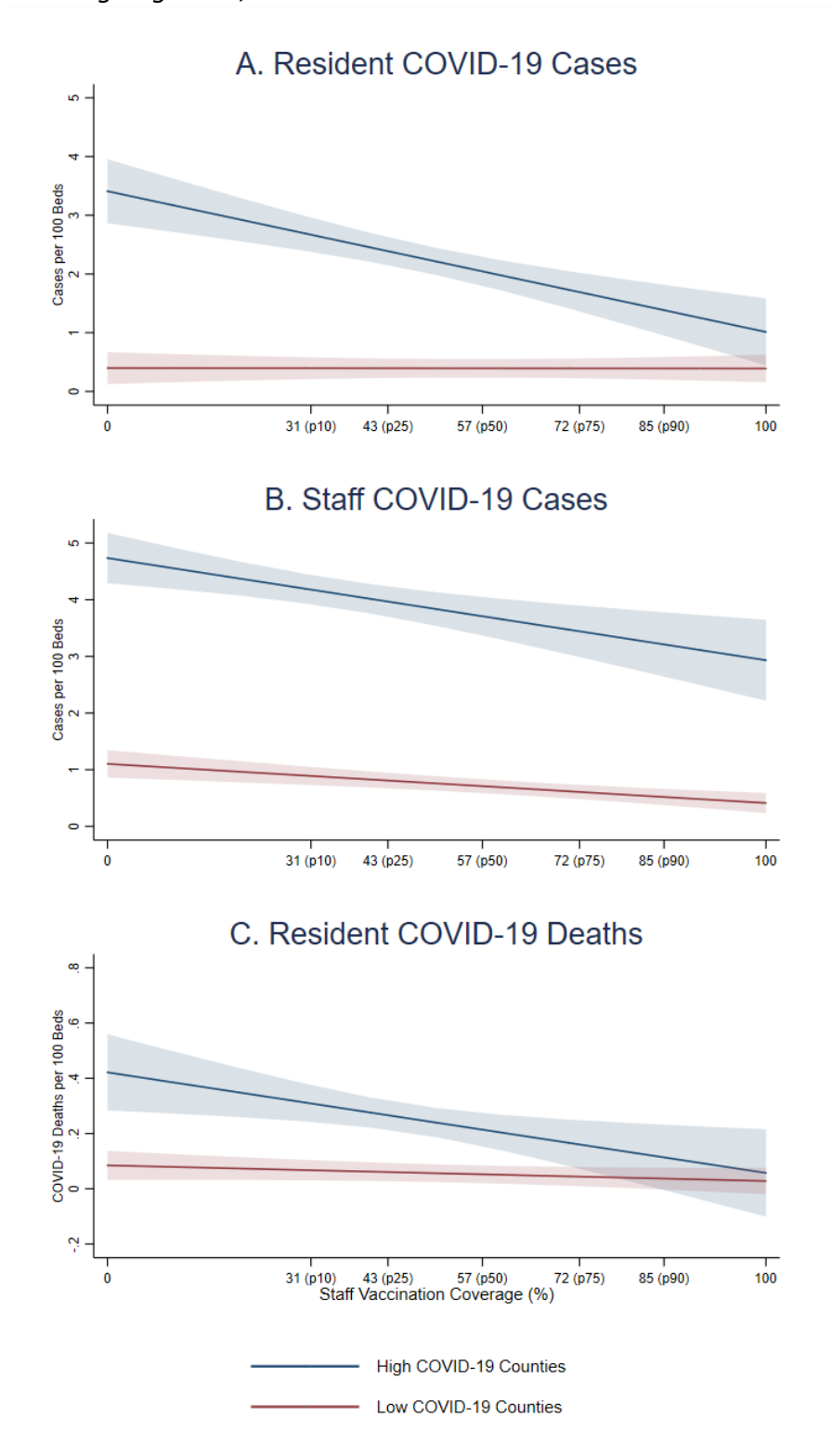


Figure S2. Cumulative Adjusted COVID-19 Outcomes by Nursing Home Staff Vaccination Coverage (all 4 quartiles) and County COVID-19 Prevalence, Weeks Ending June 13, 2021 to August 22, 2021



- — — — — Quartile 4- Highest Staff Vaccination Facilities
- — — — — Quartile 3
- — — — — Quartile 2
- — — — — Quartile 1- Lowest Staff Vaccination Facilities

Figure S3- Sensitivity Analysis: Relationship between COVID-19 outcomes and a Continuous Staff Vaccination Measure for the Week Ending August 22, 2021



Notes: Figure plots adjusted outcome rates as a function of a continuous staff vaccination measure for the last week of our study window (week ending August 22, 2021). Estimates obtained from a linear regression identical to the one described in Equation 1, except indicators for quartiles of staff vaccine coverage have been replaced with a continuous measure. The x-axis is labeled at select percentiles of baseline staff vaccination coverage (denoted in parentheses) within sample nursing homes.

Table S3. Additional Sensitivity Analyses

		(1) Base Model	(2) Random Effects	(3) Continuous Covariates
Estimated Difference between low and high staff vaccination facilities				
Resident COVID-19 Cases	Low COVID-19 Prevalence County	-0.070 (-0.289, 0.149)	-0.073 (-0.310, 0.164)	-0.058 (-0.279, 0.163)
	High COVID-19 Prevalence County	1.559*** (1.047, 2.071)	1.560*** (1.051, 2.069)	1.463*** (0.933, 1.994)
Staff covid-19 Cases	Low COVID-19 Prevalence County	0.295*** (0.104, 0.487)	0.297*** (0.119, 0.475)	0.295*** (0.103, 0.487)
	High COVID-19 Prevalence County	1.497*** (1.056, 1.939)	1.513*** (1.058, 1.969)	1.367*** (0.923, 1.810)
Resident COVID-19 Cases	Low COVID-19 Prevalence County	0.018 (-0.023, 0.059)	0.019 (-0.018, 0.056)	0.015 (-0.025, 0.056)
	High COVID-19 Prevalence County	0.187*** (0.077, 0.296)	0.189*** (0.074, 0.303)	0.178*** (0.067, 0.290)

***P<0.001

Results present the estimated difference in the cumulative outcome rate for the week ending August 22, 2021 (the last week of the study window) between nursing homes with low vs. high staff vaccination rates, by county COVID-19 prevalence. 95% confidence intervals are displayed in parentheses below the estimates.

Estimates obtained from linear regression containing a 3-way interaction between weekly indicators, indicators for quartiles of county COVID-19 prevalence, and indicators for quartiles of baseline staff vaccination rates. Column (1) reflects the results presented in the letter Figure. Column (2) replace county-level fixed effects with random effects. Column 3 uses winsorized continuous covariates and second order polynomials (as opposed to quartile categories) for the following covariates: weekly county COVID-19 case rates, staff and resident prior COVID-19 infection rates, resident vaccination rates at baseline, the share of nursing home residents with Medicaid and who are non-White race, direct care and nursing staff-to-resident ratios, and overall- and part-time staff sizes.

Table S4. Estimated Number of Preventable COVID-19 cases and deaths

	Observed Outcomes	Adjusted Outcomes (fitted values)	Counterfactual Estimates (fitted values assuming all SNFs in highest quartile of staff vaccination)	Potentially Preventable Outcomes (Observed – Counterfactual Estimates)
Resident COVID-19 Cases	15,948	16,755 (16,487, 17,023)	11,980 (11,837, 12,124)	4,775 (4,631, 4,919)
Staff COVID-19 Cases	26,002	28,558 (28,146, 28,969)	21,057 (20,771, 21,344)	7,501 (7,354, 7,646)
Resident COVID-19 Deaths	1,457	1,591 (1,566, 1,615)	888 (875, 900)	703 (686, 720)

Notes: Estimates obtained from the “Base Model” linear regression (described in the note for Tables S3). 95% confidence intervals displayed in parentheses under estimated values.

REFERENCES

1. Centers for Medicare & Medicaid Services. COVID-19 Nursing Home Data. <https://data.cms.gov/stories/s/COVID-19-Nursing-Home-Data/bkwz-xpvq/>. Published 2020. Accessed June 18, 2020.
2. Alonso-Zaldivar R. Medicare requires nursing homes to report COVID vaccinations. Associated Press. [https://apnews.com/article/nursing-homes-coronavirus-pandemic-medicare-business-health-90a6055a5469e12b634fa2d1f9b6f3e8#:~:text=WASHINGTON%20\(AP\)%20%E2%80%94%20Medicare%20will,staff%2C%20the%20government%20said%20Tuesday](https://apnews.com/article/nursing-homes-coronavirus-pandemic-medicare-business-health-90a6055a5469e12b634fa2d1f9b6f3e8#:~:text=WASHINGTON%20(AP)%20%E2%80%94%20Medicare%20will,staff%2C%20the%20government%20said%20Tuesday). Published 2021. Updated May 11, 2021. Accessed May 24, 2021.
3. Centers for Medicare & Medicaid Services. Provider Info. Nursing Home Compare Data Web site. <https://data.cms.gov/provider-data/dataset/4pq5-n9py>. Published 2021. Accessed May 15, 2021.
4. Brown School of Public Health. LTCFocus. <http://ltafocus.org/>. Published 2020. Accessed June 9, 2020.
5. Geng F, Stevenson DG, Grabowski DC. Daily Nursing Home Staffing Levels Highly Variable, Often Below CMS Expectations. *Health Affairs*. 2019;38(7):1095-1100.
6. Gandhi A, Hu Y, Grabowski DC. High Nursing Staff Turnover in Nursing Homes Offers Important Quality Information. *Health affairs*.40(3), pp. 384-391.
7. The New York Times. Coronavirus in the U.S. <https://www.nytimes.com/interactive/2020/us/coronavirus-us-cases.html>. Published 2020. Accessed 11/30/2020.