Does SARS-CoV-2 Surveillance Testing Prevent COVID-19 Transmission? Evidence from the US Nursing Home Industry

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Abstract

Surveillance testing for COVID-19 is thought to be a critical tool to control pandemic outbreaks and has been a key part of global response to COVID-19. Despite the widespread use of this tool to prevent viral spread, empirical evidence in support of surveillance testing of asymptomatic or pre-symptomatic individuals is largely limited to modeling studies. Leveraging detailed information on nearly 90 million COVID-19 tests, we examine the impact of surveillance testing on outbreaks in US nursing homes. Specifically, we evaluate whether the volume of weekly surveillance testing of nursing home staff was associated with COVID-19 cases and deaths among nursing home residents, a population highly susceptible to adverse outcomes related to COVID. We address the endogeneity of test volume with ongoing outbreaks (i.e., nursing homes perform more tests when there are active COVID-19 cases or the risk of a COVID-19 outbreak is elevated) by estimating nursing homes' propensity to test staff during weeks in which no staff or resident cases are detected relative to county-by-week average test volume. Additionally, we examine whether differences in outcomes exist by the type of test used (i.e., rapid point-of-care tests vs. lab-based tests) and, for those facilities using lab-based tests, test result turnaround time. We find that moving from the 10^{th} to the 90^{th} percentile of surveillance test propensity reduces resident cases and death from COVID by about 25% prior to the availability of vaccines. At the same time, high-test facilities are found to have about 20% more staff COVID-19 cases, consistent with surveillance testing protecting residents by detecting infected staff and disrupting viral transmission chains. Our estimates indicate that prior to vaccine availability, approximately 420 resident deaths could have been prevented for each week in which nursing homes performed 1 additional test per employee. Conditional on test volume, we find no difference in outcomes between facilities that primarily used point-of-care vs. lab-based tests, suggesting that the low-cost point-of-care tests (about $5 per test) could produce a cost per life saved of $12,630. Among facilities that predominantly used non-point-of-care tests, receiving results in 2 days or less reduced resident deaths by 28% in comparison to

facilities that received results in 3 days or more on average. This study provides some of the first real-world evidence that repeated surveillance testing can be a highly cost-effective tool to prevent the spread of infectious diseases, and that test volume with prompt turnaround time is more important than the type of test used. Furthermore, study results indicate that the US policy response to COVID in nursing homes under-invested in staff surveillance testing and that a significant number of deaths could have been prevented with more frequent (e.g., 2 tests per employee-week) testing routines.

Introduction

Surveillance testing for COVID-19 is thought to be a critical tool to control pandemic outbreaks.[1,2] Proactive testing of healthy individuals is necessary because asymptomatic or pre-symptomatic individuals are key vectors of disease spread.[3] This problem has led many organizations with high-risk individuals or closed communities to mandate regular surveillance testing for COVID-19, including health care facilities, prisons, schools, universities, and workplaces. The utility and cost-effectiveness of surveillance testing is supported by a wide range of mathematical, epidemiologic, and economic modeling studies,[4-10] but there are few studies with real-world data examining the outcomes of different testing strategies in a large population.[11,12] A recent systematic review in December 2021 identified only 4 studies, all "fair" or "poor" quality, examining the effectiveness of serial COVID-19 testing among asymptomatic individuals, with mixed results.[12] Because of the sparse literature on surveillance testing in the real world and its inconclusive results, the utility and value of surveillance testing in practice, as opposed to in simulation, is still unclear.

An especially important context for surveillance testing is in skilled nursing facilities (SNFs), whose residents and staff comprised over 20% of Covid-19 deaths in the US as of the end of 2021.[13] Surveillance testing of SNF-employed staff is particularly important because pre-symptomatic staff are likely the primary mechanism for COVID-19 to enter facilities.[14-16] Federal authorities suggest that SNFs in areas of high COVID-19 transmission to perform routine Covid-19 screening tests for asymptomatic staff up to twice weekly, though in practice this was difficult to achieve for most SNFs until at least 2021 because of test shortages, staffing shortages, supply chain issues, and slow test turnaround time.[17,18]

The large size of the nursing home industry—1.7 million staff and over 4 million short and long stay residents[19]—and substantial variation in adoption of surveillance testing across the nation's more than 15 thousand facilities provides a unique opportunity to evaluate the real-world effectiveness of surveillance testing approaches. This knowledge is crucial in

retrospectively evaluating whether earlier or more frequent surveillance testing could have lessened the devastation of COVID-19 on nursing homes, as well as in evaluating surveillance testing as a public health tool for future pandemics. Moreover, the continued threat of new coronavirus variants that could escape vaccine immunity means that testing will remain necessary in 2022 and beyond. The Biden administration internally projected that the US could face over 100 million new COVID-19 infections in late 2022.[20] Defining the potential benefit, or cost, of different testing approaches is critical data to guide public health policy for a wide range of institutions.

Using comprehensive data on COVID-19 testing, staff and resident cases and deaths in all federally-accredited SNFs, we examined the relationship between SNF testing strategies for staff, including frequency, test turnaround, and test type (PCR or antigen), and the magnitude of COVID-19 outbreaks among residents. To our knowledge, this represents the largest real-world evaluation of the impact of surveillance testing strategies in the literature.

Methods

Study Overview

We conducted a retrospective cohort study of U.S. nursing homes to examine the association of facilities' surveillance testing patterns with COVID-19 outcomes among residents. A key challenge to examining the impact of COVID testing on outcomes is that testing behavior is responsive to COVID outbreaks. That is, facilities experiencing an outbreak may perform more tests than neighboring facilities without an active outbreak as they attempt to identify and isolate infected staff and residents. This endogenous relationship biases simple point-in-time comparisons between test volumes and COVID-19 case rates (Appendix Figure XX).

To overcome this source of bias, we used multiple approaches to isolate variation in testing behaviors that is plausibly exogenous to resident COVID-19 outcomes. First, we focused

on surveillance testing, defined as tests performed in a nursing home in a week where there were no cases among staff or residents. This restriction ensures that we measure testing behaviors not driven by facilities' responses to ongoing outbreaks. Second, we examined the relationship between *staff* testing and *resident* outcomes, thereby reducing concerns that the number of cases detected among residents may mechanically be a function of the number of resident tests performed. Third, we construct a novel measure of nursing homes' relative propensity to perform staff surveillance tests in comparison to neighboring nursing homes at a given point in time.

Data Sources

The primary data source for this study was the Centers for Medicare and Medicaid Services (CMS) COVID-19 Nursing Home Data database,[21] which contains information submitted on a weekly basis by SNFs to the CDC's National Healthcare Safety Network (NHSN). All Medicare and Medicaid certified nursing homes are required to submit data to the NHSN database. Our period of analyses covers November 22, 2020 through March 20, 2022, which corresponds the period where all relevant testing questions were included in the NHSN COVID-19 modules. This data source contains information on almost 90 million nursing home staff COVID-19 tests.

Additionally, we used a number of publicly available data sources. We obtained information about the size of facilities' staff from the CMS Payroll-Based Journal Employee Detail Data (PBJ Data) and information about nursing homes—including their quality scores, ownership structure, and resident characteristics—from the LTCFocus.org database and the CMS Nursing Home Compare Provider Information file.[22,23] Finally, we used the The New York Times COVID database to obtain weekly county-level COVID-19 case rates.[24]

Study Sample and Outbreak Definition

To examine the relationship between surveillance testing and COVID-19 outcomes, we constructed a study sample consisting of SNF-weeks during which SNFs were experiencing a COVID-19 "outbreak" in the study period from November 2020-March 2022. We defined the start of an outbreak within a facility as the first week of any confirmed COVID-19 cases in residents or staff following 2 consecutive weeks of no cases within the facility. The week of the initial case was defined as outbreak week 1, and we followed outcomes over subsequent weeks until there were two consecutive weeks with no new staff or resident cases or 7 follow-up weeks, whichever came first. In instances where an outbreak ended before 7-weeks follow-up, we tracked resident COVID-19 deaths for an additional 2 weeks to account for the lag between COVID-19 cases and deaths.

Defining SNF Surveillance Testing Propensity

We defined surveillance testing volume as the total number of staff COVID-19 tests, including point-of-care and non-point-of-care tests, performed in weeks in which facilities had no confirmed COVID-19 cases among residents and staff. We normalized this measure to the size of the nursing home staff, defined as the weekly average number of unique individuals with any reported hours in the PBJ data for a SNF in the first quarter of 2021. Weekly COVID-19 tests per staff member were Winsorized at the 1^{st} and 99^{th} percentiles to account for extreme values.

Because test volume is likely endogenous to a number of factors that could also directly impact resident COVID-19 cases and deaths, we estimated each nursing homes' latent propensity for surveillance testing over the entire study window using a regression framework. To do this, we restricted the sample to all SNF-weeks with no staff or resident COVID-19 cases and estimated a linear regression of weekly tests per staff member on SNF fixed effects as well as other controls, including county-week fixed effects and time-varying weekly measures of staff and resident vaccination rates by SNF.

The facility fixed effects from this model defined our primary exposure of interest: each nursing home's latent, time-invariant propensity for surveillance testing. The other controls help

to ensure that our exposure measure does not reflect variation in testing due to location, time, or vaccination coverage. The county-week fixed effects control for variation in surveillance test volumes stemming from variation in community COVID-19 levels and local testing patterns both across counties and over time. Likewise, including staff and resident vaccination rates controls for differences in testing levels attributable to the differing testing requirements for vaccinated and unvaccinated staff and residents. [25]

The facility fixed effects can be interpreted as a SNF's surveillance testing level relative to its county-week average and adjusted for staff and resident vaccination rates. It reflects facility variation in surveillance testing volume that is not attributable to community-level risk, testing regulations, secular time trends, or degree of vaccine coverage. We used these fixed effects to divide SNFs into "high-test volume" facilities (defined as the 90th percentile of latent test volume) and "low-test volume" facilities (defined as the 10th percentile). See Appendix for full details.

Study Outcomes

Our two primary outcomes were weekly cumulative resident COVID-19 cases and deaths, as reported by facilities in the NHSN modules during an outbreak. Outcomes were scaled per 100 outbreaks. We focused on outcomes among residents because reported staff cases are, in part, a direct function of key exposure measure—the number of staff tests performed. In secondary analyses in the Appendix, we also examined cumulative staff COVID-19 cases and deaths.

Study Variables

We captured multiple facility and community characteristics. Nursing home characteristics included 5-star quality scores, staffing levels (measured by total direct care and RN hours per resident day), size of nursing home staff (measured by the average daily number of unique employees working in a facility), bed size, the share of nursing home residents that

were non-White race, the share of residents whose primary payer was Medicaid, for-profit status, weekly COVID-19 vaccination rate of residents and staff, and SNFs' prior COVID-19 experience (measured by cumulative staff and resident COVID-19 case rates prior to the start of an outbreak). Community characteristics were the weekly county rate of new COVID-19 cases per 100,000 population. See Appendix for full details on control variables.

We captured SNF testing type and test turnaround time as SNF-level testing variables. For testing type, we determined whether facilities used point-of-care (POC, i.e. antigen test) or non-POC (i.e. nucleic acid test) tests for surveillance testing by calculating the share of total staff tests performed during the week prior to the start of an outbreak that were point-of-care. Based on an observed bimodal distribution of POC test use by facility, we classified SNFs as POC users if more than 20% of their staff tests were this type (Appendix Figure XX; mean percent of POC test use in this group was 92%). We defined test turnaround based on survey responses during the week before and the first week of an outbreak as ≤2 days in both weeks or >2 days in either week. Test turnaround was only defined for SNFs who were not POC test users (i.e., fewer than 80% of staff tests being POC), since POC tests have immediate turnaround by definition.

Statistical Analysis

We estimated the association between testing patterns and weekly resident COVID-19 outcomes within an outbreak using linear regression models. We estimated separate models for each outcome where the key quantities of interest were interaction terms between SNF test propensity and indicators for each outbreak week (i.e., weeks 1-8 following the start of an outbreak). Models included the facility- and county-level covariates described above, as well as county fixed effects and fixed effects for the calendar week in which a facility's outbreak began. We also estimate separate models for SNF subgroups with different testing types (POC, non-POC) and turnaround times (≤2 days, >2 days). Standard errors were clustered at the nursing

home level. For all models, we used our estimates to plot adjusted outcomes for the 8 weeks following the start of an outbreak and examined differences at the end of the follow-up period. See Appendix for full model specification.

To examine whether test volume had different effects during different phases of the pandemic, we stratified our analyses based on the calendar-week in which an outbreak began. Our first period included outbreaks starting between November 22, 2020 and January 17, 2021, capturing a period where residents and staff were mostly unvaccinated. The second period spanned January 18, 2021 through October 31, 2021, a period in which vaccines were widely available and provided strong protection from COVID-19. The third period included outbreaks that started between November 1, 2021 and January 23, 2022. This period corresponds to the Omicron wave of the COVID-19 pandemic when vaccine effectiveness against viral infection may have waned.[26]

We performed a series of sensitivity analyses to examine the robustness of our findings, including estimating Poisson rather than linear, regression models, extending the follow-up time until a week with no cases was detected, and […]. See Appendix for details.

Results

SNF Testing Volume

Over our 61-week study window, we identified 13,971 study-eligible nursing homes and 65,360 outbreaks for an average of 4.7 outbreaks per facility On average, sample facilities performed 1.07 surveillance test per staff member per week with an interquartile range of 0.4 and 1.5 tests (Figure 1; Panel A). Estimated surveillance testing propensities ranged from -0.8 to 1.6 staff tests per week relative to the average within county-week (Panel B). Test propensities were strongly predictive of actual test volumes (r=XX, $p<0.001$, Panel C). SNFs in the high test volume group (90th percentile of latent test propensity) performed an additional 0.56 surveillance tests per staff-member-week relative to its county-week average, compared to

low test volume facilities (10th percentile of latent test propensity), who performed 0.49 fewer surveillance tests than the county-week average.

On average, high test volume facilities were more likely to be non-profit (30.0% vs. 18.9%, p<0.001), less likely to be part of a chain (49.9% vs. 59.9%, p<0.001), and more likely to have a 5-star quality score (28.3% vs. 20.5%, p<0.001) than facilities in the lowest test propensity category. Furthermore, high-testing facilities had lower proportions of non-White residents (16.2% vs. 22.8%, p<0.001) and smaller staff sizes (137.1 vs. 153.5, p<0.001). Staff ratios were generally similar across the 4 testing quartiles.

COVID-19 Outcomes

During an outbreak, high test volume SNFs had significantly fewer resident cases and deaths than low volume facilities (Figure 2; Panel A). For the full study period, there were 534.9 (95% confidence interval [CI]: 522.1, 547.8) cumulative resident COVID-19 cases per 100 outbreaks in high-testing facilities compared to 610.6 (95% CI: 598.1, 623.1) cases per 100 outbreaks in low testing facilities. High test volume SNFs had 43.7 (95% CI: 41.7, 45.6) cumulative resident COVID-19 deaths per 100 outbreaks compared with 52.1 (95% CI: 49.9, 54.2) deaths among low-testing facilities.

The difference between high- and low-test facilities was larger during the pre-vaccine period (Figure 2; Panel B). High test facilities had 766.8 (95% CI: 718.0, 815.5) cases compared to 1,066.8 (95% CI: 1,018.2, 1,115.4) cases per 100 outbreaks in low test volume facilities. High test facilities had 124.2 (95% CI: 114.5, 133.9) deaths per 100 outbreaks vs. 165.5 (95% CI: 155.1, 176.0) deaths in low test volume SNFs.

No significant differences in outcomes between high- and low-test volume facilities were detected for outbreaks that started between June 11, 2021 and October 31.2021 (Figure 2; Panel C). During outbreaks that began between November 1, 2021 and January 23, 2022 (i.e., the Omicron wave), low-test facilities were found to have 76.4 (95% CI: 22.7, 130,1) more

resident cases per 100 outbreaks relative to high-test facilities. No significant difference in resident deaths was found during this period.

The difference between high- and low-test volume SNFs in the pre-vaccine period equates to relative differences of 26% fewer cases and 25% fewer deaths for roughly one additional tests per staff-week. Our estimates suggest that, during the pre-vaccine phase, if every sample facility increased their testing by one test per employee-week, 3,059 resident COVID-19 cases and 421 resident COVID-19 deaths could have been prevented per week of heightened testing (Appendix Table XX).

In supplemental analyses, high-test SNFs were found to have more staff COVID-19 cases during outbreaks relative to low-test SNFs (Appendix Figure XX). This finding is consistent with a mechanism whereby testing prevents resident COVID-19 cases and deaths by detecting more staff cases and halting staff-to-resident transmission of SARS-CoV-2.

Adjusting for surveillance testing volume, there was a small but statistically significant difference in resident cases between POC and non-POC SNFs by outbreak end. Facilities using non-point-of-care tests had 523.7 resident COVID-19 cases per 100 outbreaks (95% CI: 507.4, 539.9) vs. 553.1 (95% CI: 543.4, 562.8) cases in facilities using POC tests. (Figure 3; Panel A). No significant differences in cumulative resident COVID-19 deaths were detected by test type (Figure 3, Panel B). No significant differences were found for either resident COVID-19 cases or deaths were found during the pre-vaccine period (Appendix Figure XX).

Among nursing homes predominantly using the non-point-of-care tests prior to the start of an outbreak, faster test turnaround time was associated with fewer resident deaths. In comparison to facilities reporting average turnaround time of 3-days or more, nursing homes receiving results back in 2 days or less had 43.2 resident COVID-19 deaths per 100 outbreaks (95% CI:40.6, 45.8) at the end of an outbreak vs. 60.8 (95% CI: 53.6, 68.0) deaths among facilities receiving results back in 3 or more days (Figure 4, Panel B). Resident cases were often lower among facilities with faster turnaround time during outbreaks, however this difference was

not significant by the final week of follow-up (Figure 4, Panel A). During the pre-vaccine phase, significant differences in resident cases and deaths were detected at the end of outbreaks (Appendix Figure XX).

Sensitivity Analyses

Results were consistent when models were estimated using Poisson regressions (Appendix Table XX). Results were also substantively similar when outbreak follow-up time was allowed to continue until two-consecutive weeks of no new cases (Appendix Figure XX). [Add sensitivity analysis stuff here]

Discussion

Greater surveillance testing of nursing home staff was associated with significant reductions in resident COVID-19 cases and deaths, particularly in the absence of highly effective vaccines. Greater surveillance testing was also associated with more staff COVID-19 cases during outbreaks, consistent with surveillance testing protecting nursing home resident by detecting more COVID-infected staff, potentially earlier in the disease course, and disrupting potential viral transmission chains. Little difference was detected when comparing nursing homes that predominantly used POC and non-POC tests, but faster turnaround time was found to be associated with reductions in resident deaths among facilities that used non-POC test that require laboratory processing.

Surveillance testing has been a key component of the global response to the COVID-19 pandemic, with numerous governments and industries implementing surveillance testing or "test-to-enter" policies in the hopes of preventing asymptomatic or pre-symptomatic viral spread. The nursing home industry, which has been at the epicenter of the pandemic in the US,[27] is no exception. In the summer of 2020, the Trump administration mandated that nursing homes in states with a 5% COVID positive test rate or greater test all staff at least weekly. In conjunction, the Department of Health and Human services distributed POC test kits and supplies to nearly

all nursing homes well before this technology was available to the general public.[28] The Biden administration continued this emphasis on surveillance testing—the Centers for Medicare and Medicaid services continues to mandate surveillance testing of staff who are not up-to-date with COVID-19 vaccines (depending on community-level COVID-19 transmission) and the administration was reported to be providing approximately 2.5 million antigen POC tests to facilities each week in February of 2022.[29,30] This study provides, to our knowledge, some of the first large-scale real-world evidence on the effectiveness of surveillance testing for limiting the spread of COVID-19 and protecting a highly vulnerable population.

Findings indicate that policy makers and administrators considering surveillance testing to prevent infectious disease spread should prioritize conducting more frequent tests, likely in excess of once per week, and ensuring quick turnaround.

Results also suggest that the policy emphasis on surveillance testing, both in general and within the US nursing home industry, was well founded. However, our findings indicate that a substantial number of resident cases and deaths could have been prevented prior to the availability of vaccines with more frequent testing. Specifically, we estimated that increasing facility test volume by 1 test per employee-week could have averted more than 400 deaths per week of increased testing. Available reports indicate that the federal government pays about $5 per POC test and about $100 per lab-based non-POC test,[31,32] and roughly 1 million employees work in a nursing home in a given week. This suggests a cost per life saved of $12,630 for POC tests and $252,646 for non-POC tests. In light of the lack of difference in resident outcomes by type of test used, this substantial cost difference is notable.

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Table 1- Sample Characteristics by Latent Surveillance Test Propensity

		Quartiles of Latent Surveillance Test Propensity				
		1 (fewest tests)	2	3	4 (most tests)	p-value
Number of Facilities		3543	3339	3224	3087	
Number of Certified Beds, mean (SD)		108.23 (57.17)	111.36 (58.23)	111.68 (59.82)	105.92 (69.49)	<0.001
Profit Status	Non-Profit	671 (18.9%)	734 (22.0%)	786 (24.4%)	925 (30.0%)	<0.001
	Government Owned	154 (4.3%)	165 (4.9%)	169 (5.2%)	245 (7.9%)	
	For Profit	2718 (76.7%)	2440 (73.1%)	2269 (70.4%)	1917 (62.1%)	
Part of a Chain	No	1150 (32.5%)	1259 (37.7%)	1217 (37.7%)	1364 (44.2%)	<0.001
	Yes	2123 (59.9%)	1906 (57.1%)	1831 (56.8%)	1540 (49.9%)	
	Missing	270 (7.6%)	174 (5.2%)	176 (5.5%)	183 (5.9%)	
Percent of Residents with Medicaid, mean (SD)		60.07 (23.32)	60.71 (21.52)	59.73 (22.01)	57.28 (23.88)	<0.001
Percent of Residents who are non-White Race, mean (SD)		22.76 (22.68)	20.81 (22.31)	18.59 (21.05)	16.15 (20.09)	<0.001
Quality Rating	1 (lowest quality)	709 (20.0%)	552 (16.5%)	463 (14.4%)	450 (14.6%)	<0.001
	2	767 (21.6%)	669 (20.0%)	588 (18.2%)	540 (17.5%)	
	3	613 (17.3%)	594 (17.8%)	591 (18.3%)	531 (17.2%)	
	4	687 (19.4%)	726 (21.7%)	735 (22.8%)	658 (21.3%)	
	5 (highest quality)	727 (20.5%)	760 (22.8%)	814 (25.2%)	874 (28.3%)	
	Missing	40 (1.1%)	38 (1.1%)	33 (1.0%)	34 (1.1%)	
Registered Nurse Hours per Resident Day, mean (SD)		0.74 (0.62)	0.69 (0.46)	0.72 (0.48)	0.79 (0.58)	<0.001
Direct Care Hours per Resident Day, mean (SD)		3.88 (1.10)	3.81 (0.92)	3.85 (0.98)	4.00 (1.25)	<0.001
Average Number of Unique Staff Members per Day, mean (SD)		153.46 (83.69)	147.03 (78.67)	144.39 (81.82)	137.11 (79.75)	<0.001
Number of Outbreaks		16361	16307	16316	16092	
Total Prior Resident COVID-19 Cases, mean (SD)		606.16 (522.91)	601.30 (769.30)	562.49 (471.93)	515.75 (482.72)	<0.001
Total Prior Staff COVID-19 Cases, mean (SD)		477.42 (272.47)	516.47 (278.24)	510.77 (280.25)	531.07 (357.82)	<0.001
Staff COVID-19 Vaccination Coverage, mean (SD)		54.99 (32.90)	56.78 (32.28)	57.01 (32.06)	58.01 (32.16)	<0.001
Resident COVID-19 Vaccination Coverage, mean (SD)		82.97 (13.89)	84.88 (12.88)	86.06 (11.92)	87.54 (11.51)	<0.001
County COVID-19 New Case Rate (per 100,000), mean (SD)		42.66 (42.34)	40.85 (40.19)	39.02 (36.10)	38.38 (35.95)	<0.001

Figure 1-

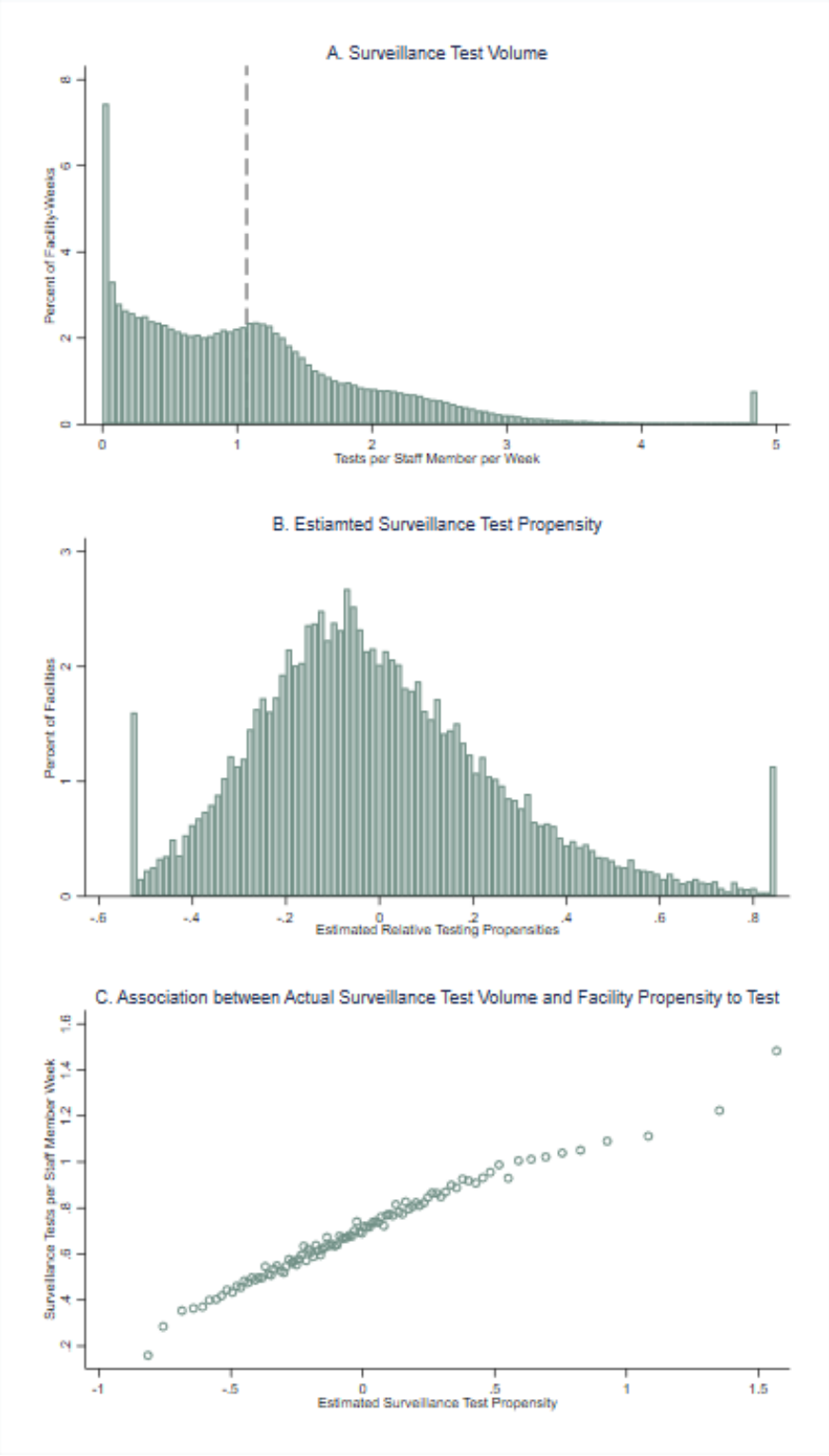

A. Surveillance Test Volume
Percent of Facility-Weeks
0
2
4
6
8
0
1
2
3
4
5
Tests per Staff Member per Week
B. Estiamted Surveillance Test Propensity
Percent of Facilities
0
1
2
3
-.6
-.4
-.2
0
.2
.4
.6
.8
Estimated Relative Testing Propensities
C. Association between Actual Surveillance Test Volume and Facility Propensity to Test
Surveillance Tests per Staff Member Week
.2
.4
.6
.8
1
1.2
1.4
1.6
-1
-.5
0
.5
1
1.5
Estimated Surveillance Test Propensity

Figure 2- Association of Surveillance Test Volume and Resident COVID-19 Outcomes

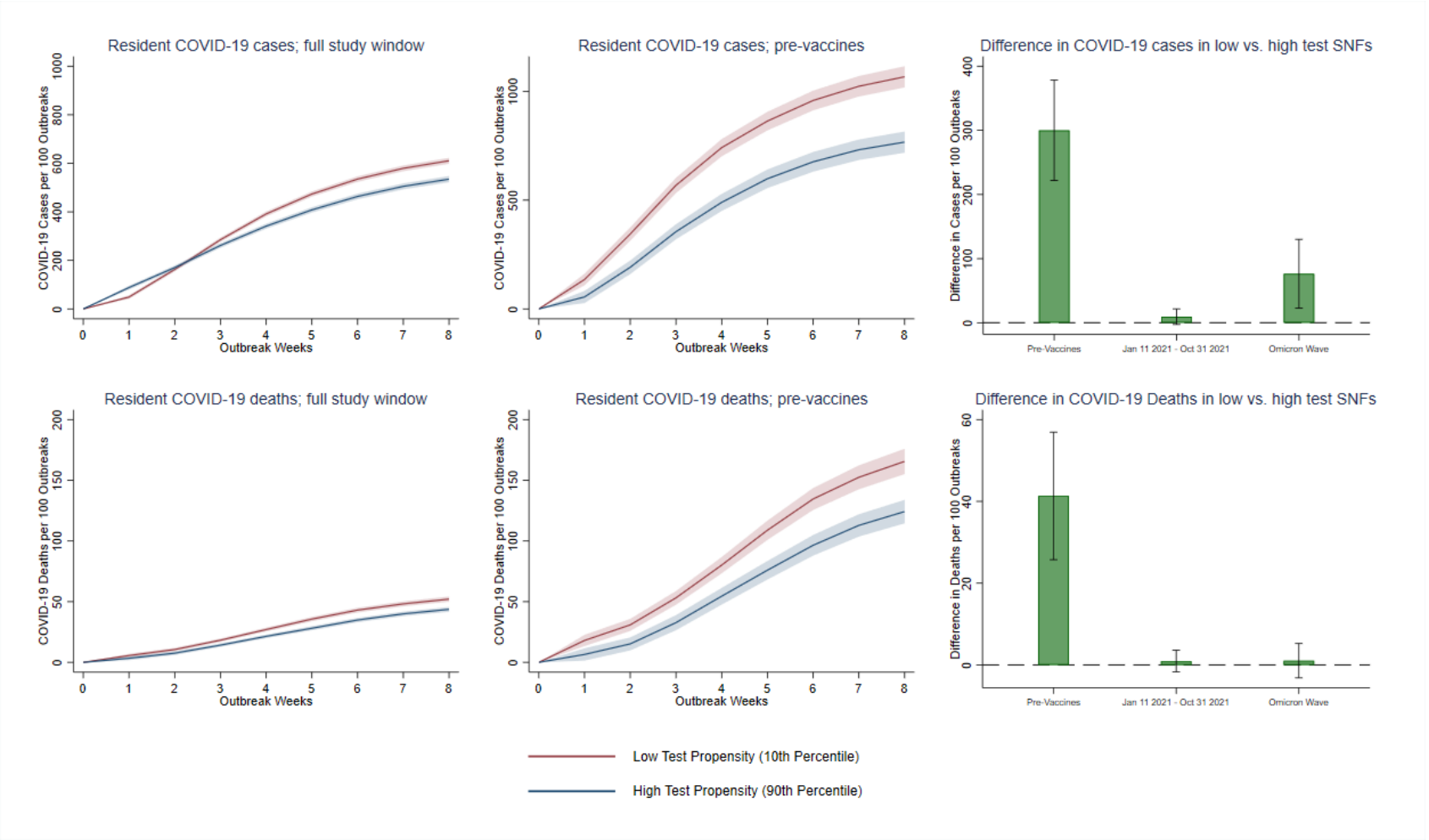


Figure 3- Association of Test Type and Resident COVID Outcomes

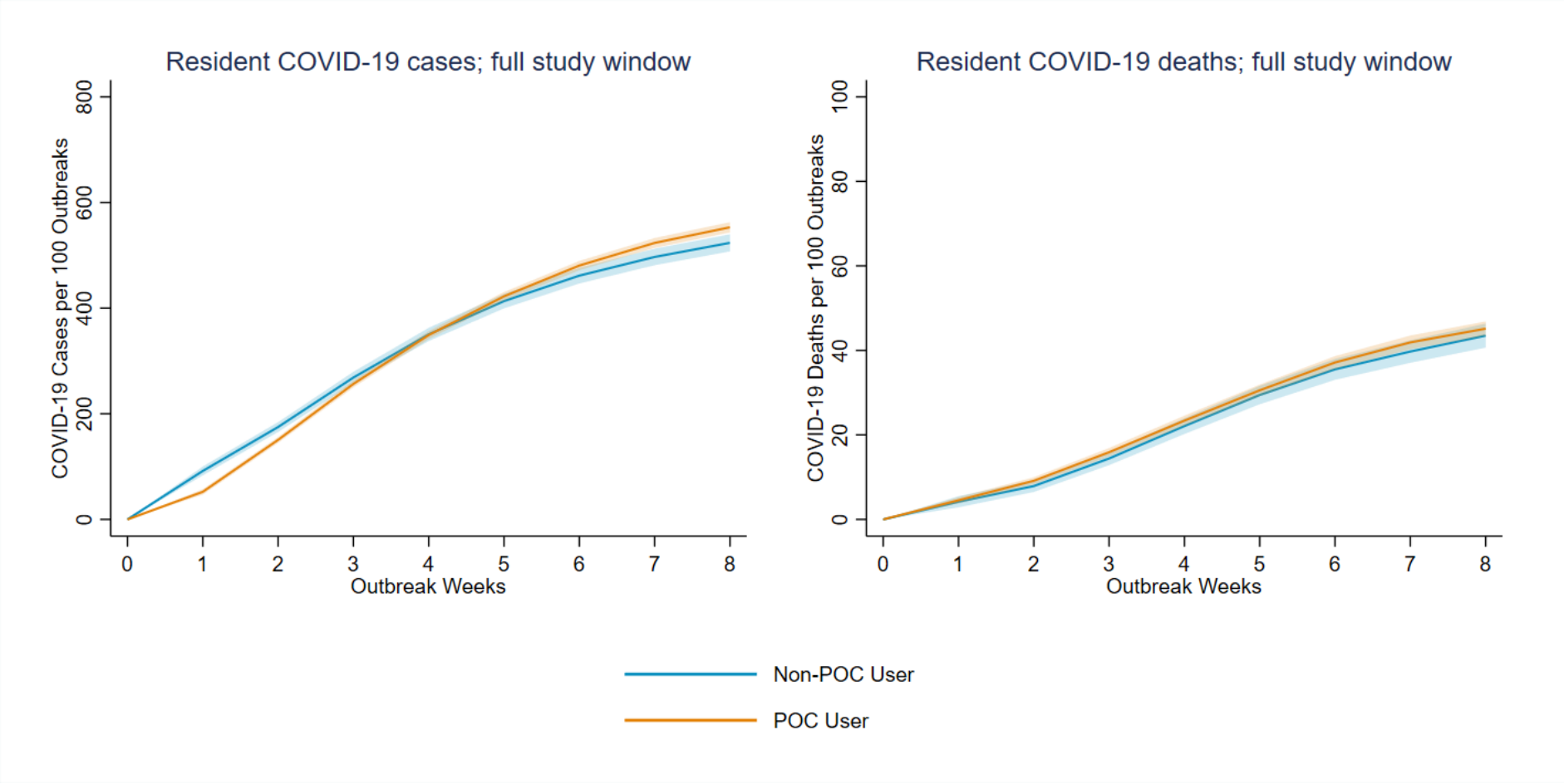
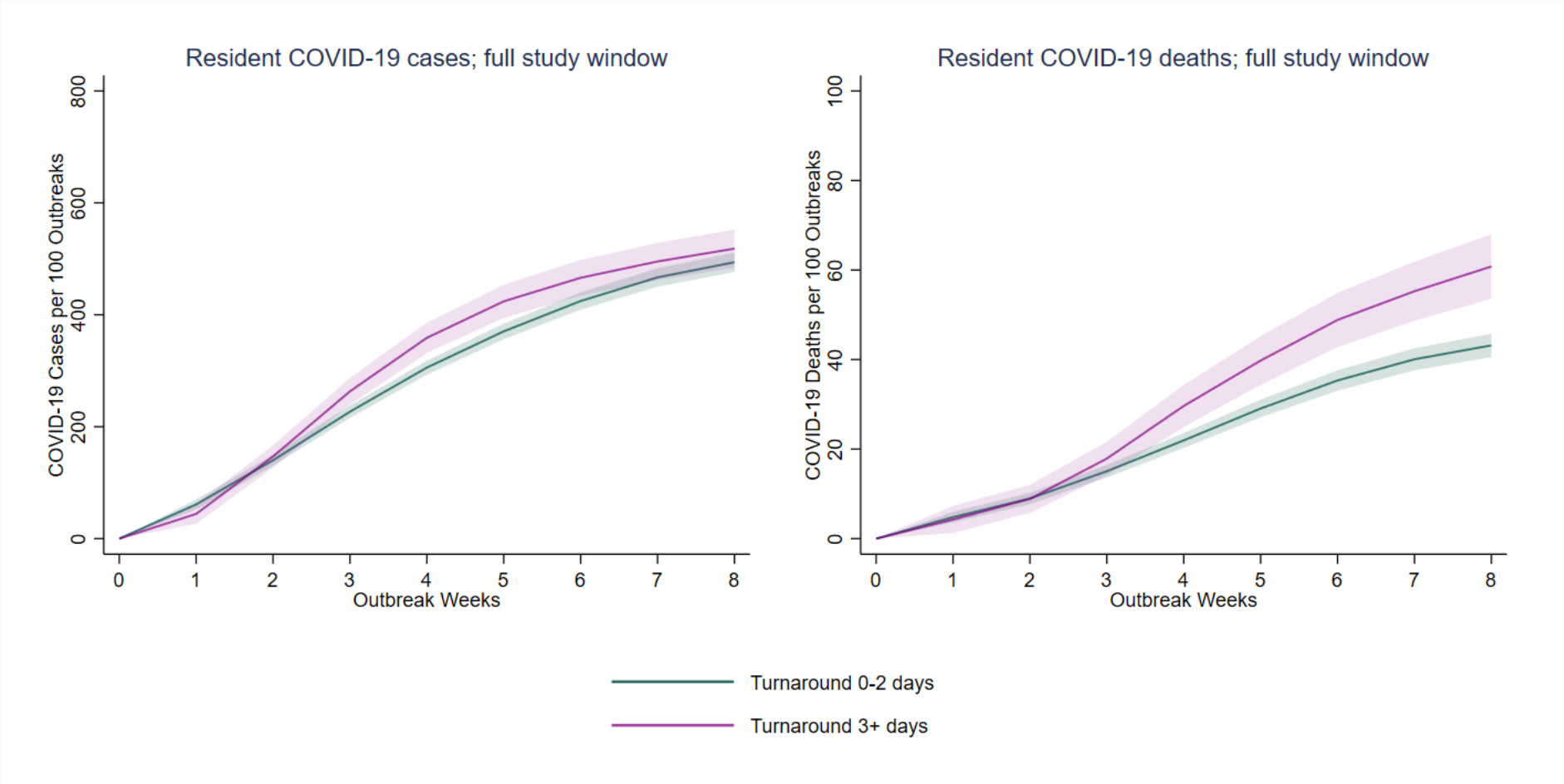


Figure 4- Association of Turnaround Time and Resident COVID-19 Outcomes



Supplementary Appendix

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

Supplement to: McGarry BE, Gandhi AG, Barnett, ML. Does SARS-CoV-2 Surveillance Testing

Prevent COVID-19 Transmission? Evidence from the US Nursing Home Industry

1. Supplementary Details on Methods

Surveillance Testing Propensity

Surveillance test volume is defined as the number of staff tests performed in a facility in a week in which there were no COVID-19 cases among staff and residents. As a result, the sample used to estimate latent surveillance test propensity is restricted to facility-weeks without any staff or resident cases. The sample is further restricted to those weeks in which the full suite of testing-related questions were included in the NHSN survey modules.

To account for potential measurement error in test volume and potential resultant outliers, weekly test volumes were Winsorized at the 1st and 99th percentiles.

To estimate latent surveillance test propensity, we estimate the linear regression described in Equation 1.

$$V_{i,t} = \gamma_i + \theta_t * \lambda + S_{i,t} + S^2{}_{i,t} + R_{i,t} + R^2{}_{i,t} + \epsilon_{i,t} \quad \text{Eq. 1}$$

Where $V_{i,t}$ is the number of surveillance staff tests performed by facility i in week t, γ_i is a facility fixed effect, $\theta_t * \lambda$ represents a county-by-week interaction (i.e., a county-specific time trend), and $S_{i,t}$ and $R_{i,t}$ represent the staff and resident vaccination rates for each facility-week. Latent test propensity is captured by the facility effect, γ_i.

Control Variables

Analytic models included a number of facility and community-level controls. From the Nursing Home Compare Provider Info file, the following measures were obtained: overall 5-star quality score, profit status, and bed size (operationalized as indicators for deciles of size). From LTCFocus.org data, the following measures were obtained: the share of residents who are non-White race (operationalized as quartiles), and the share of residents with Medicaid coverage (operationalized as quartiles). From the Payroll-based journal staffing data, the following measures were obtained: average total direct care (CNA, LPN, and RN) hours per resident day (operationalized as quartiles), average RN hours per resident day ((operationalized as quartiles), and a daily average count of total unique individuals working in the facility (operationalized as quartiles). From the NHSN data, the following measures were obtained: prior COVID-19 history for residents and staff (i.e., cumulative case rates from the start of the NHSN data collection to the week prior to outbreak start), the weekly share of staff with completed COVID-19 vaccine doses, and the weekly share of residents with completed COVID-19 vaccine doses. Additionally, we calculated second order polynomials of the measures obtained from NHSN data. From the NYTimes COVID-19 database, we obtained a measure of weekly new COVID-19 case rates at the county level, as well as the second-order polynomial of this measure.

Analysis

Our primary analytic model is described in Equation 2.

$$Y_{i,w} = \gamma_i * \delta_w + X_{i,w} + \theta + \lambda + \epsilon_{i,t} \quad \text{Eq. 2}$$

$Y_{i,t}$ represents the weekly cumulative outcome of interest (resident COVID-19 cases or deaths) for facility i in outbreak week w. γ_i is the surveillance test propensity estimated in Equation 1 and δ_w represents indicators for each week in the outbreak follow-up period. $X_{i,w}$ is a vector of facility and time-varying county-level controls described in the previous sections, while θ is a

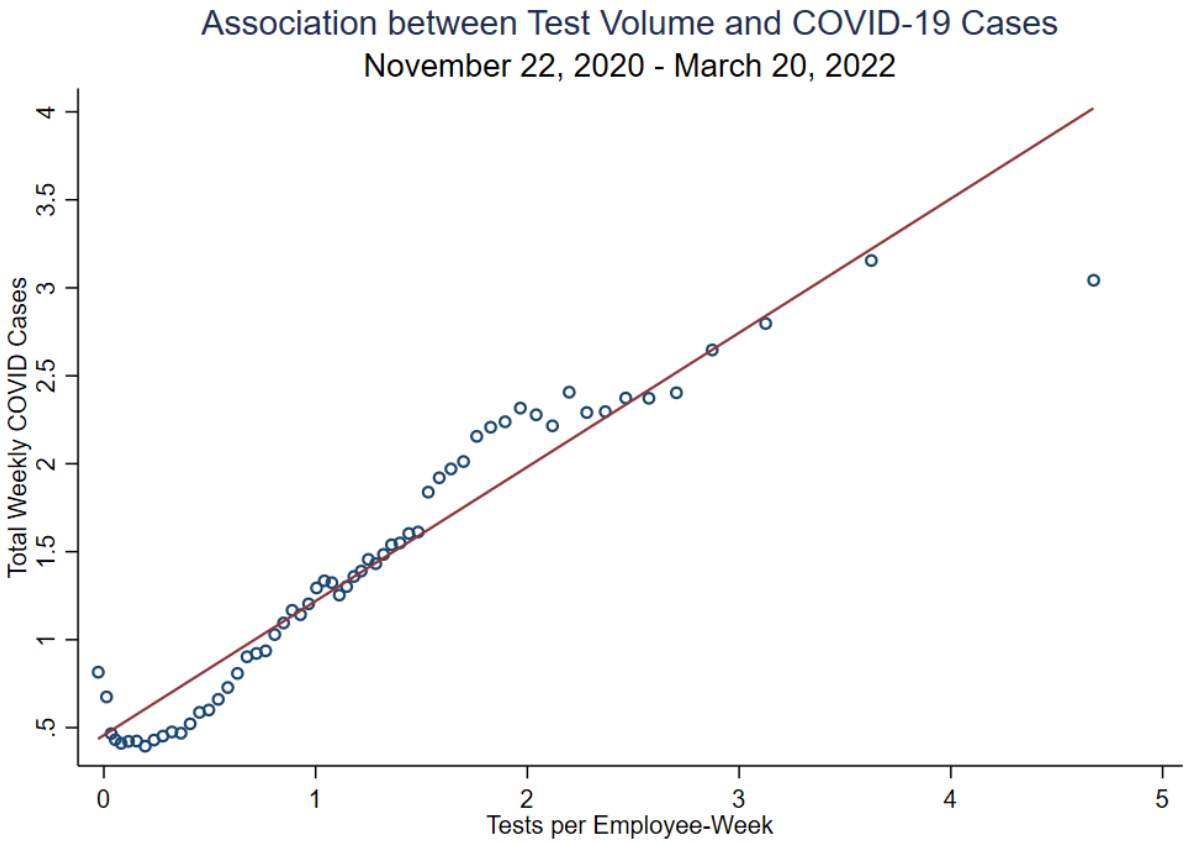
fixed effect for the calendar week in which an outbreak started and λ is a county fixed effect. Standard errors are clustered at the facility level to account for the panel nature of our data.

Sensitivity Analyses

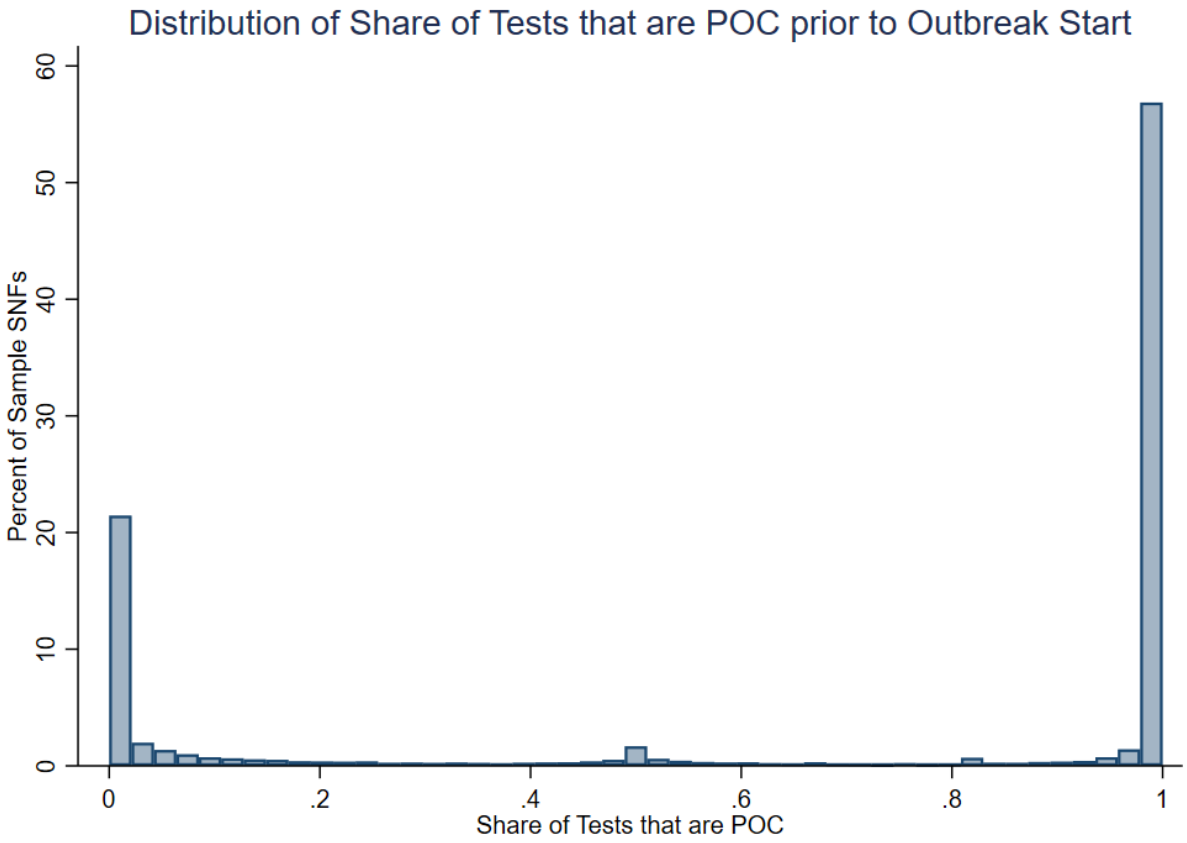
To examine the robustness of our results we performed a series of sensitivity analyses. First, we estimated Equation 2 using a Poisson model rather than linear. Second, we used an alternate specification to identify the end of outbreak follow-up time. Specifically, we considered an outbreak ongoing until there was a week without any resident cases (plus an additional 2-weeks when examining resident deaths). Finally, to examine whether there was support for surveillance testing preventing resident cases and deaths through the earlier and more frequent detection of staff COVID-19 cases, we estimated Equation 1 with weekly cumulative staff cases as the outcome of interest.

2. Additional Results

Appendix Figure 1- Relationship between Total Tests per Employee Week and Total Weekly COVID-19 Cases



Appendix Figure 2- Distribution of Surveillance Test Type Prior to Start of Outbreaks

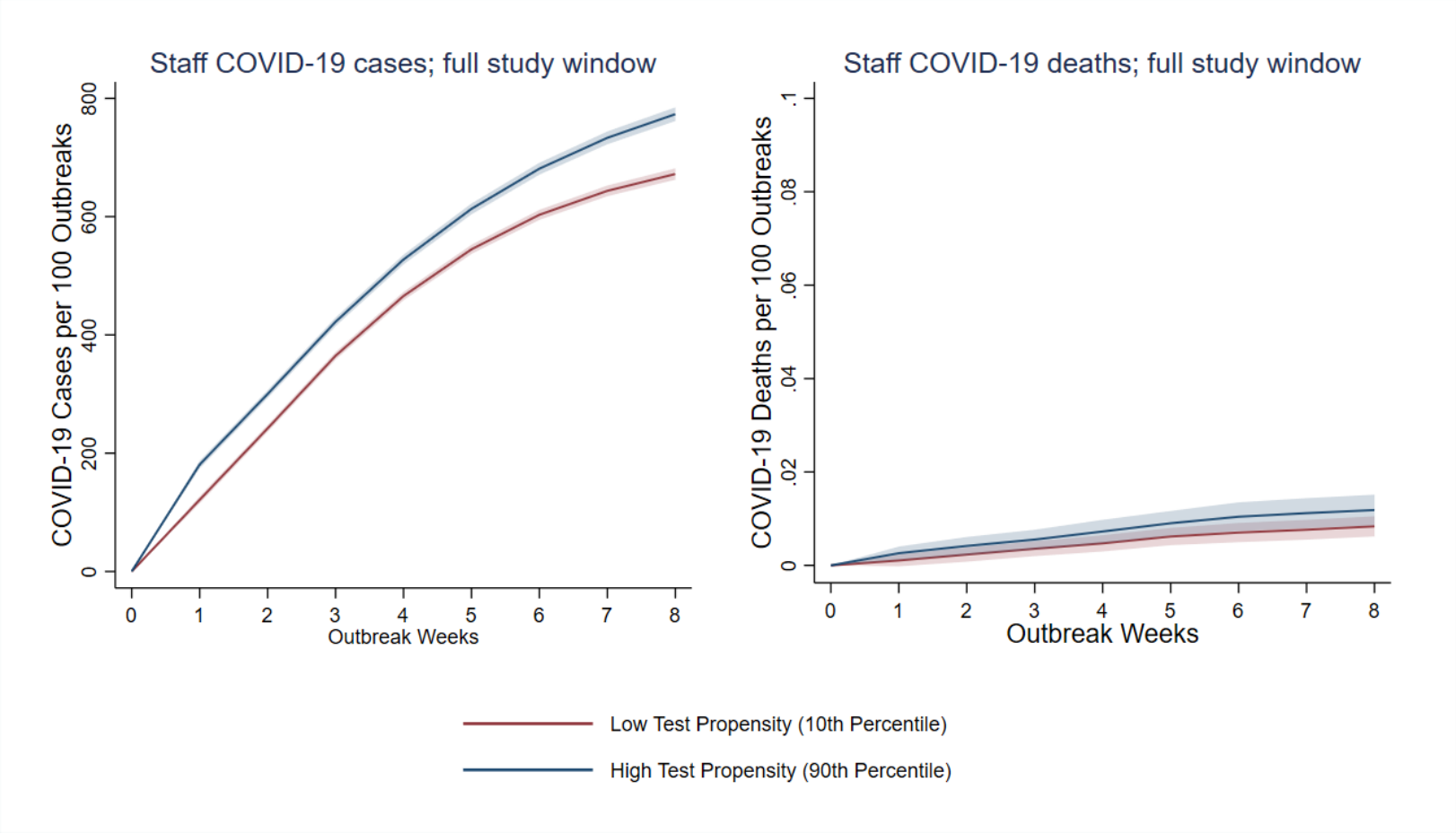


Appendix Table 1- Counterfactual Estimates under Scenario of One Additional Test per Employee Week

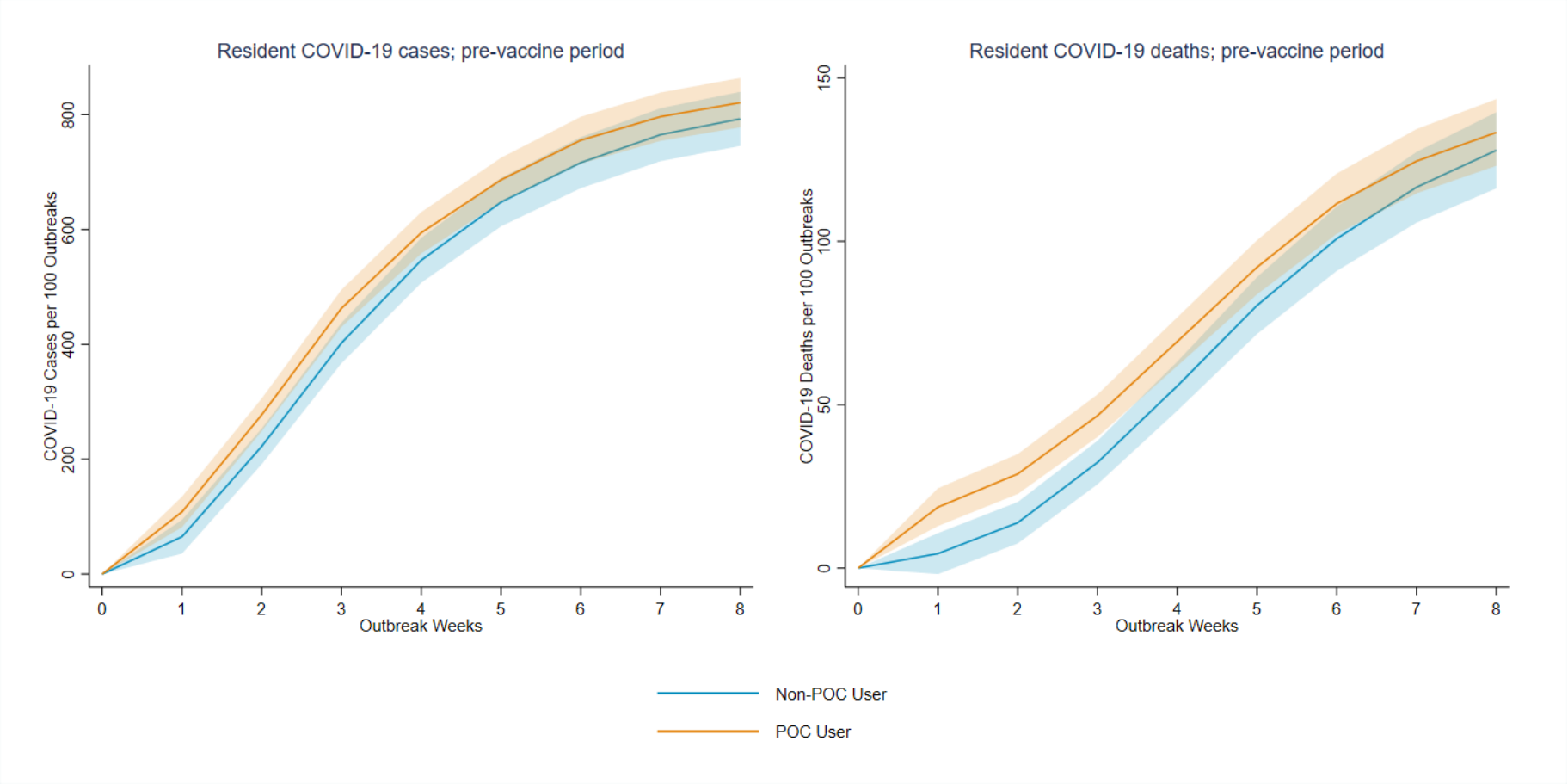
	Outbreaks Starting November 22, 2020 - January 17, 2021	
	Resident COVID-19 Cases	Resident COVID-19 Deaths
Estimated total under observed test propensity	90,219	14,241
Estimated total under counterfactual of 1 additional test per employee-week	62,685	10,448
Estimated number of preventable outcomes per week of increased testing	3,059	421

Notes: Study window contains 9 weeks of potential outbreak starts that could be impacted by surveillance test propensity. This number is used as the denominator when determining number of preventable outcomes per week of increased testing.

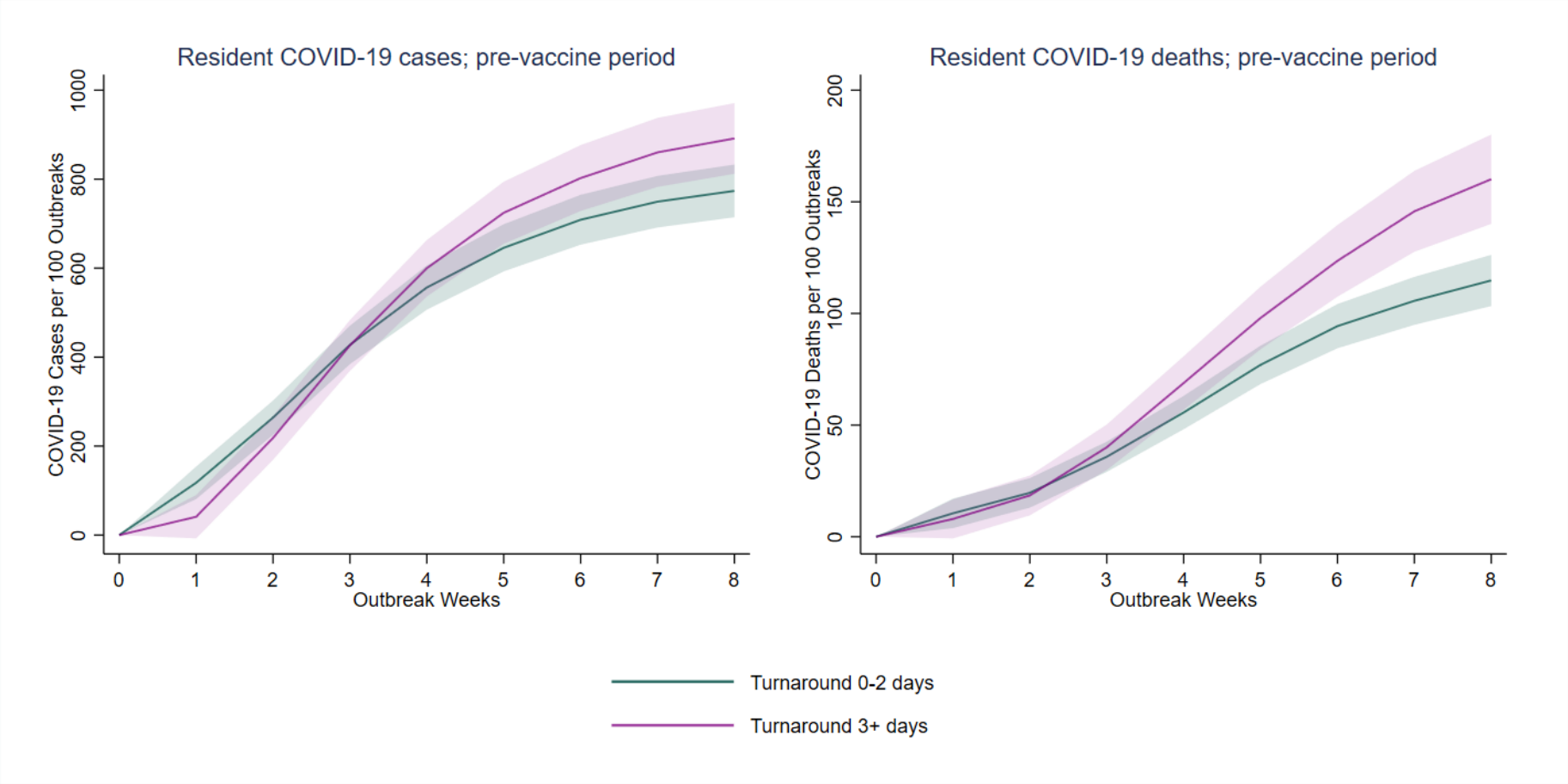
Appendix Figure 3- Association of Surveillance Test Propensity with Staff COVID-19 Cases and Deaths



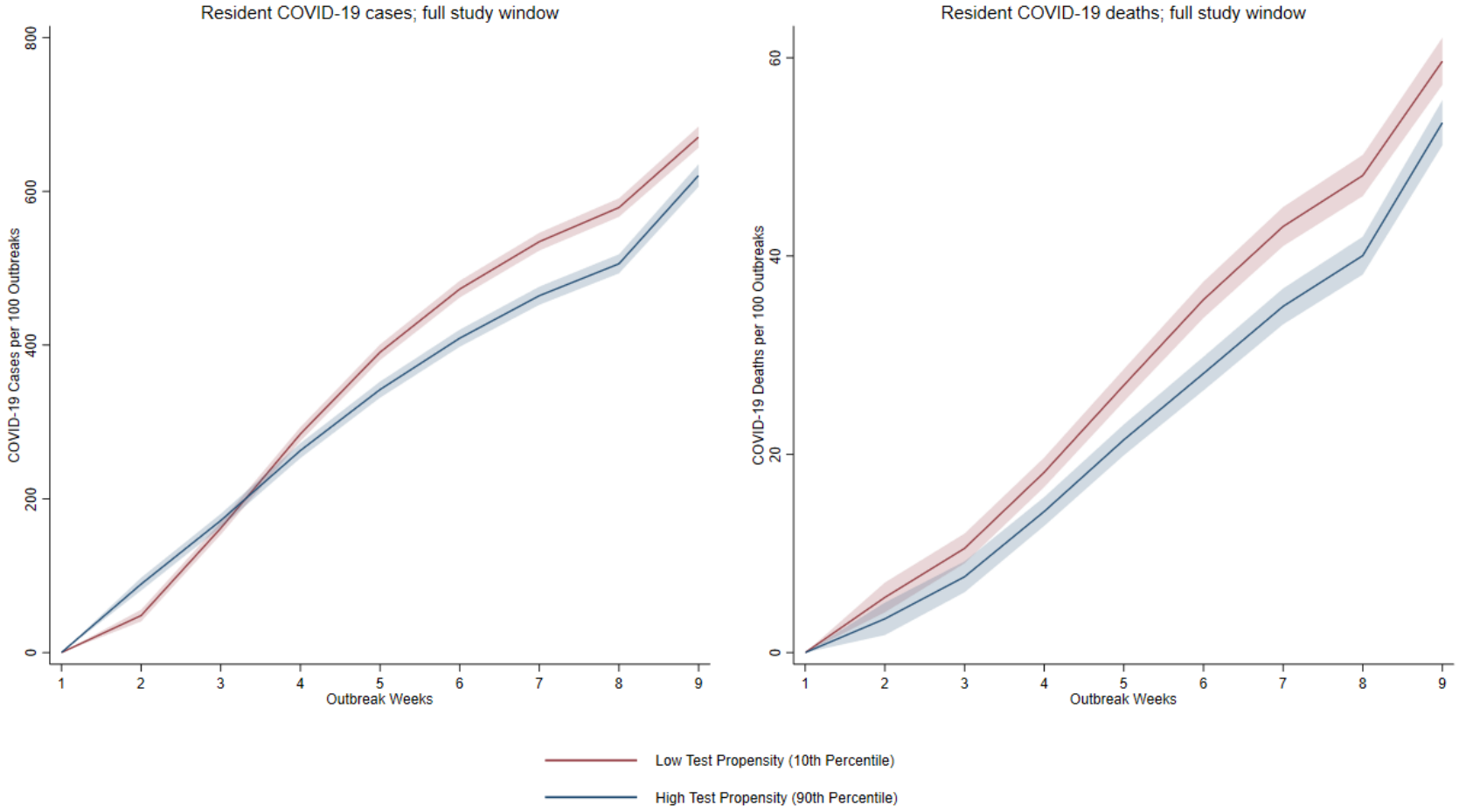
Appendix Figure 4- Association of Surveillance Test Type and Resident COVID-19 Outcomes During the Pre-Vaccine Period



Appendix Figure 5- Association of Test Turnaround Time and Resident COVID-19 Outcomes for Facilities Predominantly using non-Point-of-Care Tests During the Pre-Vaccine Period



Appendix Figure 6- Sensitivity Analysis: Association of Surveillance Test Volume and Resident COVID-19 Outcomes using Longer Follow-Up Period



Appendix Table 2 - Sensitivity Analysis: Association of Surveillance Test Volume and Resident COVID-19 Outcomes using Poisson Regression Models (Full Study Window)

	(1) Cumulative Resident Cases per 100 Outbreaks - OLS	(2) Cumulative Resident Cases (IRR) - Poisson	(3) Cumulative Resident Deaths per 100 Outbreaks - OLS	(4) Cumulative Resident Deaths (IRR) - Poisson
Change in outcome at end of outbreak per 1 unit increase in surveillance test propensity	-71.80***	0.89***	-8.00***	0.83***
	(-91.13 - -52.48)	(0.86 - 0.93)	(-11.04 - -4.97)	(0.76 - 0.90)

Robust ci in parentheses
*** p<0.01, ** p<0.05, * p<0.1