COVID-19 Surveillance and Vaccination among Non-Healthcare, Non-Congregate Workers in Chicago

BY

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THESIS

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LIST OF ABBREVIATIONS

ACH	Air Changes per Hour
ACIP	Advisory Committee on Immunization Practices
ACS	American Community Survey
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BACP	Business Affairs and Consumer Protection
BAM	Bamlanivimab
BMI	Body Mass Index
CAS	Casirivimab
CCVI	COVID-19 Community Vulnerability Index
CDC	Centers for Disease Control and Prevention
CDPH	Chicago Department of Public Health
CIC	Census Industry Code
CICT	Case Investigation and Contact Tracing
CISA	U.S. Cybersecurity & Infrastructure Security Agency
COC	Census Occupation Code
CSTE	Council of State and Territorial Epidemiologists
ddPCR	Droplet Digital Polymerase Chain Reaction
ECMO	Extracorporeal Membrane Oxygenation
ETE	Etesevimab
EUA	Emergency Use Authorization
FDA	U.S. Food and Drug Administration
HCEZ	Healthy Chicago Equity Zone
I-CARE	Illinois Comprehensive Automated Immunization Registry Exchange
IDPH	Illinois Department of Public Health
IMD	Imdevimab

LIST OF ABBREVIATIONS (continued)

I-NEDSS	Illinois Notifiable Electronic Disease Surveillance System
IRB	Institutional Review Board
KFF	Kaiser Family Foundation
mAB	Monoclonal Antibody [Therapies]
MEPS	Medical Expenditures Panel Survey
NAAT	Nucleic Acid Amplification Tests
NAICS	North American Industry Classification System
NHNCW	Non-Healthcare, Non-Congregate Workers
NIOCCS	NIOSH Industry and Occupation Computerized Coding System
NIOSH	National Institute for Occupational Safety and Health
NIH	National Institutes of Health
ORS	Outbreak Reporting System
OSHA	Occupational Safety and Health Administration
PASC	Post-Acute Sequelae of COVID-19
PreP	Pre-exposure prophylaxis
RT-PCR	Reverse Transcription Polymerase Chain Reaction
RCT	Randomized Controlled Trial
SAR	Secondary Attack Rate
SOC	Standard Occupation Codes
SOEM	SARS-CoV-2 Occupational Exposure Matrix
SOT	Sotrovimab
SVI	Social Vulnerability Index
TIX	Tixagevimab
WHO	World Health Organization

SUMMARY

This study of COVID-19 among non-healthcare, non-congregate workers in Chicago was completed using a combination of descriptive, modeling and survey analyses. Surveillance data collected by the Chicago Department of Public Health (CDPH) were utilized to characterize workplace investigations conducted by CDPH from March 2020 through May 2022. These were supplemented by laboratory and immunization records from the State to explore factors associated with COVID-19 vaccination among these workers in Chicago. In a novel application of an occupational health tool, a job exposure matrix was used to categorize cases by level of occupational risk for COVID-19 and identify populations of workers that could benefit from workplace-based vaccine promotion. Finally, a survey was developed and administered to non-healthcare businesses throughout Chicago, to assess vaccination rates and requirements among employees, strategies employers have used to promote vaccination against COVID-19, and barriers they have encountered.

Analyses of workplace investigations found that COVID-19 outbreaks among frontline and other essential workplaces decreased substantially after they were prioritized for vaccination in Chicago. Modeling analyses of vaccination status by occupational risk found that, though vaccination has reduced the risk of COVID-19 among workers indoors or in frequent, close contact with the public or each other, promoting vaccination among workers in these environments may help reduce coverage disparities among the minority groups that tend to work in them. Outreach campaigns should address vaccine mistrust and safety concerns, which were identified as prevailing reasons for vaccine hesitancy in our survey. Overall, this study reiterated the value of routine, standardized collection of industry and occupation data in testing and vaccination records: to quantify burden of disease among workers, inform interventions, and mitigate under-representation of workers who may have less access to vaccination, other healthcare, and less agency over their everyday work environments.

1. **INTRODUCTION**

1.1 SARS-CoV-2, COVID-19 Infections and Mortality: United States and Chicago

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the virus that causes COVID-19, was first identified in Wuhan, China in December 2019. The first case of person-to-person transmission in the U.S. was documented in Illinois outside of Chicago in January 2020 (Ghinai et al. 2020). As of January 28, 2022, the U.S. had seen 879,971 COVID-19-related deaths, surpassing the total attributed to the 1918-1919 Spanish flu (675,000) (Institute for Health Metrics and Evaluation n.d.). The national estimated daily case rate was 156 confirmed cases per 100,000 people (524,850 new cases, Figure 1). This is a decrease from a peak daily case count of almost 400 per 100,000 (1,334,860 cases), recorded January 10, 2022 (Centers for Disease Control and Prevention 2020d). The estimated daily death rate had fallen from a peak of 0.4 per 100,000 (4,069 deaths recorded on January 13, 2021) to 0.03 per 100,000 (3,218 recorded January 28, 2022, Figure 2), with mortality rates highest among the unvaccinated and elderly.

Over the same time, Chicago had recorded 7,132 COVID-related deaths (City of Chicago n.d.). As of January 28, the average 7-day daily case rate was 54 cases per 100,000 residents or 1,468 cases (Figure 3), a decrease from a peak of 248 per 100,000 or 9,750 cases (December 28, 2021). The 7-day average mortality rate of 0.2 deaths per 100,000 residents had decreased ten-fold from a peak of 1.8 per 100,000 (48 in one week, with a peak 58 deaths recorded May 5, 2020) (Figure 4). Across the U.S., incidence and mortality rates fell dramatically after the emergency authorization of vaccines in December 2020.

The virus's hold on healthcare systems and society as a whole has been sustained primarily by persistence of more transmissible variants, especially among unvaccinated populations. Cases increased exponentially nationwide in late 2021, when the Omicron variant (B.1.1.529), first identified on November 8, 2021 in South Africa, began to overtake the previously-dominant Delta variant (B.1.617.2) (Jansen 2021). At the time of this report, Omicron variants account for over 99% of COVID-19 cases in the United States and Chicago (Centers for Disease Control and Prevention 2020d).

The introductory sections of this review describe current knowledge of COVID-19 transmission, symptoms, and detection, and how these have shaped current disease prevention guidance in the United States. Pharmaceutical interventions (vaccines and treatments recommended for use in the United States as of January 2022) are also reviewed. These topics are contextualized where possible, by implications for control and epidemiology of COVID-19 among non-healthcare workers outside of congregate settings ("Non-Healthcare, Non-Congregate Workers", or NHNCW), the focus of this dissertation. Workers in healthcare and congregate settings, such as schools and other youth settings, senior and behavioral facilities, government, corrections, and protective service workers, are excluded from these analyses. Literature focusing on COVID-19 risk and mitigation among these populations are thus also excluded from review in the following sections.

A comprehensive characterization of differences between pre-Omicron and Omicron variants is beyond the scope of this review. However, brief summaries of current knowledge regarding Omicron's shortened incubation period and lower minimum infectious dose (Section 1.4.1) compared to previous variants, and evasion of vaccine-induced immunity (Section 1.8.1) are included, as these are germane to discussions of evolving best practices for disease prevention. Omicron's mechanisms of increased infectivity underscore the importance of non-pharmaceutical preventive measures (Section 1.2), including among vaccinated workers, to attenuate increases in risk due to more transmissible variants.

1.2 **Transmission Dynamics of SARS-CoV-2**

SARS-CoV-2 is transmitted primarily via inhalation of respiratory droplets and aerosols. The World Health Organization (WHO), U.S. Centers for Disease Control and Prevention (CDC) and other public health agencies use the terms "droplets" and "aerosols" to distinguish

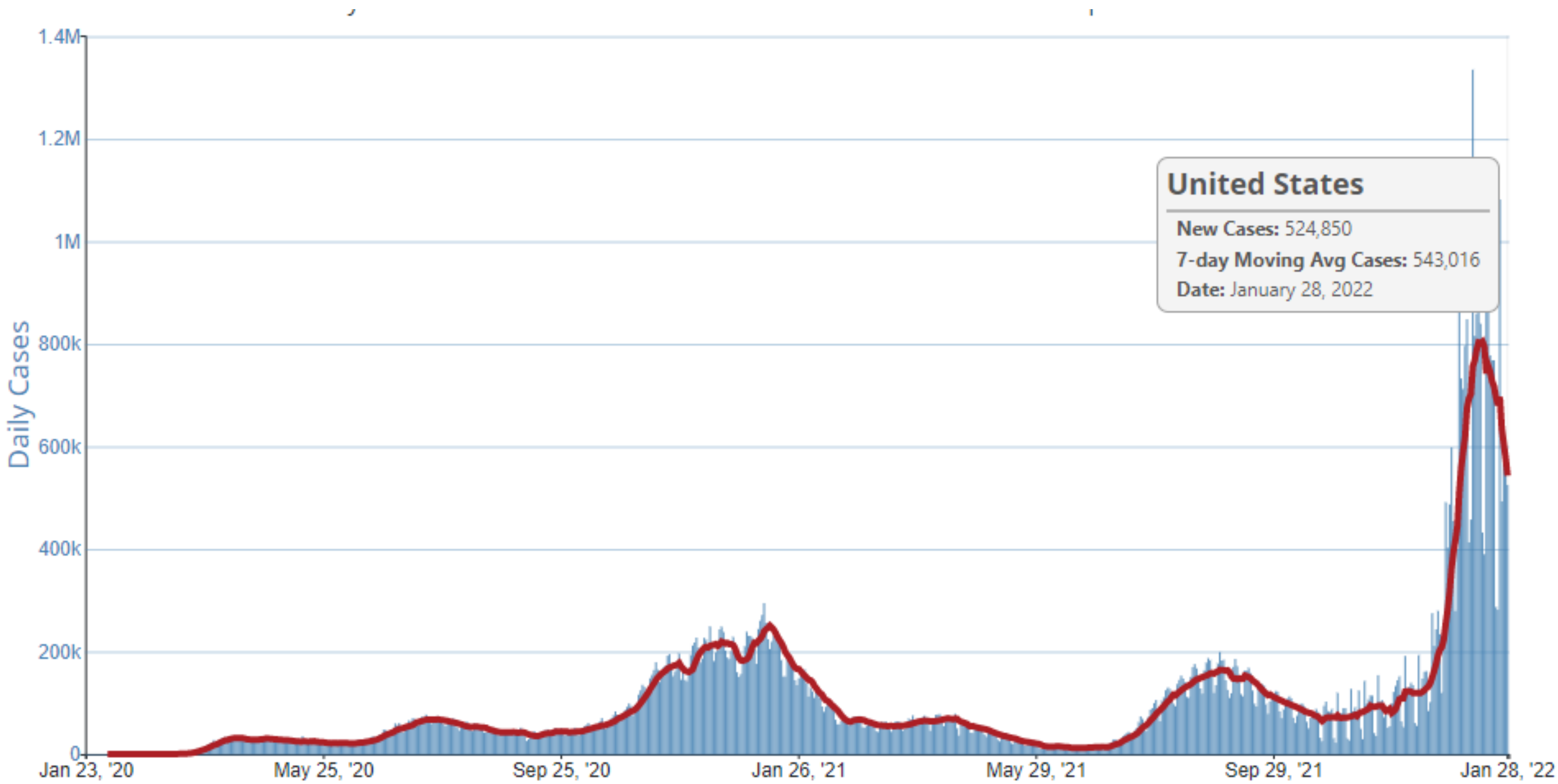

Figure 1. New confirmed COVID-19 cases and 7-day rolling average, United States, January 2020-January 2022
(*Source: Centers for Disease Control and Prevention, n.d.)*

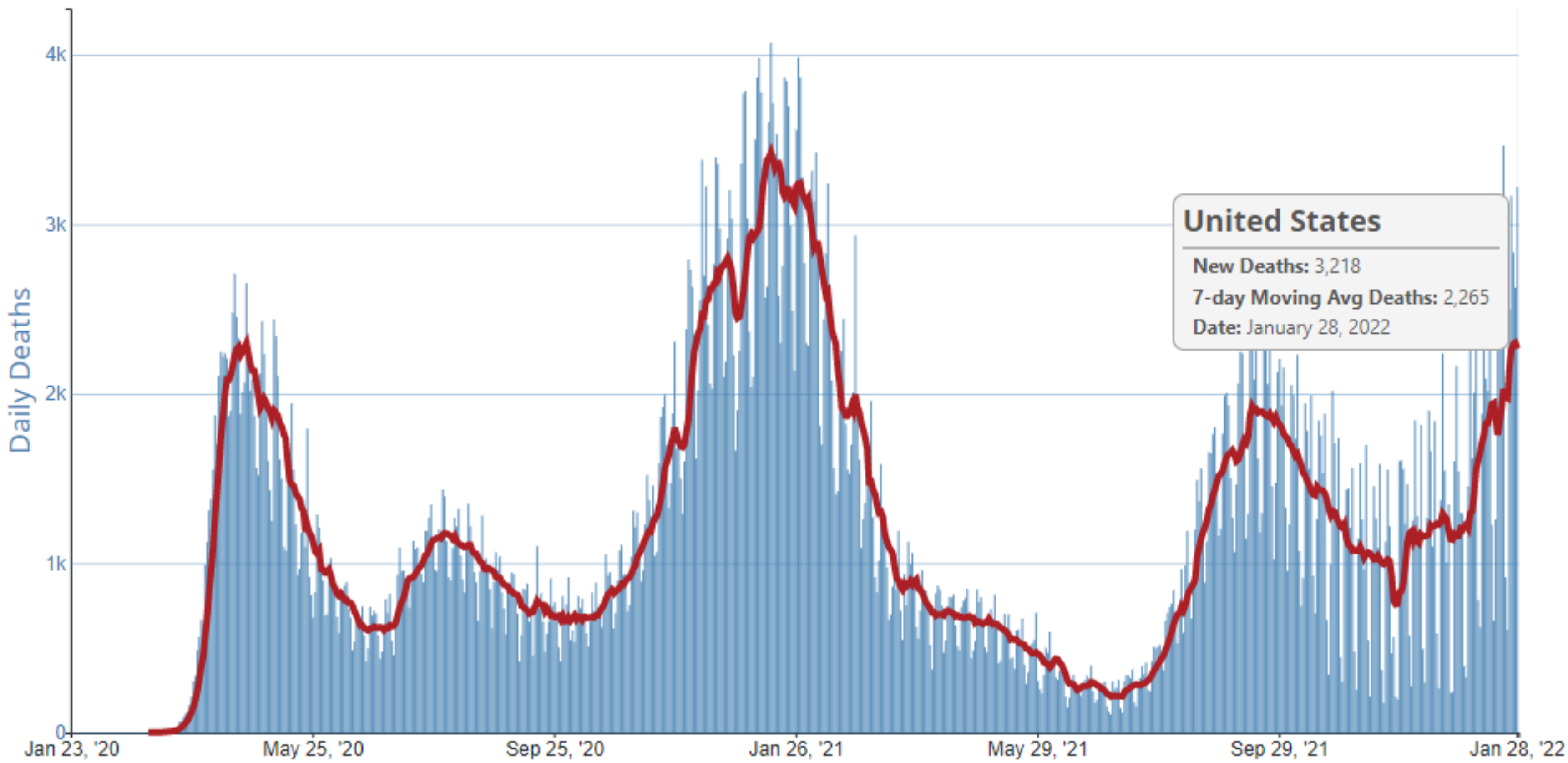

Figure 2. COVID-19 associated deaths and 7-day rolling average, United States
(*Source: Centers for Disease Control and Prevention, n.d.)*

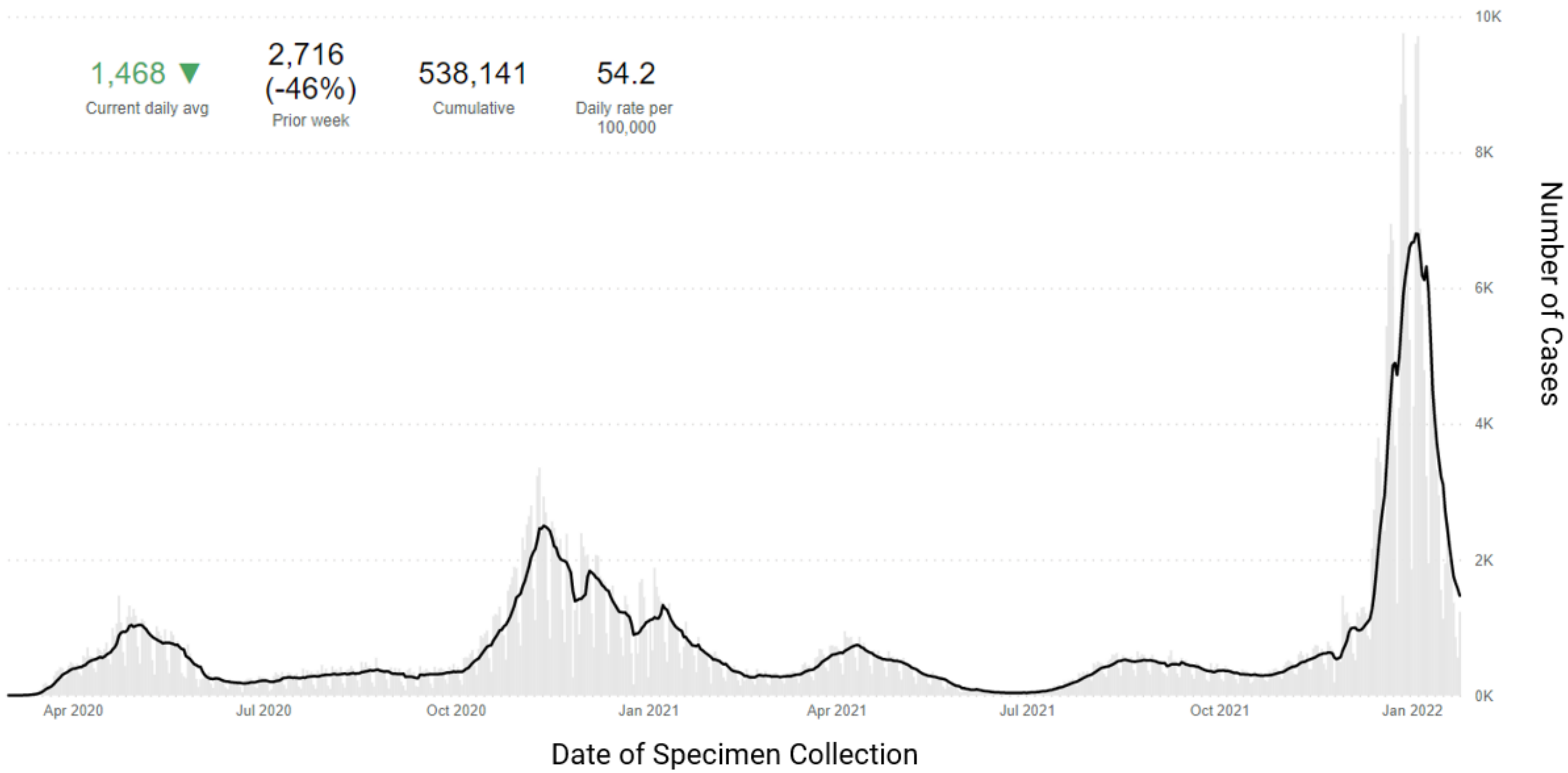

Figure 3. New COVID-19 cases with 7-day rolling average, Chicago, Illinois, April 2020 – January 2022
(Source: City of Chicago n.d.)

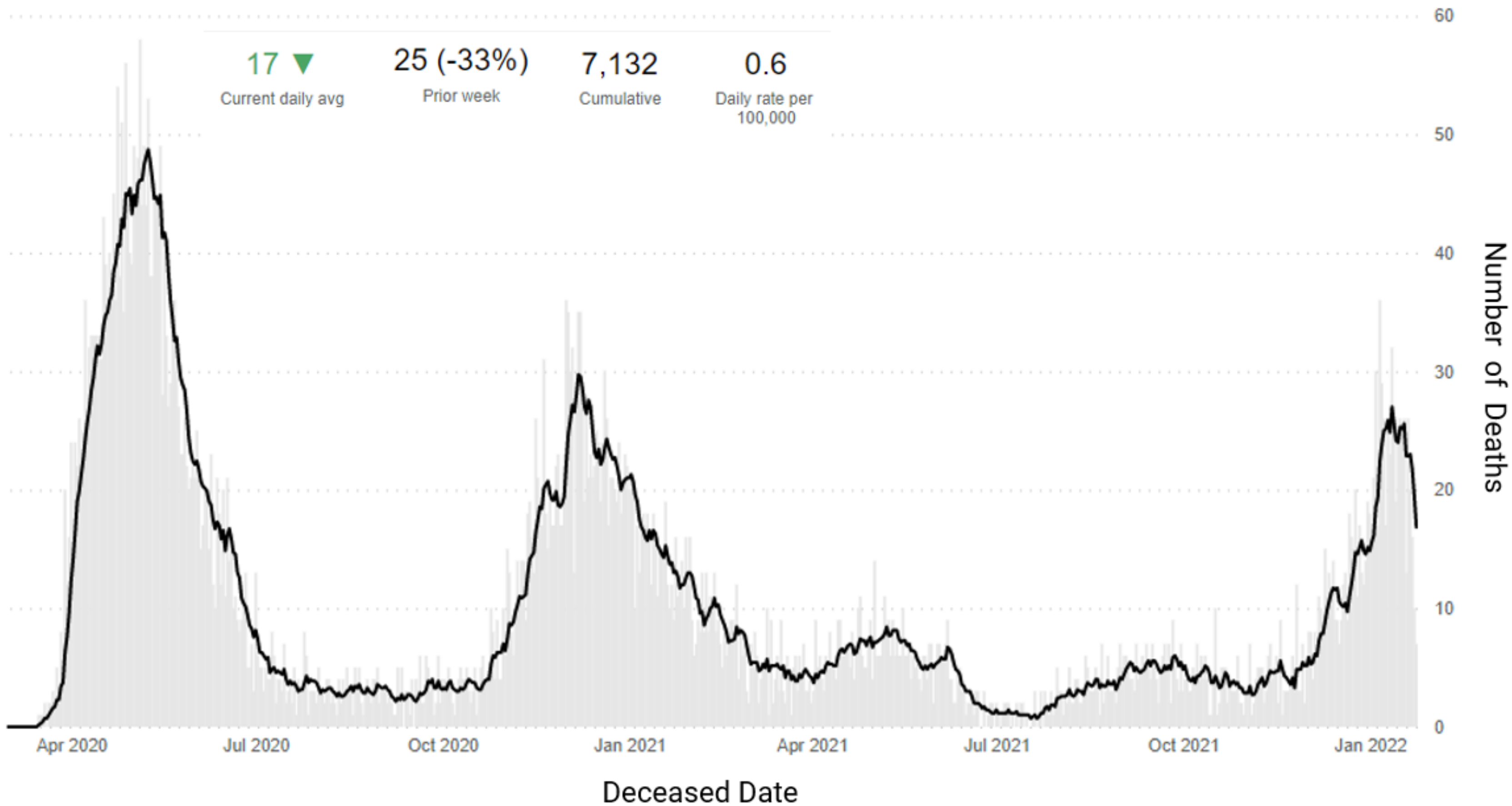

Figure 4. COVID-19-associated deaths with 7-day rolling average, Chicago, Illinois, April 2020 – January 2022
(Source: City of Chicago n.d.)

between larger exhaled respiratory particles (at least 5 μm) and smaller particles resulting from their evaporation (Bourouiba 2020). This dichotomization, derived from early research of respiratory infectious diseases (Wells 1934), is conducive to classifying pathogens and issuing public health recommendations based on observed transmission routes: respiratory droplets are heavier than aerosols, and fall out of the air much faster within a shorter distance of the source.

For example, in 1948, Hamburger et al. observed that 65% of droplets emitted by 48 patients infected with hemolytic *Streptococci* were large enough to be classified as “respiratory droplets”, and 90% fell to the ground within 5.5 feet or 1.7 meters (Hamburger & Robertson, 1948). Fluid dynamics studies such as those of Bourouiba et al. further demonstrated that (1) coughing and sneezing forcefully can project respiratory particles as far as 100 feet per second, and (2) such forced expiratory events result in “multiphase” exhalations, of both heavier respiratory droplets and clouds of lighter, mobile aerosols, to increase the range of exposure as far as 9 meters.

In their analyses of transmission dynamics of respiratory particles expired through coughing, Wei and Li report that the smallest “droplet” particles (5 μm) fall to the ground within 0.076 milliseconds and that even very large (1000 μm) droplet particles fall within a fraction of a second (395 milliseconds) at 25°C (77°F). (Wei and Li 2015). In contrast, when studying SARS-CoV-2 in both aerosolized form and after deposition on surfaces (as described in later paragraphs of this section), Van Doremalen et al. calculated the median half-life of aerosolized SARS-CoV-2 to be approximately 1.1-1.2 hours (95% confidence interval [CI]: 0.64-2.64 hours) at 21-23°C (69-73°F) (van Doremalen et al. 2020).

Findings from a 2020 investigation of COVID-19 cases at two meat processing facilities in Germany (Günther et al. 2020) illustrate compounded risk of infection due to prolonged worker proximity and environmental factors: after prevalence testing and site evaluations of one meat processing and one slaughtering facility, the attack rate among employees of the processing facility was 34% (94/279), compared to 0.06% (4/6,289) among workers in the slaughtering facility. Authors attributed the outbreak among processing workers to continuous aerosolized transmission from one infectious worker, propagated by recirculation of unfiltered air in highly confined areas at colder workplace temperatures (10°C/50°F). In contrast, the slaughtering plant reported a higher rate of air exchange at warmer temperatures (air exchange rate and “ambient” temperatures were not further specified in the report).

Current guidance for prevention of COVID-19 spread in workplaces includes measures to reduce transmission via both respiratory droplets and aerosols. Prolonged exposure and proximity to coworkers have been implicated as two of the most significant predictors of workplace-associated SARS-CoV-2 spread, in both model-based analyses of COVID-19 risk by occupation (Section 3.1 of this review) and outbreak investigations among critical infrastructure workers (Sections 3.2 and 3.3). As a result, the Occupational Safety and Health Administration (OSHA) recommends a hierarchy of controls that includes implementation of telework and staggering worker shifts to reduce workplace density, and distancing of at least six feet (two meters) between on-site workers, with the installation of “transparent shields or other solid barriers when distance cannot be maintained” (Occupational Safety and Health Administration 2021).

Masks that cover the nose and mouth with at least two layers of tightly woven breathable fabric are recommended as additional source control. In areas of substantial or high viral transmission, universal masking is recommended regardless of vaccination status. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) has issued minimum effective ventilation requirements for limiting spread of COVID-19 in industrial settings. These include maximizing the flow of outdoor air and use of systems that permit between 6-12 filtered air changes per hour (ACH) (American Conference of Governmental Industrial Hygienists (ACGIH), Industrial Ventilation Committee. Coauthored with American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 2021).

To-date, analyses of fomite transmission of SARS-CoV-2 (touching a soiled surface and then one's nose and mouth with viral particles on hands) have not consistently demonstrated recovery of viable virus from inanimate objects. Varying methodologies have precluded synthesis and comparison of results across studies of SARS-CoV-2 viability. (Marzoli et al. 2021). Van Doremalen et al. evaluated stability after application to various surfaces and found viable virus to persist the longest on plastic (72 hours) and stainless steel (48 hours), compared to cardboard (24 hours) and copper (4 hours). Riddell et al. detected viable virus for up to 28 days from glass, steel and paper at 20° C (68° F), but for less than a day on some surfaces at hotter temperatures (40° C / 100° F) (Riddell et al. 2020). Magurano et al. quantified the recovery of virus from plastic at "room temperature" (20-25° C) and "June temperature" (28° C) and, similarly, found a reduction in viral load occurring over 72 hours at room temperature (as observed by Van Doremalen et al.) that took just 8 – 12 hours in the warmer environment (Magurano et al. 2021). The temperature dependence of SARS-CoV-2 viability may help explain varying attack rates observed among workers in cooler versus warmer areas of high-density workplaces, as described previously by Günther et al.

An overarching limitation to these laboratory-based studies is that recovery of viable virus, when demonstrated, is not equivalent to confirmation that transmission has occurred. In a 2020 commentary, Goldman identifies another reason such studies likely exaggerate risk of COVID-19 transmission by fomites: the amount of virus used during simulations is often orders of magnitude greater than what would be found on surfaces in real-world settings (E. Goldman 2020). Without available data specific to SARS-CoV-2, Goldman cited studies recovering influenza virus (similar in size to SARS-CoV-2) from aerosols of infected patients. The amounts of viable virus detected from 32 aerosol samples ranged from 10^1-10^2 particle copies per cough (n=32), whereas the samples described by Van Doremalen et al., for example, contained 10^4 particle copies or more.

To mitigate risk of COVID-19 transmission due to surface contamination, the CDC recommends frequent disinfection of high-touch surfaces and spaces occupied by infectious workers using products from EPA List N (effective against SARS-CoV-2), and encouragement of hand hygiene (cleaning with soap and water for 20 seconds, or alcohol-based (60%) hand sanitizer when hands are not visibly dirty) in the workplace (Centers for Disease Control and Prevention 2020b; U.S. Environmental Protection Agency 2020).

There is a lack of data to corroborate indirect (fomite) transmission in real-world settings in absence of potential transmission by aerosolization. Sobolik et al. used quantitative microbial risk assessment to estimate the risks of infection from inhaled respiratory droplets and aerosols versus surface exposures within a typical food and vegetable processing facility (10 x 10 x 10 meters at 70°F) at varying distances from an infectious worker (Sobolik et al. 2022). Analyses were also conducted at “refrigerator temperature” (38°F) to simulate meat processing and other colder work environments.

Parameters used in these simulations were informed by particle dynamics research described previously in this section, including the assumption of exposure to both aerosols and respiratory droplets within 3 meters, and only aerosolized droplets at greater distances. These studies estimated that, for a worker remaining within 1 meter of an infectious worker over an 8-hour shift without preventive measures, the risk of transmission by respiratory droplets was highest (0.96, 95% CI 0.67-1.0), compared to aerosols (0.05, 95% CI 0.01-0.13) and 0.26 (95% CI 0.10-0.56) by the droplets falling onto stainless steel surfaces within 1 m of the exposed worker. Additionally, respiratory droplets comprised > 98% of transmission risk, compared to <1% each by aerosols or fomites. At 3 meters, combined risk of transmission was much lower overall (0.09, 95% CI 0.04-0.18), with the greatest proportion attributable to aerosols (65%), versus respiratory droplets (31%%) or fomites (4%).

In evaluating the reductions in risk of SARS-CoV-2 transmission after implementation of workplace controls (mask use, ventilation, hourly handwashing, surface disinfection and distancing), these simulations found that distancing was the most effective, followed by masking and increasing ventilation. Two-meter distancing alone resulted in an estimated 84% reduction in risk after 8 hours, compared to 1 meter distancing. Compared to no mask use, universal mask use alone reduced infection risk by 52% for cloth masks (risk of infection: 0.47, 95% CI 0.20-0.87) or as much as 99% with an N95 respirator (0.01, 95% CI 0.004-0.02). Increasing ventilation from 0.1 to 2-8 ACH resulted in a an estimated 14-54% reduction in risk at 1 meter. Implementation of masking, handwashing and surface disinfection resulted in a combined risk reduction of over 99% (0.001 after 8 hours, 95% CI 0.0004-0.004).

In addition to the primary limitation of being generated from a simulation study, these data estimate risk in the presence of only one infectious coworker; investigators did not estimate effectiveness of preventive measures assuming multiple infectious workers in one space. Additional estimations of risk incorporating the effects of partial and full vaccination among coworkers were not summarized here, because they cannot be extrapolated precisely to real populations of workers with heterogenous immunity. Nonetheless, these studies provide some insight into the relative influence of SARS-CoV-2 transmission pathways and effectiveness of workplace-level interventions, as data generated in real-world settings are lacking.

In summary, inhalation and deposition of respiratory particles and aerosols are currently considered the principal exposure routes for SARS-CoV-2. Limited studies of competing transmission mechanisms suggest that risk of fomite transmission is plausible, but relatively low compared to respiratory transmission. A hierarchy of controls is recommended for mitigating risk of workplace-acquired COVID-19. Distancing of six feet or more and installation of physical barriers between workers are recommended to reduce transmission by respiratory droplets, with masking and adequate ventilation to decrease risk of transmission by aerosols. While fomite transmission has not been confirmed, hand hygiene and frequent workplace disinfection are advised to reduce any risk of contracting SARS-CoV-2 through contact with contaminated surfaces. Simulation studies of workplace transmission estimate that combining vaccination with

OSHA-recommended controls leads to a greater reduction in risk of workplace-acquired COVID-19 than employing any one intervention alone.

1.3 **Detection of SARS-CoV-2**

Two types of viral tests are available to diagnose current SARS-CoV-2 infection: nucleic acid amplification tests (NAAT) and “rapid” viral antigen tests. The NAAT utilize reverse transcription polymerase chain reaction (RT-PCR) to detect viral RNA. RT-PCR tests of sputum samples are considered the “gold standard” diagnostic for active infection: in their 2021 meta-analyses, Böger et al. pooled results from 4 studies assessing the accuracy of RT-PCR in detecting SARS-CoV-2, calculating sensitivity estimates of 97% (95% CI 90.3-99.7%) and 74% (68-78%) for tests of sputum and nasopharyngeal samples, respectively.

Given a lack of publications reporting accuracy of RT-PCR tests among COVID-negative patients, pooled estimates for specificity were not generated (Böger et al. 2021). Yu et al. evaluated the performance of multiple types of NAAT in detection of SARS-CoV-2 (Yu et al. 2020) and found agreement between RT-PCR and all 157 negative results from the more sensitive ddPCR (droplet digital PCR) test, implying 100% specificity. While ddPCR identified 4 samples with low viral load as positive when RT-PCR testing yielded a negative result, the 95 samples identified as positive by RT-PCR were also found to be positive by ddPCR. In their preliminary comparison of ddPCR and RT-PCR analyses of samples from one COVID-19 positive and one control patient, Falzone et al. estimated ddPCR to take approximately 15% longer and cost 5-10% more per test, offsetting marginal gains in accuracy over RT-PCR for timely population-level surveillance (Falzone et al. 2020).

Tests for viral antigen (“rapid tests”) are less sensitive than RT-PCR but also highly specific, less expensive, and can be self-administered in the home with faster results (as quick as 15-30 minutes versus hours to days for RT-PCR). In 2021, Lee et al. conducted a systematic literature review and meta-analysis of studies assessing accuracy of rapid tests, including 24 studies (n=14,188 patients) (J. Lee, Song, and Shim 2021). Pooled sensitivity for SARS-CoV-2 diagnosis was found to be 68% (95% CI 59% - 76%) and specificity estimated to be 99% (95% CI 99%-100%). Sensitivity was reduced in samples with lower viral load or collected prior to onset of symptoms. These reports are reflected in current public health guidance describing rapid tests as most accurate among symptomatic patients or 3-5 days after exposure, consistent with the median incubation period (see: Section 1.4.1). In the U.S., rapid tests are sold in packs of two or more with the recommendation of serial testing for improved sensitivity (Food and Drug Administration 2022). Given the sensitivity of SARS-CoV-2 diagnostics, individuals can test positive long after they are symptomatic or infectious; for this reason, workplace requirements for "re-testing" or negative testing for employees to return to work are not advised.

In December 2021, the F.D.A. issued a statement acknowledging that performance of diagnostic tests may be impacted by the emergence of new SARS-CoV-2 variants, including Omicron (Food and Drug Administration 2021). Based on their mechanisms of viral detection (i.e., genetic targets), some RT-PCR tests have been identified as expected to fail detecting the Omicron variant, whereas others are expected to display detection patterns suggesting presence of the Omicron variant (S-gene, N-gene target failure or "dropouts"). Early reports suggest that antigen tests may have reduced sensitivity in detecting Omicron, given the variant's ability to cause infection with a lower viral load. A January 2022 report summarized discordant surveillance testing results from 30 COVID-19 cases associated with five workplace outbreaks in New York City, Los Angeles and San Francisco (Adamson et al. 2022). All cases tested negative for SARS-CoV-2 via NAAT on the same day or day after receiving positive RT-PCR results. All but 1 case (29/30) exhibited S-gene target failures suggestive of Omicron. As data are still emerging at the time of this report (and tests themselves are being modified), this topic will not be reviewed in depth. Confirmatory results will be summarized in this report when available.

1.4 Characteristics of COVID-19: Incubation, Infectious Periods and Symptoms

This section summarizes current knowledge of SARS-CoV-2's incubation and infectious periods, and estimated frequency of asymptomatic infections caused by pre-Omicron and Omicron variants. The constellation of symptoms known as "long COVID" is also summarized. The factors associated with progression from acute to long COVID are still being elucidated. Description and frequency of severe COVID-19 outcomes and factors associated with these are summarized in Section 1.5.

1.4.1 Incubation and Infectious Periods

Prior to the emergence of the Omicron variant, the incubation period for SARS-CoV-2 was estimated to range from 2-14 days, with a median incubation period of 4-5 days among cases (Li et al. 2021; Lauer et al. 2020). The infectious period was defined as the two days prior to onset of symptoms through the longer of ten days or end of a patient's symptomatic period. For asymptomatic infections (see: Section 1.4.3), this infectious period is estimated relative to the date of first positive SARS-CoV-2 test.

In December 2021, shortly after Omicron was first detected in the United States, the CDC released a report characterizing a cluster of six SARS-CoV-2 cases in Nebraska identified to be caused by this variant. Jansen et al. reported that the median incubation period among these cases was markedly shorter, about 3 days (range: 33-75 hours) (Jansen 2021). Subsequent reports characterized Omicron cases identified in late November through December of 2021 and corroborated these findings. A Norwegian study of 81 cases associated with an outbreak among attendees of a Christmas party estimated the median incubation period to be 3 days (interquartile range [IQR]: 3-4 days) (Brandal et al. 2021). A Korean study estimated a mean incubation period of 4.2 days (with range 2-8 days) among of 80 cases confirmed to be caused by Omicron (J. J. Lee et al. 2021).

As described further in Section 1.4.2, infections caused by Omicron have been described as milder and shorter than those caused by previous variants, implying a shortened infectious period. Preliminary analyses of specimens collected from patients with Omicron versus the previously dominant Delta variant suggest this is partially explained by a lower median viral load and faster clearance of the virus observed among Omicron infections. For example, Hay et al. analyzed specimens from 204 COVID-19 cases detected among professional basketball players undergoing routine, occupational COVID-19 testing between July 2021 and January 2022 (Hay et al. 2022). Among 97 specimens identified as the Omicron variant, the peak viral load was lower than among 107 cases identified as Delta. The median time to clearance of Omicron infections was found to be shorter for Omicron (5.35 days, 95% CI 4.8-6.0 days), compared to Delta (6.2 days, 95% CI 5.4-7.2 days for Delta).

A caveat to these findings is that this study did not control for vaccination or prior infection, or report on vaccination status aside from describing the population as “highly vaccinated”. While vaccination decreases likelihood of severe illness (see further: Sections 1.5 and 1.8.1), vaccinated individuals have been more susceptible to Omicron than to any pre-Omicron variant (see, Section 1.8). In absence of more evidence from studies among the unvaccinated and COVID-naïve, it is unclear how much Omicron’s milder presentation is attributable to underlying host immunity versus characteristic of the variant itself.

Evidence of Omicron’s decreased incubation period and duration of Omicron infections informed updates to the federal quarantine and isolation guidance. Until December 2021, the C.D.C. advised that individuals who were not up-to-date on vaccinations (fully vaccinated or, if eligible, boosted) should quarantine and monitor for symptoms through 10 days after last known COVID-19 exposure. Individuals with COVID-19 were advised to isolate through the longer of (1) 10 days after onset of symptoms (or positive test, if asymptomatic), or (2) 48 hours after improvement of symptoms including fever, in absence of fever-reducing medication (such as acetaminophen). Current guidance, released December 27, 2021, advises that quarantining individuals who test negative for COVID-19 and are asymptomatic at Day 5 post-exposure may end quarantine “early”, but should mask for 5 more days to reduce risk of transmission after a later or asymptomatic infection. These recommendations apply to both vaccinated and unvaccinated individuals, given the transmissibility of Omicron. Finally, individuals whose COVID-19 symptoms have resolved after 5 days no longer need to isolate for a full 10 days but should wear masks in public settings or around higher-risk individuals (see: Section 1.5.1) for an additional 5 days.

1.4.2 Clinical Presentations of Mild COVID-19: Pre-Omicron and Omicron

The spectrum of mild to critical COVID-19 symptoms as described by the National Institutes of Health highlights the diverse presentation of SARS-CoV-2 (National Institutes of Health, n.d.). The NIH considers **mild COVID-19 infections** to include any of the following without shortness of breath or abnormal findings from chest imaging: fever, cough, sore throat, malaise, headache, muscle pain, nausea, diarrhea, vomiting, loss of taste or smell**. Moderate infections** include lower respiratory infections with reduced blood oxygen level (≤94%). **Severe infections** include reduced blood oxygenation, “reduced arterial partial pressure of oxygen to fraction of inspired oxygen” (PaO_2/FiO_2) <300 mm Hg, and a ”respiratory rate >30 breaths/min, or lung infiltrates >50%”. Infections that have progressed to respiratory failure, septic shock or multi-organ dysfunction are considered **critical illness.** The epidemiology of severe outcomes is summarized in more detail in Section 1.5.1.

Results from a large case-control study of COVID-19 infections among adults in the United Kingdom illustrate that vaccination reduces the frequency and severity of symptoms. Comparing symptoms reported by vaccinated and unvaccinated adults using a mobile app between December 2020 and July 2021, Antonelli et al. examined the association between reported symptoms and vaccination status using logistic regression models adjusted for age, body mass index (BMI) and sex (Antonelli et al. 2022). Among adults ages 18-59, vaccinated cases (n=455) were found to have reduced odds of reporting more than five symptoms compared to unvaccinated cases in the same age range (n=474) (odds ratio [OR] 0.59, 95% CI 0.38-0.90). Vaccinated cases also had increased odds of asymptomatic infection (OR 1.49, 95% CI 0.99-2.25). One quarter (24.8%) of vaccinated cases and 32% of unvaccinated cases reported more than five symptoms, while 14.9% of vaccinated and 10.6% of unvaccinated cases reported asymptomatic infection. This study also found that the frequency and odds of having symptoms longer than 28 days were substantially lower among vaccinated versus unvaccinated individuals (5.2% vs. 11.4%, OR 0.21, 95% CI 0.08-0.59).

These data were collected prior to emergence of the Omicron variant, and more recent symptom studies speak to this new variant's milder presentation. The decreased presentations of loss of smell or taste, COVID-19's most specific symptoms, have made this disease increasingly difficult to distinguish from other illnesses such as the common cold and influenza. In logistic regression models using data collected from 182,133 Omicron cases and 87,920 Delta cases in England from December 1 through December 28, 2021, these symptoms were less than half as likely to be reported among Omicron cases compared to Delta (13% of Omicron vs. 34% of Delta, OR 0.22 95% CI 0.21-0.23), after adjusting for age, sex, race/ethnicity, and self-reported vaccination status (UK Health Security Agency 2022). The only symptom found to have more reports among Omicron versus Delta cases was sore throat (53% of Omicron and 34% of Delta, OR 1.93, 95% CI: 1.88-1.98).

1.4.3 <u>**Prevalence of Asymptomatic COVID-19: Pre-Omicron and Omicron**</u>

Precise measurement of the proportion of COVID cases that occur without symptoms is logistically challenging, since it would require broad population-based testing. In their meta-analysis of 95 studies including 29,776,306 individuals tested for SARS-CoV-2 prior to the Omicron wave, Ma et al. estimated the proportion of confirmed infections that were asymptomatic to be 50% (95% CI 33.5-65.5) among adults aged 20-39 and 32% (95% CI 11.6-53.3) among those aged 40-59 (Ma et al. 2021).

Garrett et al. describe how screening results from COVID-19 vaccine trials in South Africa during the Omicron wave were extrapolated to the broader population, to suggest substantially increased prevalence of asymptomatic infections among cases caused by Omicron. During December 2021, 31% of patients screening into Moderna's COVID-19 studies tested positive for SARS-CoV-2 via RT-PCR, in absence of symptoms, and with RT-PCR results characteristic of the Omicron variant (see: Section 1.3). Garrett et al. applied this prevalence estimate to the demographic distribution of infections among the general population to estimate that as many as 90% of COVID-19 infections during South Africa's Omicron wave could have been asymptomatic (Garrett et al. 2022).

Given (1) the decreased viral load observed among Omicron infections (as described in Section 1.4.1), (2) correlation between viral load and symptom severity, and (3) ability of Omicron to infect vaccinated individuals (who have a much lower risk of severe illness), it is unsurprising that the frequencies of asymptomatic and mild infections have increased during the Omicron wave. These findings bear implications for measures to prevent spread among workers: symptom screening is decreasingly effective at identifying infectious individuals for exclusion from the workplace, and layered interventions to minimize workplace exposure to SARS-CoV-2 are thus of heightened importance.

1.4.4 **Long-term Symptoms of COVID-19 or "Long COVID"**

SARS-CoV-2 has been recognized to impact several organ systems (cardiovascular, dermatologic, endocrine, gastrointestinal, renal, musculoskeletal, neurologic, and pulmonary) more than 4-12 weeks after initial infection among some cases. The frequency, duration, and mechanisms of COVID-19's post-acute sequelae (PASC), which have become known as "long COVID", are still being elucidated.

A November 2021 study by the U.S. Department of Veteran affairs compared frequency of 33 PASC ranging from mild (fatigue, constipation, diarrhea, and headache) to severe (chronic kidney disease, thromboembolism, heart failure) among 181,384 COVID-19 cases and 4,397,509 non-infected controls. Approximately 7% of cases reported at least one of these PASC 30 days after infection, and prevalence of any reported symptoms was estimated to be about 73% higher (95 CI 72.1% - 74.7%) after 6 months among cases versus controls (Xie, Bowe, and Al-Aly 2021). About 59 in every 1,000 cases reported PASC at 6 months post-infection, though proportions were greater among hospitalized (21.7%) and those admitted to intensive care (36.5%) compared to all others (4.4%). Shortness of breath (28.8%, 95% CI, 27.6-30%), sleep disorders (19.5%, 95% CI 18.1-20.9) and hyperlipidemia (17.09, 95% CI 15.3-18.8%) were the most prevalent.

At the time of this report, estimated of rates of PASC from countries who experienced early surges of Omicron cases (e.g., South Africa and the United Kingdom) have not yet been widely reported. The findings from Xie et al. indicate that long COVID is more common after more severe infection, suggesting that Omicron may be less likely to lead to PASC than other variants. At the same time, given the sheer number of cases requiring hospitalization during the Omicron surge in the United States, prevalence of PASC could increase substantially over the next several months.

Xie et al. also found that long-COVID symptoms were substantially more common among individuals with the pre-existing conditions described in the next section. Current literature summarizing studies of long COVID by occupation have focused on healthcare workers. Increased risk for long COVID among NHNCW is a supposition, given the disproportionate frequency of comorbidities among NHNCW relative to the general population, as described in Section 1.5.1.

1.5 **Severe COVID-19 Outcomes: Hospitalization and Death**

1.5.1 **Individual Risk Factors for Severe COVID-19 Outcomes**

In 2021 the CDC published a science brief summarizing the underlying medical conditions associated with increased risk of severe COVID-19 outcomes (Centers for Disease Control and Prevention n.d.): cerebrovascular, heart, lung, kidney and liver diseases, cancer, Type I and Type 2 Diabetes, tuberculosis, obesity, pregnancy, mental health disorders and disabilities, HIV, sickle cell disease, solid organ transplantation, other use of immunosuppressive medications, substance use disorders and smoking. In this review, namely the summaries of primary data from COVID-19 clinical trials in Section 1.8, references to underlying conditions associated with severe outcomes refer to these comorbidities unless otherwise specified. Age has been widely recognized as a risk factor for severe COVID-19 outcomes, as reflected in age-based prioritization for vaccine allocation in the U.S., in addition to the workplace-related prioritization described in Section 1.8 (Centers for Disease Control and Prevention 2021a). Reviews of this evidence will not be included in this review; age-based prioritizations for vaccination in the U.S. apply to adults ages 65 and older, while this analysis is limited to COVID-19 burden among working-age Chicagoans (ages 18-64).

Hospitalization rates have differed dramatically between vaccinated and unvaccinated individuals in both pre-Omicron and Omicron variants. For example, results from a cohort study of Omicron and Delta cases in Ontario Canada indicate a 65% reduced risk of hospitalization (hazard ratio [HR] 0.35, 95% CI 0.26-0.46) among 29,564 Omicron cases when matched with at least one Delta case (n=14,181) by age, sex, vaccination status, health region and onset date. Risk of ICU admission or death was 83% lower (HR =0.17, 95% CI 0.08-0.37) among Omicron cases compared to Delta (Ulloa et al. 2021).

Figures 5 and 6 show hospitalization and mortality rates among COVID-19 cases in Chicago to re-iterate the ability of vaccination to protect against severe illness. Primary data supporting the approval of available vaccines are described in Section 1.8**.** The overwhelming majority of hospitalizations and deaths among Chicagoans of all ages since the advent of vaccination have been among the unvaccinated, including during the Omicron wave. In January 2022, the peak of hospitalizations due to Omicron infection, hospitalization rates were ten times higher among unvaccinated versus vaccinated and boosted Chicagoans (150 versus 16 per 100,000). Mortality rates were over 30 times higher (22 versus 0.64 per 100,000).

1.5.2 Studies Describing Individual Risk Factors for Severe COVID-19 Outcomes among Working-Age Americans

Selden and Berdahl used estimates from the 2014-2017 Medical Expenditure Panel Survey (MEPS), a nationally-representative dataset including both health and employment data for household members surveyed, to estimate the proportion of working adults in the U.S. who are at risk for severe COVID outcomes due to underlying conditions (Selden and Berdahl 2021). They first estimated the proportion of persons at increased risk of severe illness due to obesity (BMI of 30 or higher), age of 65 years or older, or any of the following treated conditions: diabetes, emphysema or other chronic obstructive pulmonary disease, kidney disease, cancer (other than nonmelanoma skin cancers), or coronary heart disease. They created a second variable representing a broader definition of increased risk, including current smoking, treated asthma, or treated hypertension. This study estimated that half (50%) of working adults in the U.S. were at increased risk of severe COVID outcomes (61% using the broader categorizations), and that 41% -54% met criteria for increased risk due to COVID outcomes.

Over a quarter (28%) of the adult U.S. population who were at increased risk according to the CDC’s definitions also described themselves as essential workers. These analyses may not represent pandemic-era health expenditures or employment in the U.S. and unlike the analyses planned for this dissertation, they include workers over age 65 and industries excluded from planned analyses (healthcare, education). Finally, similar studies cannot be conducted at the city level; these datasets are not available for narrower geographies..

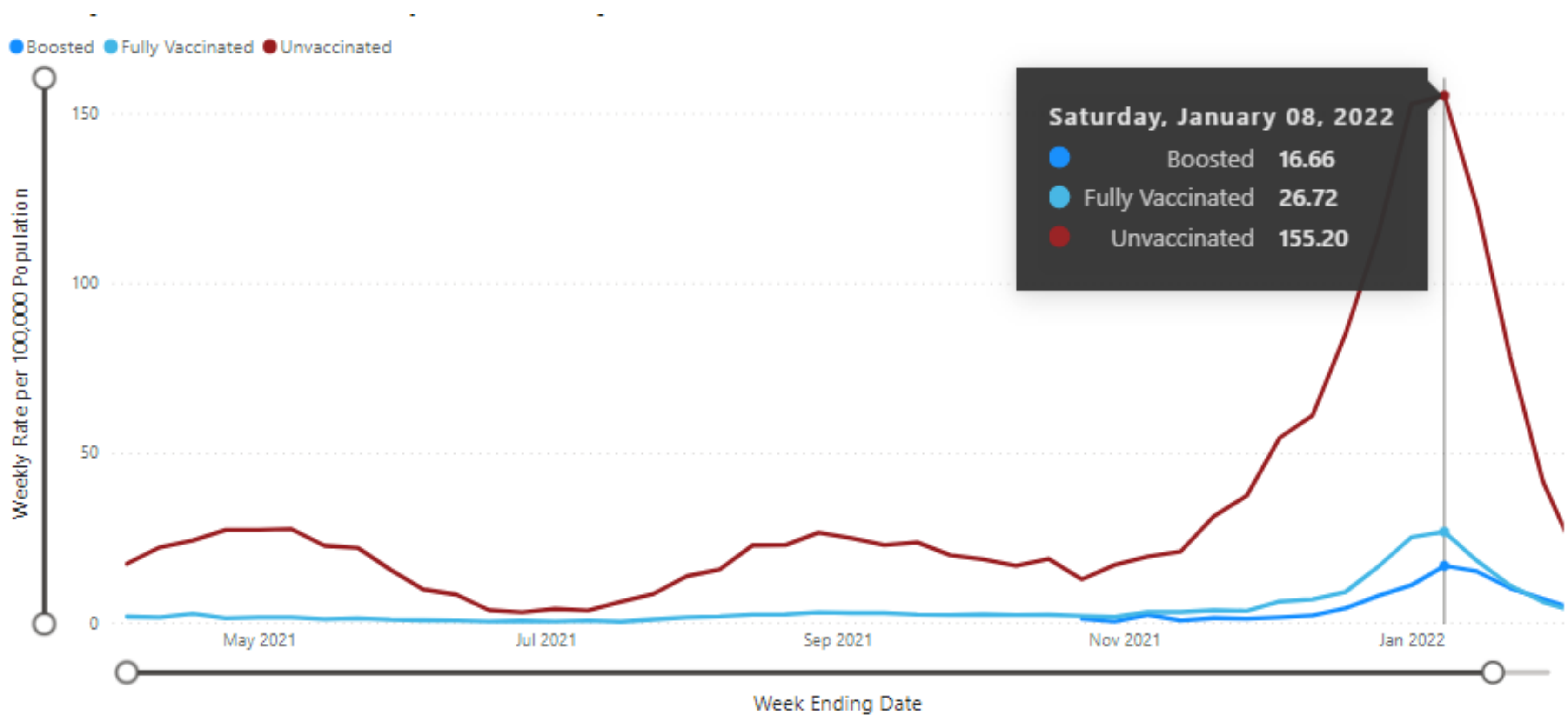

Figure 5. Rate of COVID-19 hospitalizations by vaccination status in Chicago.
(Source: Chicago Department of Public Health, 2022)

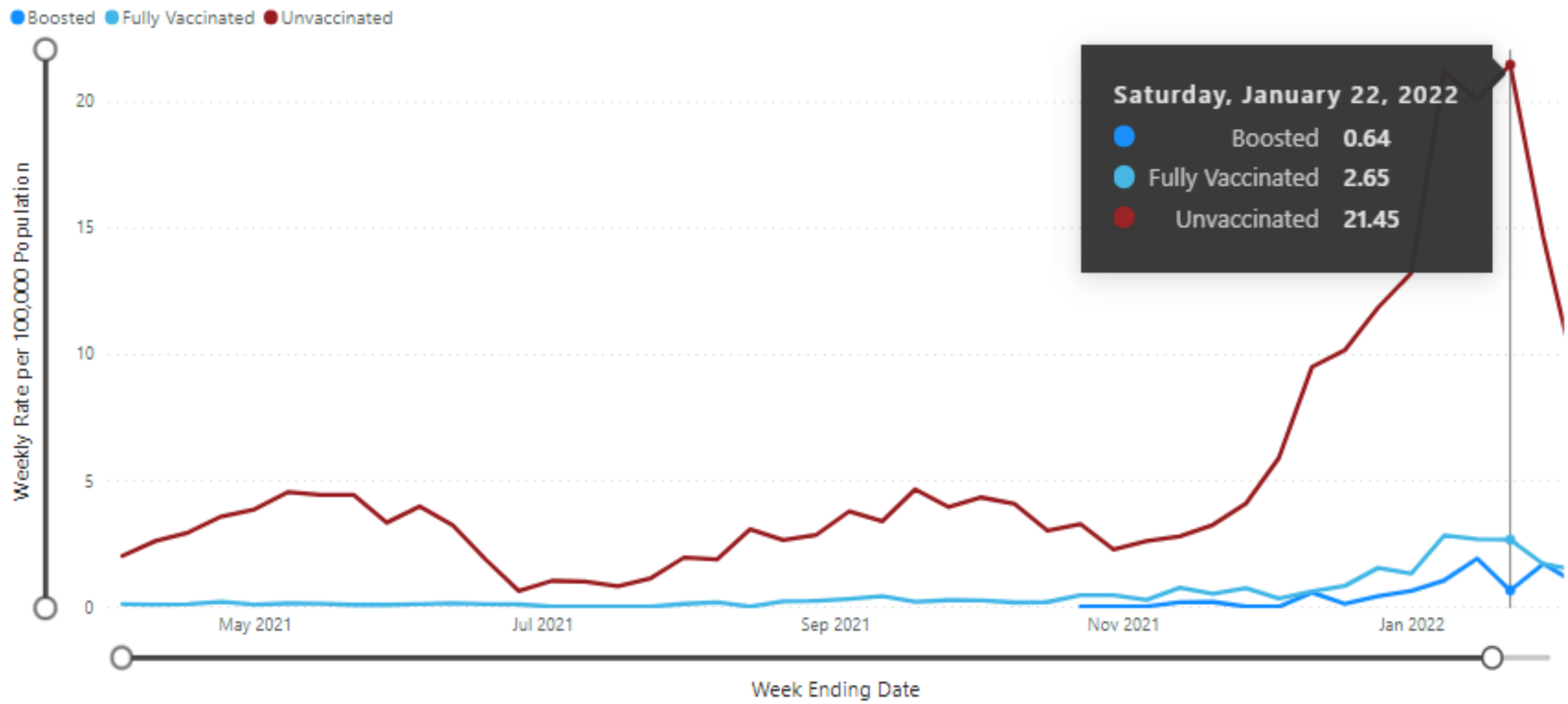

Figure 6. Rate of COVID-19 deaths by vaccination status in Chicago.
(Source: Chicago Department of Public Health, 2022)

Subsequent studies incorporate measures of COVID-related mortality among NHNCW, with similar limitations summarized on the following pages. Low income impacts workers' abilities to quarantine, isolate, and afford treatment, resulting in worse outcomes than among workers who can afford to (1) take leave (including without pay) to reduce exposures, and (2) access care for worsening illness.

A 2020 estimate of the socioeconomic vulnerabilities of essential workers in the U.S. utilized American Community Survey (ACS) data from 2018 to estimate that over half (51%) of the households represented in the survey contained at least one essential worker and that 8 of 21 industry sectors account for 73% of these, with healthcare being the highest. One quarter (25%) of essential workers were estimated to have low income, 18% to have at least one household member un-insured, and 18% to live with someone 65 years or older (McCormack et al. 2020).

Rogers et al. used both ACS and Current Population Survey to estimate the correlation between COVID-19 mortality rates and occupational distribution by race and ethnicity group across 35 states and Washington, D.C. (Rogers et al. 2020). They found COVID-19 mortality to be higher among non-Hispanic Black compared to non-Hispanic Whites, with non-Hispanic Blacks disproportionately occupying essential occupations. Occupations with the greatest disparities in proportion of non-Hispanic Black versus non-Hispanic White workers across all states included transportation and material moving (10.6% of non-Hispanic Blacks versus 5.3% of non-Hispanic Whites) and food preparation and serving (6.6% vs. 4.5%).

A 2020 report by the Brookings Institute estimated the distribution of essential workers across major U.S. cities using data from the Bureau of Labor Statistics and the same CISA industry classifications as described in this review (Kane 2020). This report estimated that essential worker industries comprised 34-43% of the U.S. workforce, with Chicago having over a million workers in these designated categories. They found that workers reporting physical proximity to others and frequent face-to-face interactions "most of nearly all the time" also tended to earn well below the median hourly wage of $18.58 in 2018. For example, 86% of grocery store cashiers and 72% of hand packers and packagers reported being near others, and had mean hourly wages of $10.93 and $11.82, respectively. Overall, 65% of lower-wage workers reported frequent proximity to others versus 45% of higher-wage workers. These reports did not include extensive analyses of workers by all occupation groups or more granular geographics such as cities but speak to the compounding of socioeconomic and occupational risks among NHNCW. As described in the next section, Chicago has developed a neighborhood-level indicator called the Community COVID-19 Vulnerability Index (CCVI), to approximate areas where a high proportion of residents are at increased risk for severe COVID-related outcomes due to these factors combined. CCVI will be used in this dissertation's analyses to adjust for confounding by such factors, since these data are not available at the individual level.

1.6 Neighborhood Health Indicators in Chicago

Chicago devised two neighborhood-level risk categorization frameworks for direction of vaccines, outreach, and other resources during the COVID-19 pandemic. The first of these is a Community COVID-19 Vulnerability Index (CCVI), described in Section 1.6.1. The second is the Healthy Chicago Equity Zones (HCEZ) described in Section 1.6.2. Both are defined by Community area.

1.6.1 Definitions of Chicago's COVID-19 Community Vulnerability Index

Chicago's local CCVI was constructed following the methodology that Surgo Ventures used to develop a national CCVI in 2020. The purpose of this national CCVI was to help policymakers make evidence-based allocations of limited resources to areas of greatest need during the pandemic response. Surgo defines COVID vulnerability as 'limited ability to mitigate, treat, and delay transmission of [COVID-19], and to withstand its secondary effects on health, economic and social outcomes” (Smittenaar et al. 2021). To identify U.S. Census tracts that have been most adversely impacted by COVID-19, Surgo expanded on the CDC’s existing Social Vulnerability Index (SVI) by incorporating indicators associated with poor COVID-19 outcomes as of November 2020. Like SVI, Surgo’s CCVI is a continuous measure with a minimum of 0 (no vulnerability) to a maximum of 1 (highest vulnerability). As the national CCVI is not used in this analysis, further details on the 40 indicators, data sources and aggregation will not be detailed. Construction of Chicago’s CCVI will be described. Of note, both the national and CDPH-designed CCVI are informed by 2020 surveillance data. In their validation of this national index (Figure 7), Smittenaar et al. note that through May 2021, residents living in the top third of highest-CCVI counties in the U.S. saw 21% more cases and 47% more deaths than the third of counties with lowest CCVI. This suggests that CCVI remains representative of high-burden areas in the periods after constituent surveillance data were gathered.

In Chicago’s CCVI, each of the city’s 77 community areas received one ranking for each of 10 socioeconomic, epidemiological, occupational, and COVID-related components (0 being least vulnerable and 76 most vulnerable), then averaged into one index per area (City of Chicago n.d.). The least vulnerable community has a CCVI of 4 (North Center) and the most vulnerable has a CCVI of 64 (West Englewood). CCVI has been presented in terciles (25 low, 26 medium and 26 high-vulnerability areas, Figure 8). High-CCVI areas are concentrated in the West and South, in contrast to low-CCVI areas concentrated in the North and East. The ten components and their constituent variables are grouped by component type (socioeconomic, epidemiological, occupational, and COVID-related) as shown in Figures 9 and 10. Variables are derived from the 2018 and 2019 ACS, 2019 Healthy Chicago Survey, and BlueDot mobility data. Some data are available at the census tract level while others, only available at county or state levels, are applied to all constituent census tracts. The CCVI has two epidemiological components (Figure 9): percentage of residents ages 65 and older, and percentage of the population indicating any of diabetes, obesity, or currently smoking.

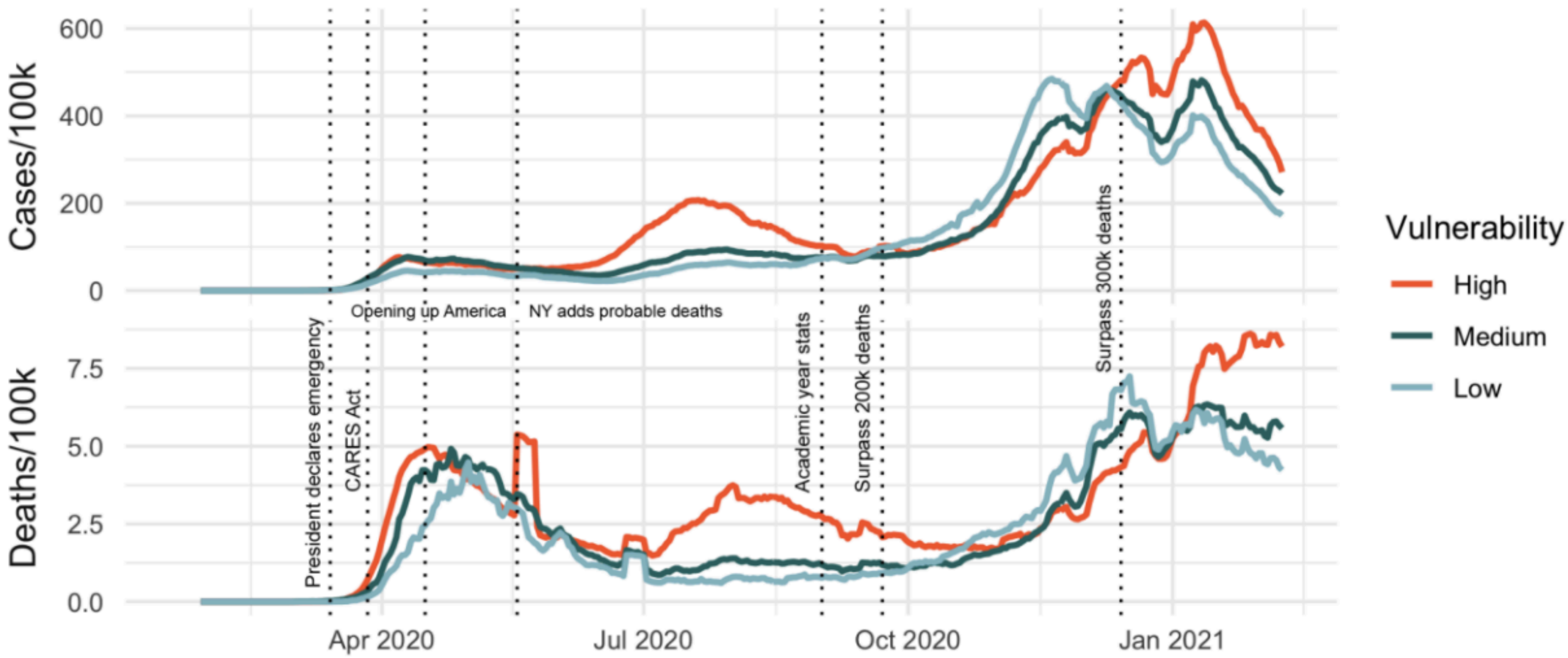

Figure 7. COVID-19 case and mortality rates in the United States by CCVI of U.S. counties, in low to high terciles
(*Source: Smittenaar et al., 2021)*

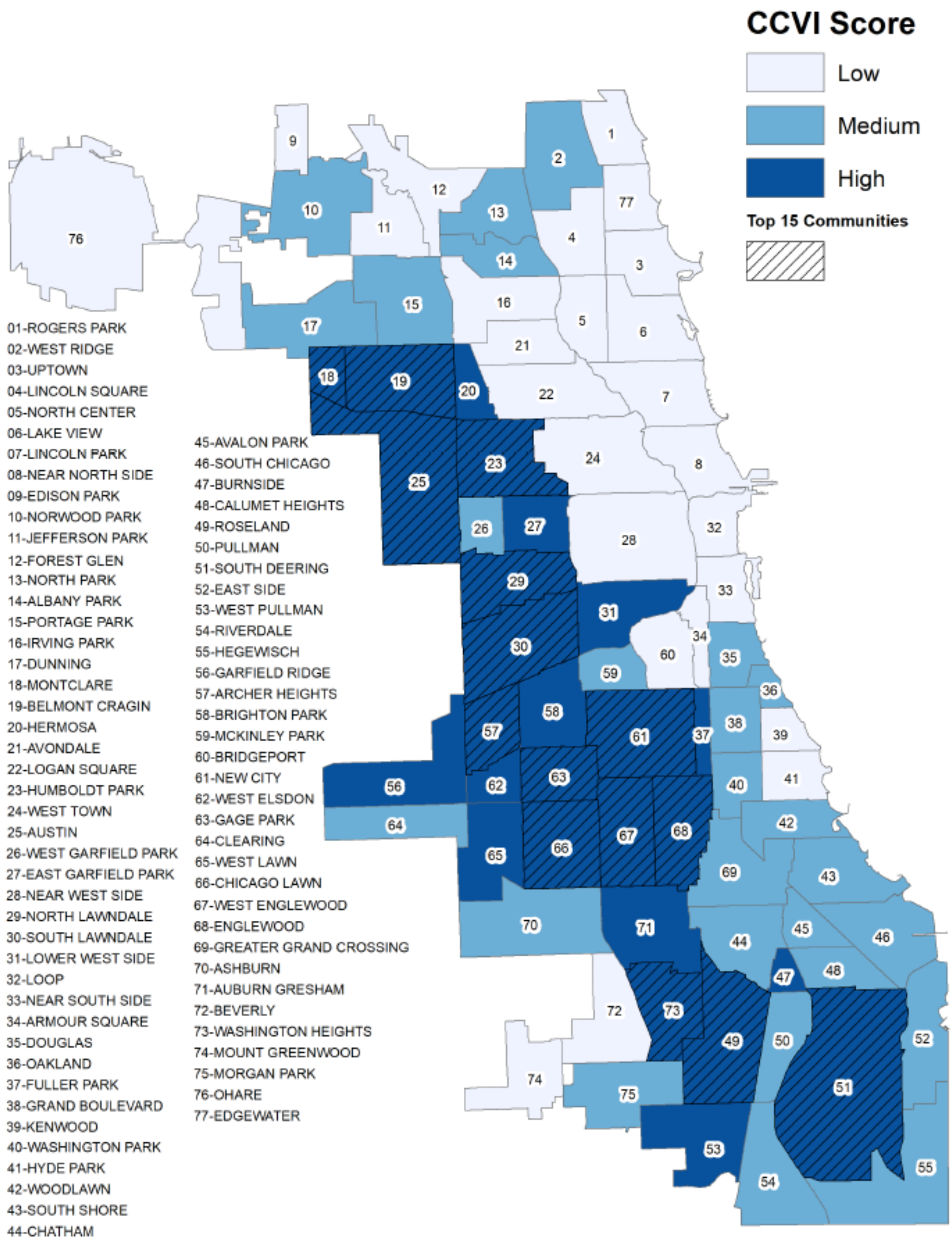

Figure 8. CCVI and corresponding community areas in Chicago.
(Source: City of Chicago, 2021)

The first of two occupational risk components of CCVI (Figure 10) is the total percentage of population reporting any essential work, as estimated from the 2019 ACS. These ‘essential’ occupations included here are pre-pandemic estimates and include some occupations excluded for this analysis of NHNCW: education, first responders, corrections, and childcare. As a result, this indicator is not directly adjusting for the distribution of NHNCW in Chicago. The second occupational component describes mobility of Chicagoans throughout the pandemic compared to a 'baseline' period of 2019-2020. Frequency of leaving home is approximated by calculating the proportion of mobile devices found within 200 m of their 'home' location across all check-ins at 30-minute intervals over a given period (BlueDot n.d.). “Home location” is the place a device is most often found between midnight and 9 a.m. This assumption may underrepresent mobility among night-shift workers, for example, who spend this time at work and most hours elsewhere.

Finally, three components represent COVID-19 burden (Figure 10), incorporating I-NEDSS (Illinois Notifiable Electronic Disease Surveillance-System) case data from January 1 through December 2020. Components represent (1) diagnosed cases,(2) COVID-19-related hospital admissions and (3) COVID-related deaths per 100,000 city residents. Because 3 of 10 components represent COVID incidence and severity, CCVI is weighted toward COVID-related burden, while incorporating additional factors excluded from CDC’s SVI. Beyond this section of this report, the term CCVI refers to Chicago's version of this indicator unless specified.

1.6.2 **Healthy Chicago Equity Zones**

In 2021, as part of Healthy Chicago 2025 campaign, CDPH defined six Healthy Chicago Equity Zones (HCEZ) (Figure 11) defined by CDPH (City of Chicago n.d.): Northwest, West, Southwest, Far South, Near South, and North Central zones. These were created, with designated lead organizations coordinating strategies to address the greatest needs identified for residents within the region.

Chicago CCVI Sociodemographic Risk Factors

At the community area level:	
% Individual Poverty	2018 US Census American Community Survey
% 16+ unemployment	2018 US Census American Community Survey
% Per capita income	2018 US Census American Community Survey
% 25+ no HS diploma	2018 US Census American Community Survey
% Uninsured	2018 US Census American Community Survey
% Population 17 and under	2018 US Census American Community Survey
% living w disability	2018 US Census American Community Survey
% Crowded housing	2018 US Census American Community Survey
% Single-parent households	2018 US Census American Community Survey
% w/ no primary care provider	2019 CDPH Healthy Chicago Survey

Surgo combined 9 equally weighted values into 2 components:
- ***Socioeconomic (percentile)***
- ***Household (percentile)***

Data analyzed and compiled by CDPH into one component

Chicago CCVI Epidemiological Risk Factors

At the community area level:	
% 65+ years	2019 US Census American Community Survey
% adult obesity	2019 CDPH Healthy Chicago Survey
% adult current smoking	2019 CDPH Healthy Chicago Survey
% adult diabetes	2019 CDPH Healthy Chicago Survey

Data analyzed and compiled by CDPH into one component

3 indicators were equally weighted and combined into 1 component:
% of population w/ one or more of these comorbid conditions

Figure 9. Sociodemographic and epidemiological factors of Chicago's Community COVID-19 Vulnerability Index
(Source: City of Chicago, 2021)

Chicago CCVI Occupational Risk Factors

At the community area level:	Data Source
Education (teachers, support staff)	2019 US Census American Community Survey
Manufacturing/Food production	2019 US Census American Community Survey
Material moving (grocery store, laborers, freight)	2019 US Census American Community Survey
Personal Service (Childcare, recreation and entertainment workers)	2019 US Census American Community Survey
Public Safety (first Responders/corrections)	2019 US Census American Community Survey
Transportation (public transit, airport truck, taxi)	2019 US Census American Community Survey
Food Service (cooks, servers, food prep, kitchen)	2019 US Census American Community Survey
Ratio of mobility in 2020 compared to 2019	BlueDot (2019 and 2020)

Data analyzed and compiled by CDPH based on ACIP guidance and US Bureau of Labor Statistics Occupation Classifications

Total # of each occupation group in each community area were equally weighted and combined into 1 component **[% of population that are essential workers]**

Data compiled by CDPH into one component

Chicago CCVI Cumulative COVID Burden

At the community area level:	
Diagnosed COVID-19 cases (rate per 100k)	CDPH Communicable Disease Surveillance, I-NEDSS, Jan 1 – Dec 31, 2020
COVID-19 hospital admissions (rate per 100k)	CDPH Communicable Disease Surveillance, I-NEDSS, Jan 1 – Dec 31, 2020
COVID-19 mortality rate (rate per 100k)	CDPH Communicable Disease Surveillance, I-NEDSS, Jan 1 – Dec 31, 2020

Data analyzed and compiled by CDPH into 3 components

Figure 10. Occupational and COVID-related factors of Chicago's Community COVID-19 Vulnerability Index

(Source: City of Chicago, 2021)

As of January 2022, lead organizations are:

- Phalanx Family Services (Far South region),
- Greater Auburn Gresham Development Corporation (Near South),
- Swedish Covenant (North/Central),
- Northwest Side Housing Center (Northwest),
- Southwest Organizing Project (Southwest)
- Rush University Medical Center (West).

HCEZ mirror regions used for planning by other city agencies. Far South and Southwest HCEZ have high proportions of residents in medium and high CCVI communities (Figure 12) and in contrast, all but one of the community areas in the North/Central zone is considered low-vulnerability. While evaluation of COVID-19 risk by HCEZ may not have the granularity of CCVI, definitions of public health need by HCEZ can yield data that readily inform planning with lead coordinating organizations. HCEZ also resemble the distribution of racial and ethnic minorities in Chicago, a highly segregated city (see Figure 13), and CCVI does not incorporate race or ethnicity. Therefore, another advantage of using HCEZ in these analyses is ability to assess ecological-level associations of race/ethnicity with COVID-19 infection and mortality. These sections have reviewed individual risk factors for COVID-19 that may exacerbate occupational risk, and neighborhood level variables that provide more insight into these factors among NHNCW in Chicago. These comorbidities and sociodemographic factors are excluded from many reports described in Section 3, given lack of complete data on COVID-19 cases. Inclusion of CCVI in models of the association between workplace risk and COVID-19 outbreaks helps adjust for confounding by socioeconomic factors, despite a lack of individual level data. Characterizations of COVID-19 among workers and industries by HCEZ in Chicago enable dissemination of targeted data to lead organizations.

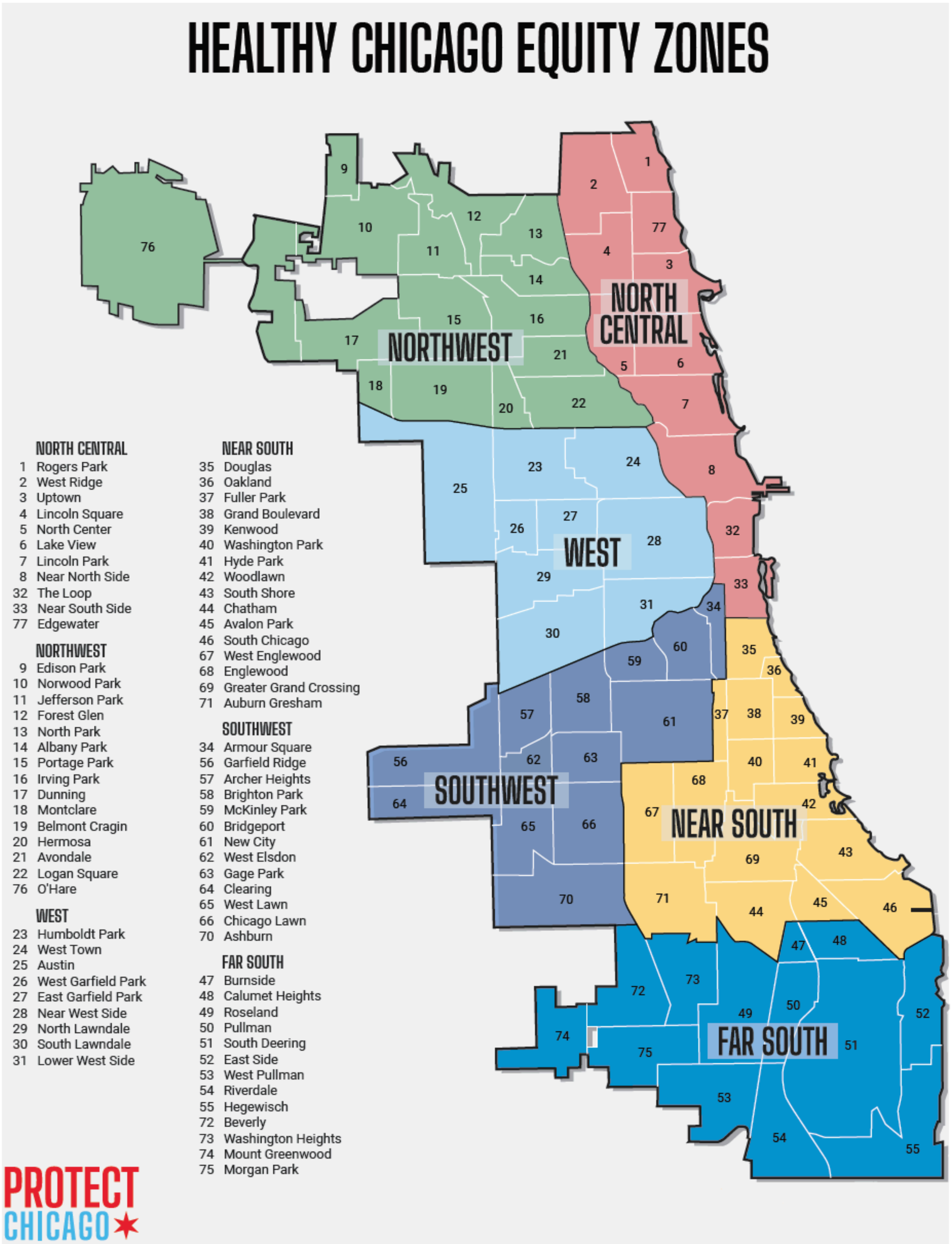

Figure 11. Healthy Chicago Equity Zones and corresponding community areas.
(Source: City of Chicago, 2021)

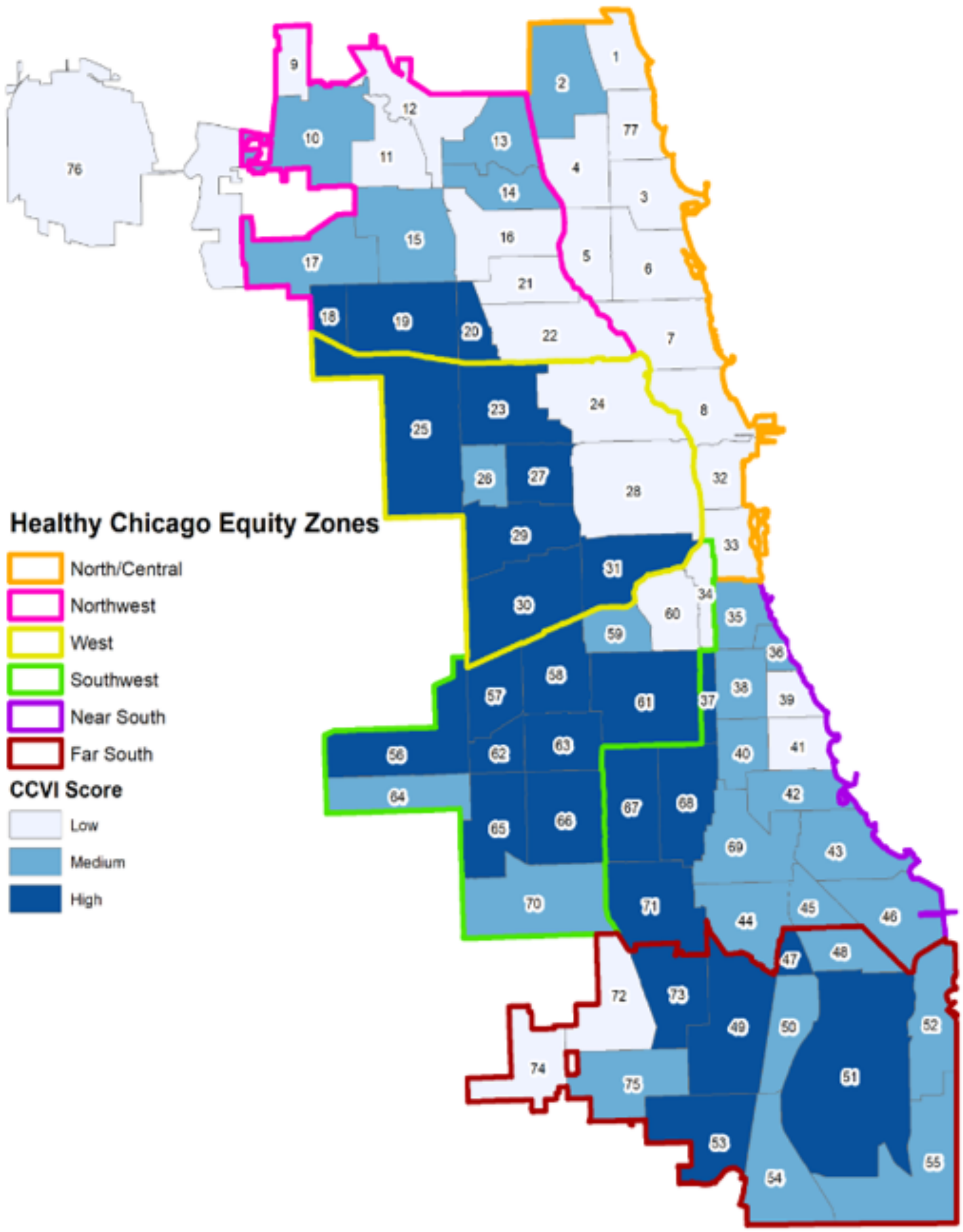

Figure 12. Comparison of Healthy Chicago Equity Zones and Community COVID-19 Vulnerability Indices in Chicago
(*Source: City of Chicago, 2021)*

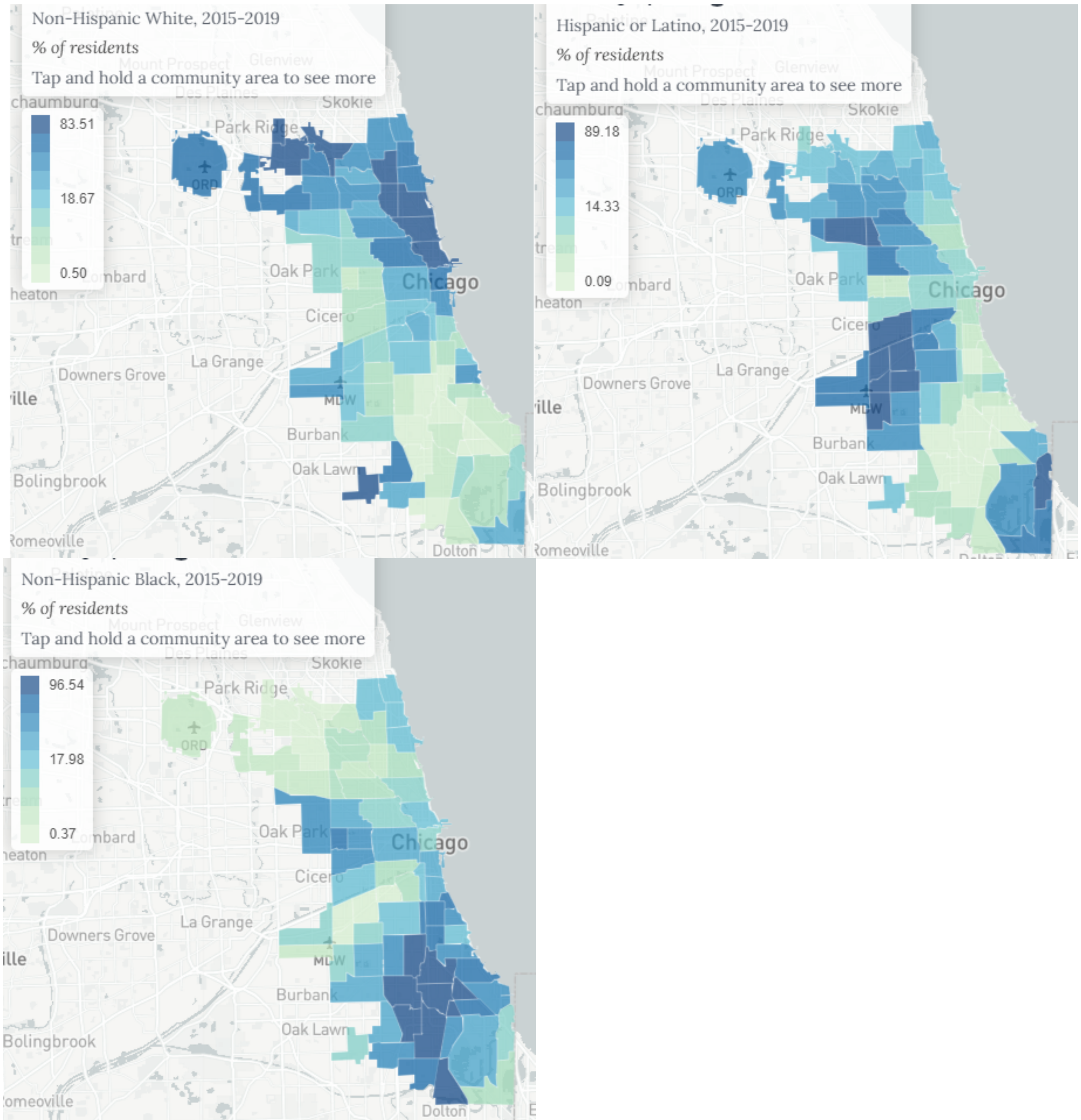

Figure 13. Distributions of non-Hispanic White, non-Hispanic Black, and Hispanic/Latino populations in Chicago.
(Source: City of Chicago, 2022

1.7 “Pre-Vaccination Era”: Stay-at-Home Orders, Closure of Non-Essential Businesses in Response to COVID-19

Before the availability of vaccines, COVID-19 overwhelmed the global healthcare infrastructure so rapidly that governments were forced to implement business shutdowns and stay-at-home orders, as extreme measures of limiting person-to-person transmission. Industries in which employees could function remotely transitioned to telework As described later in this review (Section 2.6), the United States government established definitions of critical infrastructure (“essential”) industry sectors, whose continued operations were necessary to preserving economic functioning of economies and public safety. Timelines for closure and re-opening of “non-essential” businesses were determined state by state. Chicago established a more conservative five-phase framework than the rest of Illinois, based on case and positivity rates throughout the city, ranging from Phase I (“Strict Stay At Home”) to Phase V (“Protect”). In Phase III (“Cautiously Reopen”), offices, hotels, restaurants, non-essential retail, personal services, construction were among the businesses that re-opened at limited capacity on June 3, 2020, with the remainder of businesses re-opening in Phase IV, (“Gradually Resume”) on July 24, 2020. As described in this literature review, analyses of the impact of re-opening and vaccination on relative COVID-19 burden among “essential” and “non-essential” workers outside of healthcare settings have been limited.

1.8 Pharmaceutical Interventions: Vaccination and Treatment

This section reviews pharmaceutical interventions that have been developed and tested specifically to target SARS-CoV-2 virus, and existing therapies listed as ‘strongly’ recommended for use among COVID-19 patients, based on evidence summarized by NIH’s COVID-19 Treatment Guidelines updated December 2021 (National Institutes of Health, n.d.).

1.8.1 **Vaccines for Prevention against Infection and Disease Severity**

The advent of vaccines that protect against severe SARS-CoV-2 infection marked a turning point in the pandemic. The Pfizer-BioNTech mRNA vaccine ("Comirnaty" commonly referred to in the U.S. as the Pfizer vaccine) was the first to be granted emergency use authorization (EUA) in the United States, followed by the Moderna mRNA vaccine (Spikevax, commonly referred to in U.S. as the Moderna vaccine), both in December 2020. Both are given in a two-dose series and have since received full FDA approval. Pfizer doses are spaced three weeks apart, Moderna's four weeks apart. The Johnson & Johnson-Janssen (J&J)'s vaccine was the third vaccine to be granted EUA for use as a single-dose vaccine and is pending full FDA approval. The Pfizer and Moderna vaccines contain mRNA encoding production of SARS-CoV-2's hallmark 'spike protein', to which the body's immune system responds by generating antibodies that protect against future infection. In contrast, the J&J vaccine is a 'viral vector' vaccine, using altered non-replicating adenovirus vectors to introduce SARS-CoV-2 antigen DNA into cells. This induces production of cells containing the abnormal spike proteins, to trigger immune response and antibody production (Janssen Global Services, LLC n.d.).

An individual is considered fully vaccinated 14 days after their second dose of mRNA vaccine or after one dose of the J&J vaccine according to current guidance (Centers for Disease Control and Prevention 2022b). Booster doses were first recommended for higher-risk populations beginning in October 2021; in December 2021, the CDC began advising booster shots for all vaccinated individuals, at an interval contingent on type of initial doses received: five months after receiving a second dose of Pizer, six months after second dose of Moderna or two months after a first dose of J&J (Centers for Disease Control and Prevention 2022a). These broader recommendations were informed by efficacy data indicating that the protection conferred by all three COVID-19 vaccines declines over time and that the currently dominant, highly transmissible Omicron variant is capable of immune escape as summarized in later paragraphs.

In December 2021, the CDC further refined vaccination guidance to recommend mRNA vaccines over J&J, after studies observing a causal relationship between receipt of J&J and incident thrombosis with thrombocytopenia (TTS, blood clotting with concomitant low platelet count) (See et al. 2021). As of January 2022, reported incidence of TTS among recipients of the J&J COVID-19 vaccine in the U.S. was 57 events after 17.7 million doses administered (0.00003% or approximately 3 events per one million doses). Although extremely rare, this was over 500 times the reported incidence after doses of mRNA vaccination (3 cases after 496 million doses).

Studies from South Africa, where the Omicron variant was first sequenced, indicate a substantial reduction in effectiveness of Pfizer vaccine against this variant versus the previously dominant Delta variant. Collie et al. found Pfizer vaccine to be 33% protective against infection with Omicron versus 80% protective against infection with Delta, and 70% protective against hospitalization with Omicron (95% CI 62-76%), versus 93% protective against hospitalization with Delta (95% CI 90—94%). In a pre-Omicron comparator period of September 1 – October 31, 2021, 706/8,569 positive tests (8.2%) and 77/925 COVID-related hospitalizations (8.3%) were among vaccinated patients, versus 6,290/19,070 positive tests (33%) and 121/429 hospitalizations (28.9%) during the Omicron wave (November 15-December 7, 2021) (Collie et al. 2021).

Studies from the United Kingdom, where a wave of Omicron infections occurred ahead of that in the U.S., indicate similar results of decreased effectiveness of mRNA vaccines to prevent infection against Omicron versus Delta. Andrews et al. report that Pfizer vaccine was found to be between 34-37% effective against Omicron from 15 weeks after the second dose. This is substantially lower than 64% effectiveness at 25 weeks (95% CI: 61.4-65.5%) estimated during the U.K.'s Delta wave. Administration of a booster dose resulted in 76% effectiveness against Omicron (95% CI 56.1 to 86.3%), though lower than the 93% effectiveness (95% CI 92.0-93.1%) of booster doses against Delta (Andrews et al. 2021).

Early studies comparing transmission dynamics of Omicron vs. previous variants, also described in Section 1.2, suggest that increased transmissibility is mostly due to this observed ability of Omicron to evade protectiveness afforded by vaccines. For example, a pre-print study of SARS-CoV-2 transmission among 11,937 Danish households with at least one identified COVID-19 case in December 2021 found a secondary attack rate of 31% among households with the Omicron variant compared to 21% among households with the Delta variant. Among boosted individuals, the secondary attack rate (SAR) for Omicron was significantly higher than among Delta (3.66, 95% CI 2.65-5.05) suggesting that boosters are more protective against household transmission of Delta than Omicron (Lyngse et al. 2021). Among the partially vaccinated and unvaccinated there was no observed difference in household transmission by variant of virus (SAR ratio 1.17, 95% CI 0.99-1.38). The previously described difference in SAR among boosted individuals was attenuated among fully vaccinated but not boosted household members (2.61, 95% CI 2.34-2.90). No difference in SAR was observed when stratifying comparisons of transmission rates during Omicron and Delta by vaccination status of the primary case alone. A partially or unvaccinated primary case had an OR of 1.41 (CI: 1.27-1.57) for potential secondary cases compared to fully vaccinated primary cases.

1.8.2 **COVID-19 Vaccine Prioritization by Age and Occupation**

When the first COVID-19 vaccines were authorized for emergency use in the U.S. in December 2020, demand far outpaced the initial availability. The Advisory Committee on Immunization Practices (ACIP) prioritized populations at greatest risk of severe outcomes due to age and comorbid-conditions, and increased risk of infection due to occupational exposure (McClung 2020). Healthcare personnel and residents of long-term care facilities comprised first eligible group (Phase 1a), followed by individuals ages 75 and older and non-healthcare 'frontline' workers defined in Section 2.6 (Phase 1b). Individuals ages 65-74 or 16—64 with high-risk medical conditions (see Section 1.5.1) and the remaining non-healthcare 'essential worker' groups comprised Phase 1c ahead of all other Americans ages 16 and older (Phase 2).The NAICS coding for classification of workers by industry, as described in Section 2 of this review, was used to define priority groups (1a-1c) by industry. Table I lists examples of 1b groups and corresponding NAICS codes.

Chicago followed federal guidance for vaccine allocation, with 1a residents becoming eligible on December 15, 2020, 1b on January 25, 2021 and 1c on March 29, before general eligibility on April 19, 2021 (City of Chicago n.d.). Examples of Chicago's 1b and 1c groups and the estimated number of workers within 1b groups are in Tables II and III. Initially, Chicago vaccinated older age groups and healthcare workers in clinical settings, while establishing and reserving mass vaccination sites (such as the United Center, O'Hare International and Midway International Airports) for 1b/1c workers. Chicago also established a mobile vaccination program for 1b/1c workers, sending 'strike teams' to workplaces. This strategy first targeted manufacturing, food and agriculture facilities disproportionately impacted in pre-vaccination phases of the pandemic as described in Section 4. As eligibility broadened and measures of neighborhood vulnerability were established (Section 1.6.1), mobile efforts targeted neighborhoods with low uptake despite vulnerability; mass vaccination sites were opened to the broader population.

As mentioned elsewhere in this report, a major limitation to further quantifying and reporting the success of these efforts in reaching high-risk workers is that industry and occupation data are not routinely collected in the State vaccination record, thus coverage trends among high-risk workers cannot estimated. Broader descriptive analyses quantifying trends in COVID-19 cases by occupation over time, as planned in this dissertation, will help illustrate the impact of prioritizing these populations in Chicago.

TABLE I. PHASE 1B NON-HEALTHCARE, NON-CONGREGATE INDUSTRIES IN THE U.S.

2017 NAICS Code*	2017 NAICS Title	CISA v4.0 Sector	ACIP Workforce Category
11xxxx	Agriculture, Forestry, Fishing and Hunting	Food and Agriculture	Food and Agriculture
311xxx	Food Manufacturing	Food and Agriculture	Food and Agriculture
3121xx	Beverage Manufacturing	Food and Agriculture	Food and Agriculture
44422x	Nursery, Garden Center, and Farm Supply Stores	Food and Agriculture	Food and Agriculture
54194x	Veterinary Services	Other Community- or Government-based Operations and Essential Functions	Food and Agriculture
445xxx	Food and Beverage Stores	Food and Agriculture	Grocery Store Workers
4523xx	General Merchandise Stores, including Warehouse Clubs and Supercenters	Food and Agriculture	Grocery Store Workers
491xxx	Postal Service	Transportation and Logistics	U.S. Postal Service Workers
4851xx	Urban Transit Systems	Transportation and Logistics	Public Transit Workers
4854xx	School and Employee Bus Transportation	Transportation and Logistics	Public Transit Workers
322xxx	Paper Manufacturing	Food and Agriculture	Manufacturing
32411x	Petroleum Refineries	Energy	Manufacturing
32412x	Asphalt Paving, Roofing, and Saturated Materials Manufacturing	Energy	Manufacturing
325xxx	Chemical Manufacturing	Chemical	Manufacturing
326xxx	Plastics and Rubber Product Manufacturing	Transportation and Logistics; Critical Manufacturing	Manufacturing
331xxx	Primary Metal Manufacturing	Critical Manufacturing	Manufacturing
332xxx	Fabricated Metal Product Manufacturing	Critical Manufacturing; Law Enforcement, Public Safety, and Other First Responders	Manufacturing
333xxx§	Industrial Machinery Manufacturing	Critical Manufacturing; Food and Agriculture; Transportation and Logistics	Manufacturing
334xxx	Computer and Electronic Product Manufacturing	Critical Manufacturing	Manufacturing
335xxx	Electrical Equipment, Appliance, and Component Manufacturing	Commercial Facilities; Energy; Critical Manufacturing; Communications and Information Technology	Manufacturing
3391xx	Medical Equipment and Supplies Manufacturing	Healthcare/Public Health	Manufacturing

TABLE II. PHASE 1B VACCINATION GROUPS BY INDUSTRY IN CHICAGO.

CATEGORIES	CITY OF CHICAGO DEFINITION	CHICAGO ESTIMATE*
Non-healthcare residential settings	Homeless shelters, women's shelters, adult day care programs, correctional settings (jail officers, juvenile facility staff, workers providing in-person support, detainees), and other non-healthcare residential settings that have experienced outbreaks (e.g., convents)	21,000
First Responders	Fire, law enforcement, 911 workers, security personnel, school officers	42,000
Grocery Store Workers	Baggers, cashiers, stockers, pick-up, customer service, those working in feeding or at food pantries	17,000
Education	Teachers, principals, student support, and student aides at pre-K-12 schools, day care staff	142,500
Public Transit Workers	Bus drivers, train conductors, flight crews, taxi drivers and ride sharing services (workers that have worked an average of at least 20 hours per week for the last three months), and all persons working for local transit agencies unable to work from home	60,000
Manufacturing	Industrial production of goods for distribution to retail, wholesale or other manufacturers	53,000
Food and Agriculture	Processing plants, veterinary health, livestock services, animal care, greenhouses and indoor locations where food is grown en masse	10,000
Government	U.S. Postal Service Workers; City government leaders and City elected officials critical to maintain continuity of governmental operations and services	5,300
Caregivers	Parents, including foster parents, and other primary caregivers of medically fragile children or adults who live at home but require a level of ongoing medical care typically provided by a rehabilitation hospital or skilled nursing facility	~35,000

TABLE III. PHASE 1C VACCINATION GROUPS BY INDUSTRY IN CHICAGO

.CATEGORIES	CITY OF CHICAGO DEFINITION
Clergy and religious organizations	Clergy, church workers, and religious organizations
Energy	Workers supporting the energy sector, including those involved in energy manufacturing, distribution, repair
Finance	Banks; currency exchanges; consumer lending; credit unions; appraisers; title companies; financial markets; financial institutions; institutions that sell financial services; accounting services, and insurance services
Food and beverage service	Restaurant and other facilities that prepare and serve food (including bars); entities that provide food services
Information technology and communications	Internet, video and telecommunications systems, consumer electronics repair, computer and office machine repair
Legal	Workers providing legal services or supporting the operations of the judicial system, including judges, lawyers, paralegals, legal assistants, process servers, couriers, bail bond agents, parole officers, probation offices, court personnel, and others providing legal assistance or performing legal functions
Media	Newspapers, periodicals, television, radio, and other media services, news dealers and newsstands, broadcasting, news syndicates, printing, and book publishers
Other community- or government-based operations and essential functions	Other governmental employees; community based essential functions (e.g., urban planning, offices that provide basic needs such as food, childcare, shelter, and social services); workers in libraries
Personal care services and hygiene	Businesses that provide personal care services, such as hair, nails, and non-medical massage. Laundromats, dry cleaners, industrial laundry services, and laundry service providers
Public health	Public health entities; pharmaceutical, medical device and equipment, and biotechnology companies
Public safety	Workers that ensure public safety systems function properly, including building inspectors, civil engineers, chemical engineers, aerospace engineers and hazardous materials responders. Workers who construct and maintain roads, highways, railroads, and ports. Cybersecurity operations workers
Retail	Workers in retail stores including but not limited to stores that sell alcoholic and non-alcoholic beverages, medication not requiring a medical prescription, other non-grocery products (e.g., electronics, optical goods, books, etc.), other household consumer products, wholesalers, licensed cannabis dispensaries and cultivation centers
Shelter and housing	Hardware stores and businesses; construction and maintenance of buildings, real estate; hotel and motel workers
Transportation and logistics	Workers at gas stations; auto and bike supply and repair; businesses that supply shipping and delivery services; couriers; warehouses; private mail; Airline workers not included in 1b; workers in rail, water, truck, charter bus transportation or transportation rental
Water and wastewater	Workers involved in wastewater treatment and operations; sanitary and storm maintenance crews performing emergency and essential maintenance of systems

1.8.3 **COVID-19 Vaccination Coverage in the United States and Chicago**

As of January 31, 2022, an estimated 64% of the U.S. population (74% of the population at least 18 years of age) is fully vaccinated. Approximately 45% of fully vaccinated adults have received a booster dose; just over half of adults who are eligible for a booster dose have not yet received one (51%). Vaccine coverage in the U.S. varies dramatically by geographic area, race/ethnicity, and age. This is in part due to the U.S. Advisory Committee on Immunization Practices (ACIP) recommendations for phased distribution of an initially limited supply of vaccine in the U.S., which prioritized older-age Americans and those at increased occupational risk as described in Section 1.8 of this review. For example, Figure 14 below shows the cumulative coverage (full vaccination) rates in the U.S, across all age groups, by race and ethnicity as of January 2022. (Note: the CDC website states that race/ethnicity data are missing for about a third of vaccinees, such that all reported races are underestimates) (Centers for Disease Control and Prevention 2020d.)Coverage rates are highest (e.g., 59% on January 24) among individuals reporting non-Hispanic, Asian race/ethnicity and lowest (39%) among those reporting non-Hispanic Black race/ethnicity.

As described in Section 1.5.1, this disparity is problematic because non-Hispanic Black Americans are more likely to reside in high-burden communities. They are also the only demographic group to be overrepresented among ‘Frontline’ workers (17%) compare to the overall working population (12%) (Center for Economic and Policy Research 2020), thus disproportionately at risk for occupation-related infection as described in Section 1.5.1. The number of doses administered in the U.S. peaked in April 2021 at just over 4.5 million (Figure 15), as eligibility was expanded to most working adults. Vaccinations declined steeply through July of 2021 then gradually increased through early December given targeted and then broadened recommendations for booster doses. The nationwide count of doses administered has been declining since December 2021.

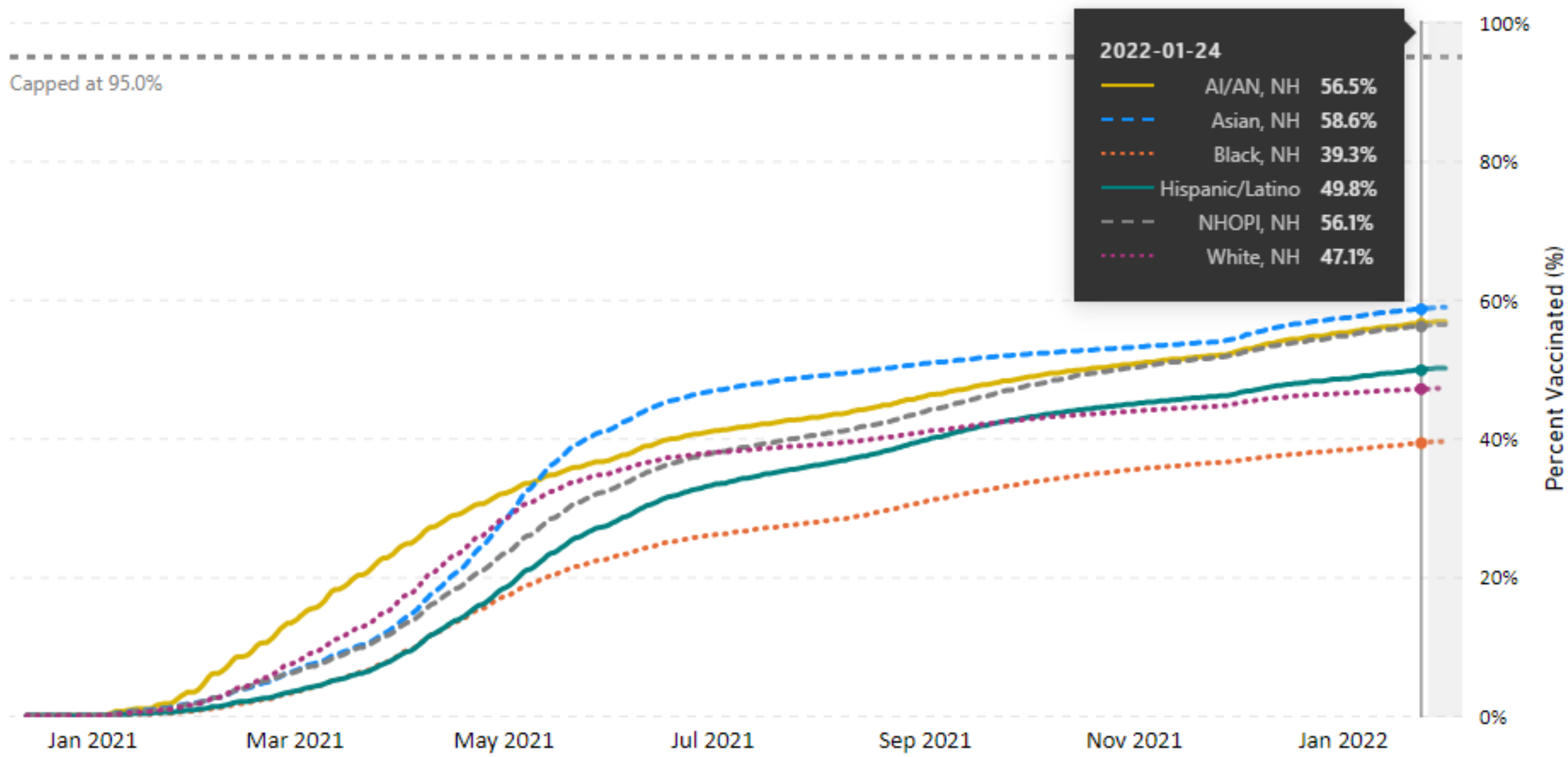

Figure 14. Cumulative COVID-19 vaccination coverage (fully vaccinated) rates among U.S. population, by race and ethnicity: January 2021-January 2022.

(Source: Centers for Disease Control and Prevention 2022)

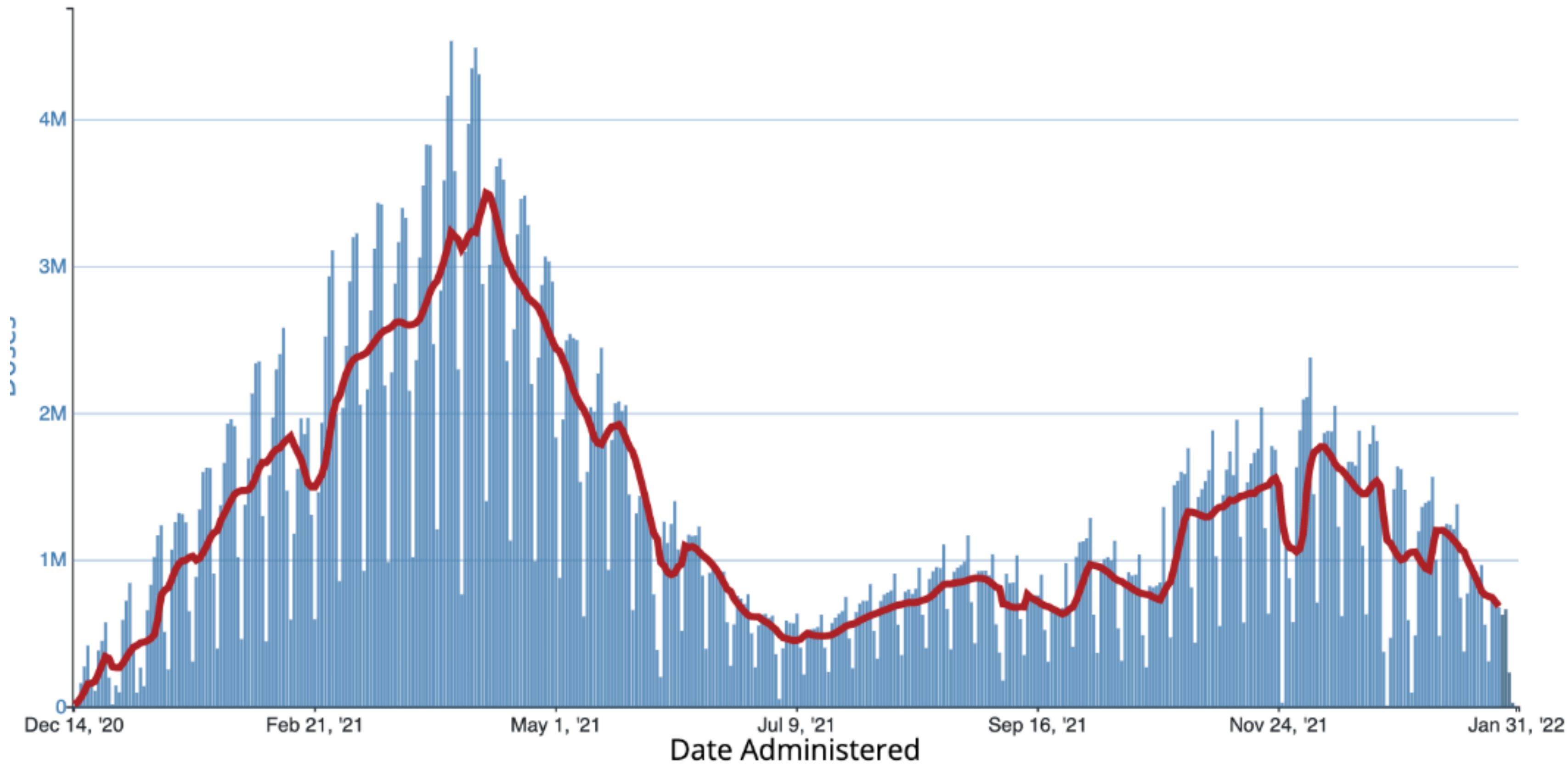

Figure 15. Daily count of total COVID-19 vaccine doses by date administered, United States: December 2020-January 2022

(Source: Centers for Disease Control and Prevention 2022)

Figure 16 shows the daily doses administered in Chicago through January 2022. The number of doses administered in Chicago peaked in April 2021 at just over 40,000. Mirroring nation-wide trends, vaccinations declined steeply through July of 2021 then later increased through early December 2021 with eligibility of children and booster recommendations, before beginning to decline again.

In February of 2021, the Protect Chicago Plus campaign targeted the 15 highest-CCVI areas (See: Section 1.6.1), including through door-to-door canvassing efforts to increase vaccination. These neighborhoods are shown in Figure 17 below. Table IV shows the resulting increases in vaccine coverage among adults in these community areas, with rates improving as much as ten-fold in some areas over three months (City of Chicago n.d.). Figure 18 below shows the cumulative coverage rates in Chicago (all age groups) and persisting disparities by race and ethnicity groups as of January 2022. Coverage rates are highest (75% on January 30) among individuals reporting non-Hispanic, Asian race/ethnicity and lowest (52%) among those reporting non-Hispanic Black race/ethnicity (City of Chicago n.d.)

Reasons for persisting vaccine hesitancy in Chicago are summarized in the final section of this review. Some individuals have reported that pending advent of COVID-19 antivirals negates need to vaccinate for protection against severe illness due to COVID. However, as the next few sections describe treatment options for COVID-19 remain limited, are reserved only for use among individuals at increased risk for severe illness and have a limited period of effectiveness. Furthermore, these therapeutics interact with drugs used to manage common chronic illnesses such as hypertension and high cholesterol and, may be contraindicated for a large fraction of the adult population in the U.S. In contrast, there are very few medical contraindications for the vaccines currently authorized for use in the U.S., re-iterating their importance as the most important tool for preventing severe COVID-19 outcomes.

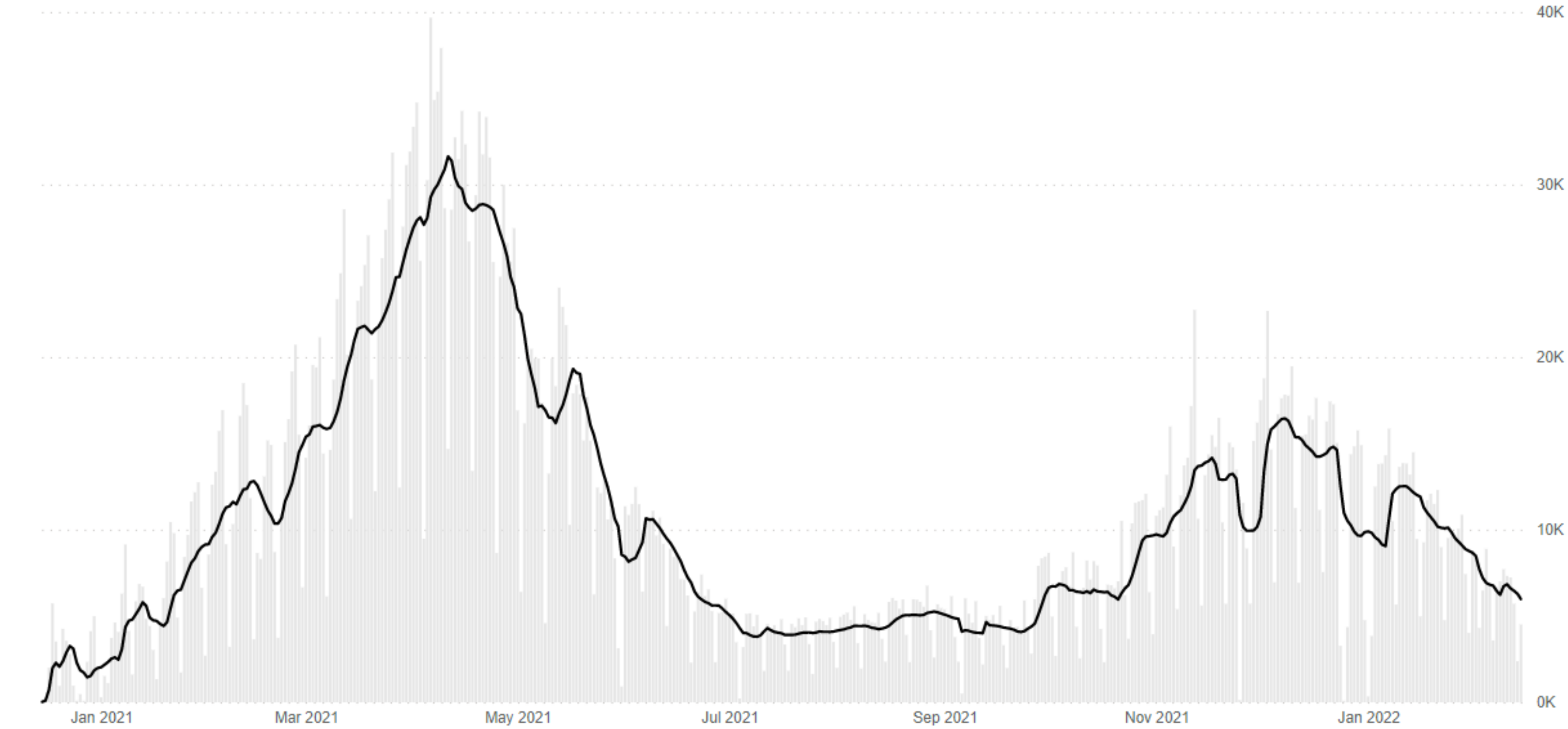

Figure 16. Daily count of total COVID-19 vaccine doses by date administered, Chicago: December 2020-January 2022.

(Source: Chicago Department of Public Health, 2022)

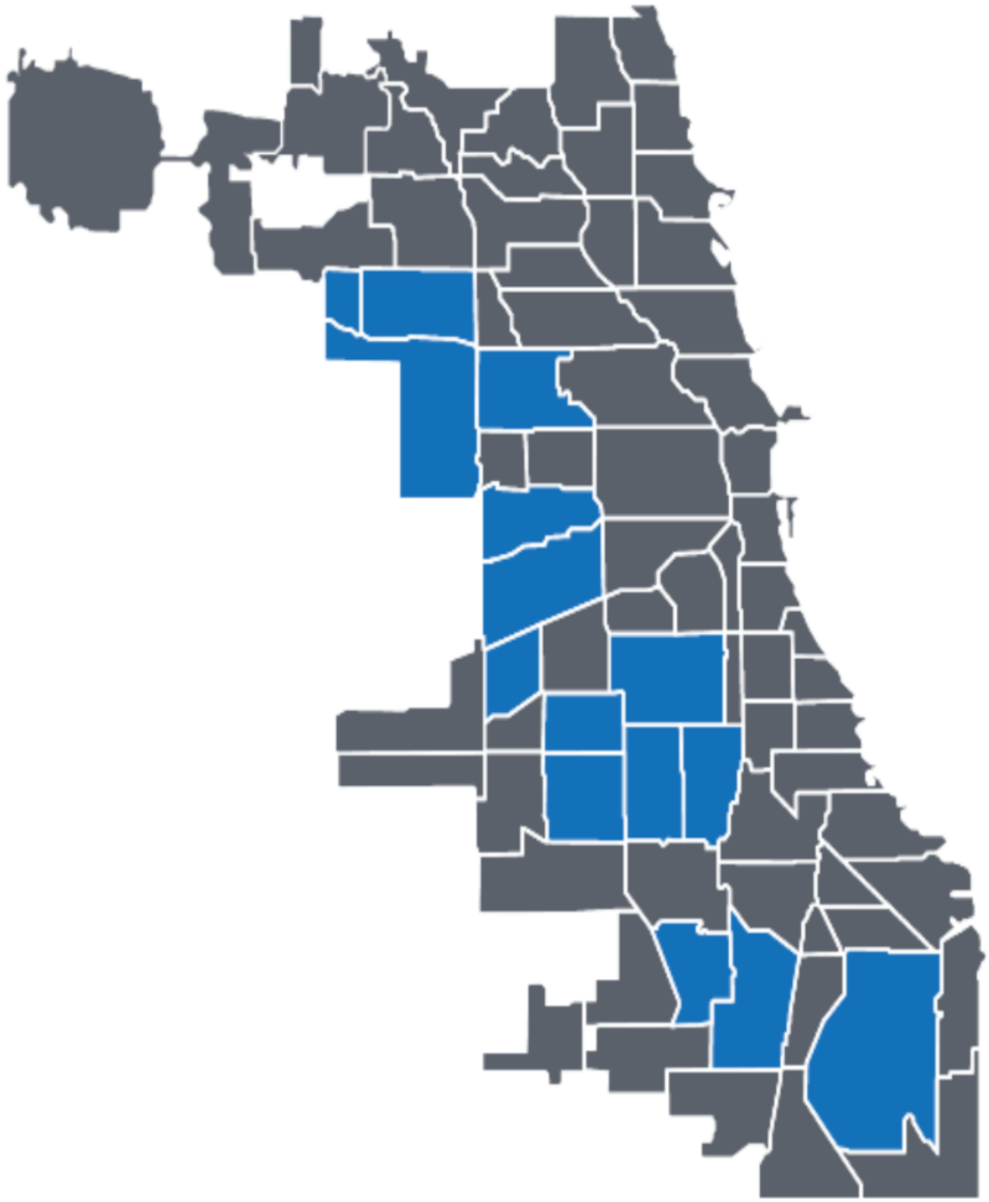

Figure 17. Community areas prioritized for Protect Chicago Plus vaccination outreach in Chicago, February 2021.

(Source: Chicago Department of Public Health, 2022)

TABLE IV. VACCINATION RATES AMONG COMMUNITY AREAS PRIORITIZED FOR PROTECT CHICAGO PLUS VACCINATION OUTREACH IN CHICAGO, FEBRUARY 2021

	Week ending 2/6/21	**Week ending 5/8/21**	**Percent Change from 2/6 to 5/8**
Chicago	**10.6%**	**58.4**%	**452**%
Archer Heights	7.1%	**64.4%**	807%
Austin	6.9%	44.1%	539%
Belmont Cragin	6.9%	**61.7%**	794%
Chicago Lawn	5.3%	50.1%	845%
Englewood	4.6%	34.9%	659%
Gage Park	6.4%	**62.3%**	873%
Humboldt Park	6.4%	53.7%	739%
Montclare	7.7%	45.9%	496%
New City	5.5%	49.1%	793%
North Lawndale	5.6%	38.0%	579%
Roseland	7.1%	41.4%	483%
South Deering	7.3%	44.1%	504%
South Lawndale	6.7%	54.3%	710%
Washington Heights	7.1%	44.1%	521%
West Englewood	4.4%	36.6%	732%

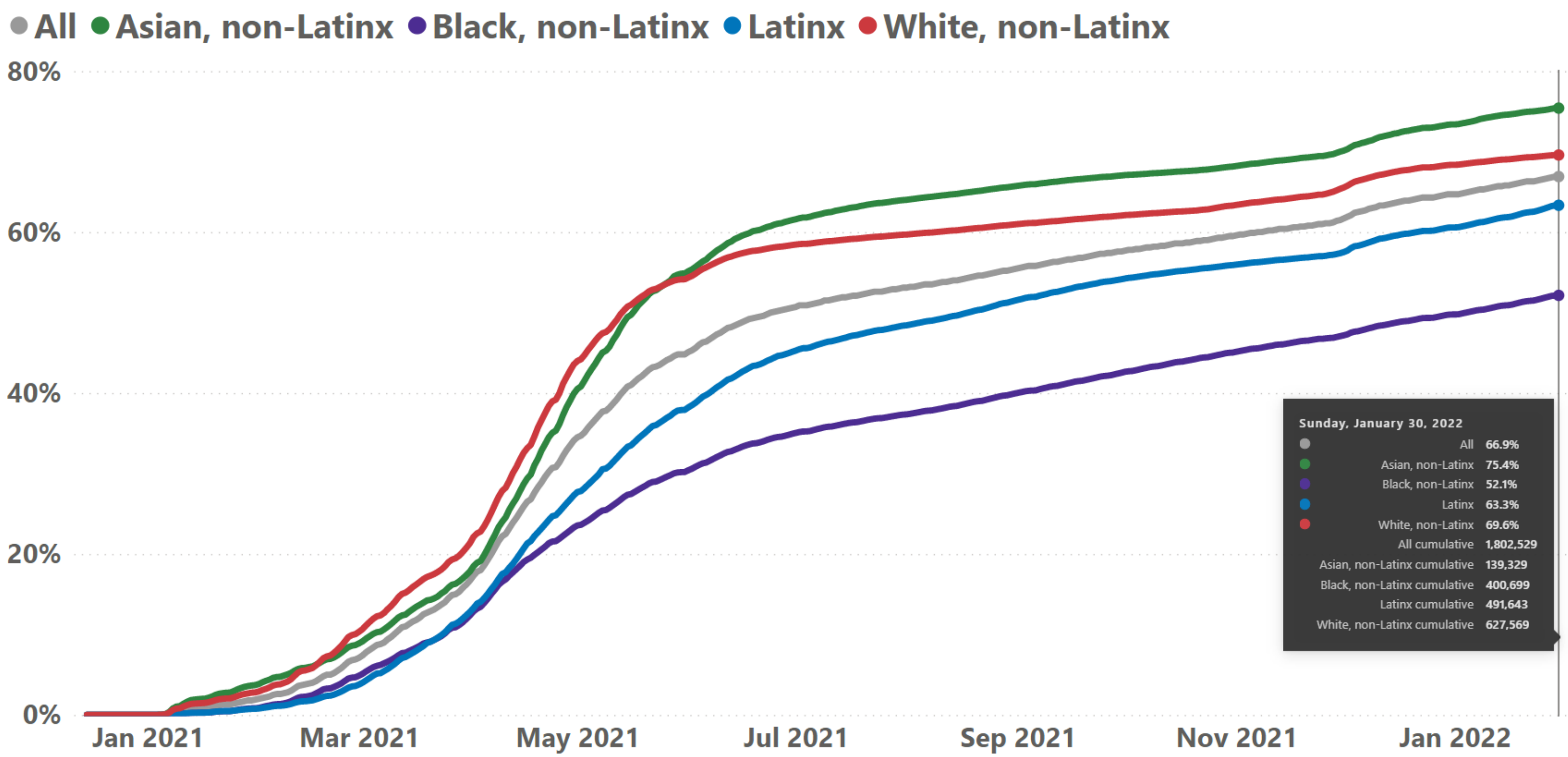

Figure 18. Cumulative vaccination coverage (fully-vaccinated) rates among Chicago population, by race and ethnicity: January 2021-January 2022

(Source: City of Chicago n.d.)

1.8.4 **Pre-exposure Prophylaxis for Unvaccinated and High-risk Individuals**

In December 2021, the U.S. FDA issued an EUA for the combination mAB therapy tixagevimab plus cilgavimab (“Evusheld”) as pre-exposure prophylaxis (PreP) for individuals who are immunocompromised or unable to be fully vaccinated against COVID-19 (e.g., due to allergic reactions to vaccines) (Commissioner 2021). The authorization was based on interim analyses from the double-blind, Phase 3 PROVENT trial (ongoing as of January 2022), a RCT including 5,197 COVID-naïve, unvaccinated adults at risk of severe COVID-19 (age 60 years or older, or with an underlying illness) or increased risk of infection (e.g., due to living or working in congregate settings). The incidence of symptomatic infection was significantly lower among 3,461 recipients receiving treatment versus 1,736 receiving placebo (8 participants or 0.2%, versus 17 or 1.0%), a 77% reduction in risk (AstraZeneca 2021).

1.8.5 **Approved and Authorized Intravenous COVID-19 Treatments**

As of November 2021, the only FDA-approved treatment for COVID-19 is intravenous antiviral remdesivir (“Veklury”), for use in some hospitalized, severely ill patients (Food and Drug Administration 2020). Remdesivir is a ‘chain terminating’ antiviral, interfering with the enzymes that synthesize SARS-CoV-2 RNA (Willyard 2021). The approval, issued in October 2020, cited data from two randomized controlled trials (RCT) indicating significantly improved outcomes among patients administered remdesivir versus placebo or standard-of-care: In the double-blind, placebo-controlled ACTT-1 trial of n=1,062 hospitalized patients with mild to severe COVID-19, the median time to discharge or significant improvement while hospitalized (ceasing need for oxygen or ongoing medical care) was 15 days among placebo patients (n=521) versus 10 days in patients administered remdesivir (n=541). In a multinational open-label study of hospitalized patients with moderate COVID-19 (Spinner et al. 2020), those treated with remdesivir for 5 days (n=191) had significantly greater odds of symptom improvement compared to standard-of-care patients (n=200) (OR 1.65; 95% CI 1.09-2.48; p=0.02).

An August 2021 Cochrane review synthesizing data from four RCTs with a total N= 7,142 participants concluded that remdesivir "probably makes little or no difference in all-cause mortality at up to day 28", citing a relative risk of 0.93 (95% CI 0.81-1.06) and risk difference of 8 fewer deaths per 1,000 (95% CI of -21 – 7) (Ansems et al. 2021). However, results from the PINETREE RCT of non-hospitalized, high-risk patients, published in December 2021, reported 2 hospitalizations or deaths among 279 patients who received 3 days of intravenous remdesivir (0.7%), versus 15 among 283 placebo-treated patients (5.3%), an 87% reduction in relative risk (HR 0.13, 95% CI: 0.03-0.59, p=0.008) (Gottlieb et al. 2022).

Three intravenous infusions of anti-SARS-CoV-2 monoclonal antibodies (mAbs) are currently under Emergency Use Authorization (EUA) for use in non-hospitalized patients at high risk for severe outcomes (hospitalization or death): bamlanivimab (BAM) plus etesevimab (ETE), casirivimab (CAS) plus imdevimab (IMD), and sotrovimab (SOT). As described by the National Institutes of Health Coronavirus Disease 2019 (COVID-19) Treatment Guidelines (National Institutes of Health, n.d.), monoclonal antibodies target the hallmark 'spike proteins' of SARS-CoV-2 by interfering with their binding of the virus to host cells and reducing infection severity. BAM+ETE (Eli Lilly) and CAS+IMD ("REGEN-COV", Regeneron) regimens are also recommended as post-exposure prophylaxis for high-risk individuals. CAS+IMD is also available via subcutaneous injection.

The EUA follow significant reductions in severe outcomes among high-risk patients with mild to moderate COVID-19 when administered mAbs in RCT. For example, in the 2:1 randomized controlled, double-blinded BLAZE-1 trial (n=769), 4 hospitalizations or deaths were observed among 511 participants administered BAM+ETE within 3 days of a positive SARS-CoV-2 test (0.8%) versus 15 among 258 participants administered placebo (5.8%) for 5% reduction in absolute risk and 87% reduction in relative risk (Dougan, Nirula, et al. 2021). In a second, higher-dose 1:1 randomized controlled trial (n=1,035) excluding patients with decreased cardiovascular function, 11/518 patients treated with BAM+ETE experienced COVID-related hospitalization or death (2.1%), compared to 36/517 treated with placebo (7.0%), for a similar risk difference (4.8%, 95% CI -7.4 to -2.3) and significant relative risk reduction (70%; p<0.001) (Dougan, Azizad, et al. 2021).

In 1:1 placebo-controlled trials of low-dose and high-dose CAS+IMD (n=1,474 and n=2,696), both regimens were associated with approximately 70% reduction in relative risk of hospitalizations and all-cause mortality among non-hospitalized adult COVID-19 patients after 29 days (Weinreich et al. 2021). In a 2021 interim analysis from the 1:1 "COMET-ICE" trial of SOT (Vir Biotech and GlaxoSmithKline) versus placebo (n=583), 3/291 participants receiving SOT (1%) experienced hospitalization or death versus 21/292 (7%) of placebo-treated participants, a 6% risk reduction and 85% decrease in relative risk (97% CI: 44-96%, p=0.002).

Several classes of immunomodulators are being evaluated for treatment of the hyperactive inflammatory response elicited by SARS-CoV-2. According to the October NIH review, the corticosteroid dexamethasone is currently the only immunomodulator with 'strong' evidence for use among hospitalized patients requiring oxygen, ventilation or extracorporeal membrane oxygenation (ECMO). Results from the RECOVERY trial indicate reduced mortality among patients who required supplemental oxygen without ventilation and received dexamethasone versus standard-of-care (23.3 vs. 26.2%, rate ratio 0.82, 95% CI 0.72-0.94). Mortality rates were also reduced among patients who required both oxygen and ventilation and received dexamethasone vs. standard-of-care (29.3% vs. 41.4%, rate ratio 0.64, 95% CI 0.51-0.81) (The RECOVERY Collaborative Group 2021).

Intravenous treatments require are resource-intensive. This limits their uptake, namely in healthcare settings with already limited capacity, and among high-risk patients who may not have access. Furthermore, a December 2021 study found that Omicron is at least partially-resistant to 9 mAB tested, including those summarized in this review (Planas et al. 2021), re-iterating the risk of reliance on treatment alone as more virulent variants emerge.

1.8.6 <u>**Oral COVID-19 Therapeutics with Emergency Use Authorization**</u>

Oral therapeutics, easier to distribute and administer than intravenous treatment, have tremendous potential to reduce the global burden of COVID-19 by decreasing hospitalization and death among the unvaccinated, especially in resource-limited countries with poor access to vaccines and healthcare in general. As of January 2022, ritonavir-boosted nirmatrelvir ("Paxlovid", Pfizer) is the only oral therapeutic strongly recommended in the U.S. for use among non-hospitalized patients at risk of severe COVID-19 outcomes. It was authorized for emergency use in December 2021. Paxlovid works by inhibiting enzymes that SARS-CoV-2 requires to replicate. Co-administration with ritonavir, which slows the body's metabolism of Paxlovid, allows it to work for longer. Interim analyses from the 1:1 EPIC-HR RCT showed that patients who began Paxlovid (n=389) with low-dose ritonavir in the first three days of onset, in a twice-daily, five-day regimen saw an 89% reduced risk of severe outcomes (0.8% versus 7.0%) over placebo patients (n=385), with 3 deaths in the treatment group versus 7 among controls.

The FDA issued an EUA for oral antiviral molnupiravir (Merck & Co. with Ridgeback Biotherapeutics) at the same time. Molnupiravir works by inhibiting replication of SARS-CoV-2 RNA, encouraging the virus to mutate randomly and destroy itself. An interim analysis of the MoVe-OUT trial, of unvaccinated patients with mild to moderate COVID-19 who were at risk of severe outcomes, found that hospitalization rates were halved among those who received molnupiravir versus who those received placebo (28/385 or 7.3%, versus 53/377 or 14.1%). No deaths were observed in the treatment group while 8 were observed among controls. Enrollment was stopped early due to these results (Merck & Co 2021). Molnupiravir was authorized in the U.K. in November 2021, with the planned tradename of Lagevrio. It is not *strongly* recommended in the U.S., given limited efficacy data among vaccinated patients. It is not recommended for pregnant patients unless they are at high risk for severe outcome and informed of fetal toxicity observed in preclinical studies. (National Institutes of Health, n.d.).

1.9 **Summary and Structure of Literature Review of COVID-19 among Non-Healthcare, Non-Congregate Workers**

The introductory section of this report has reviewed COVID-19 epidemiology and prevention at both national and local levels. This provides a foundation for subsequent in-depth reviews of COVID-19 surveillance and vaccination among NHNCW in the U.S. and Chicago, and knowledge gaps that this dissertation will aim to address. The remainder of this literature review is divided into six parts:

1. *Collection of occupation and industry in the United States*: this section explains standardized systems for coding occupation and industry in the United States, and how these were used to define ‘essential’ workers during the pandemic. The ACS, referenced in subsequent surveillance reports and used to define sociodemographics among NHNCW in Chicago, is also described briefly.
2. *COVID-19 risk and surveillance and burden among non-healthcare, non-congregate workers*: this section reviews how job exposure matrices were used to define occupations at increased risk for COVID-19 before real-world surveillance data were available. Cross-sector and industry-specific investigations of COVID-19 among NHNCW are summarized. Implications for workplace-based prevention, limitations and remaining knowledge gaps are discussed.
3. *COVID-19 surveillance among NHNCW in Chicago*: this section summarizes data sources and processes currently used to conduct COVID-19 surveillance among these workplaces and workers in Chicago, including findings to-date and how this dissertation plans to begin to address limitations.
4. *Vaccine hesitancy (Definition of terms and established models):* this brief section overviews the WHO definition of vaccine hesitancy and two frameworks for considering reasons that individuals choose not to be vaccinated, before summaries of NHNCW-specific studies and current evaluation approaches in Chicago.

5. *COVID-19 vaccine hesitancy among NHNCW*: this section briefly describes findings from COVID-19 vaccine hesitancy studies among NHNCW, encouragement practices reported by employers, and limitations to the available data on these topics.
6. *COVID-19 vaccine hesitancy in Chicago*: this section describes how vaccination details from case investigation and contact tracing efforts in Chicago are utilized to report frequency of vaccination among interviewees and vaccination hesitancy among Chicagoans. Key findings and limitations to these methods are also summarized.

2. COLLECTION OF INDUSTRY AND OCCUPATION DATA IN THE UNITED STATES

This section provides a foundational overview of how workplace data are collected and standardized in the United States. It begins by distinguishing between the terms “industry” and “occupation”: the U.S. Census Bureau surveys define **Industry** as “the kind of business of a respondent’s employer”, and **Occupation** as “the kind of work the respondent does at their job”. In some instances, an occupation is also classified by the skills, training or education required to perform the tasks that comprise it. As noted by the ACIP, public health interventions such as COVID-19 vaccine allocation are more readily enacted at the industry and workplace versus occupation levels (Dooling et al. 2021). At the same time, risks of COVID-19 transmission may differ among occupational subgroups within one workplace, depending on job characteristics; evaluations of these differences in risk are thus necessary to inform effective infection control practices and guidance for employers. As such, this dissertation refers to COVID-19 data, analyses, risk and mitigation strategies by both industry and occupation.

2.1 The North American Industry Classification System

The North American Industry Classification System (NAICS, pronounced “nakes”), is a “2- through 6- digit hierarchical classification system” developed by government statistical agencies in the United States, Mexico and Canada, to produce common descriptions of industries and occupations for the collection, analyses and dissemination of economic data (U.S. Census Bureau n.d.). This system replaced Standard Industrial Classification (SIC) codes, used for a similar purpose, in 1997. NAICS codes are “production-oriented”: industries are grouped “according to similarity in the processes used to produce goods or services”. Complete NAICS codes have six digits with designations that become progressively narrower from right to left (Figure 19)(U.S. Census Bureau 2020). The first two digits represent one of twenty major industry economic sectors, third represents the subsector, fourth represents the industry group, fifth represents the industry and sixth the national industry. NAICS codes are comparable at the 5-digit level: industries across the U.S., Mexico and Canada that have the same first five digits are comparable to one another, with the sixth allowing for country-specific industry detail. The U.S. Census Bureau assigns one NAICS code per business, generally determined by surveys and administrative records indicating primary revenue-generating activities of that establishment. The entire classification system is scheduled to be reviewed every 5 years. The current system is NAICS 2017, which contains codes for 1,057 industries. NAICS is correlated to the International Standard Industrial Classification System (ISIC) from the United Nations and the European General Industrial Classification System of Economic Activities (NACE). NAICS is scheduled to be reviewed in 2022.

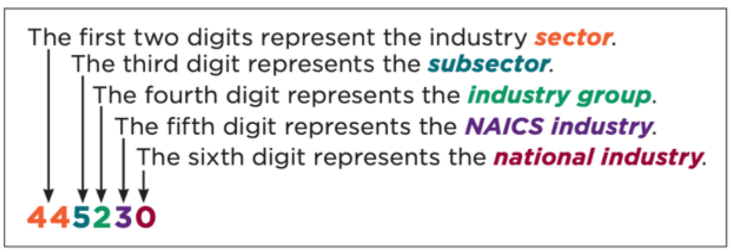

Figure 19. 6-Digit North American Industry Classification System schema.
(Source: U.S. Census Bureau 2020)

2.2 <u>Standard Occupational Classification in the United States</u>

As NAICS standardizes descriptions of industries, the Standard Occupational Classification (SOC) is a federal system for standardizing descriptions of occupations. The 2018 system is currently in use and, as with NAICS, is a 6-digit hierarchical system (Figure 20). The first two digits define major occupational group, third and fourth the minor group, fifth the broad group and sixth the detailed occupation, such that occupations differing by the sixth (last) digit are within the same broad group. This system includes all occupations in which workers receive pay or profit and excludes those unique to volunteers. When an occupation includes more than one job activity, it is classified by the activity requiring the highest level of skill or, secondarily, the role in which the worker spends the most time. Workers who spend at least 80% of their time in a supervisory role are categorized as “first-line supervisors” within their respective occupational categories (Centers for Disease Control and Prevention n.d.). The Bureau of Labor Statistics distinguishes between **jobs** and **occupations**: jobs are sets of work activities that vary depending on the size and organization of a business and can be unique to individual workers. Occupations group individual jobs by a common SOC code for consistent reference across government agencies, including the U.S. Census Bureau (under the Department of Commerce), Department of Health and Human Services, and Bureau of Labor Statistics (under the Department of Labor).

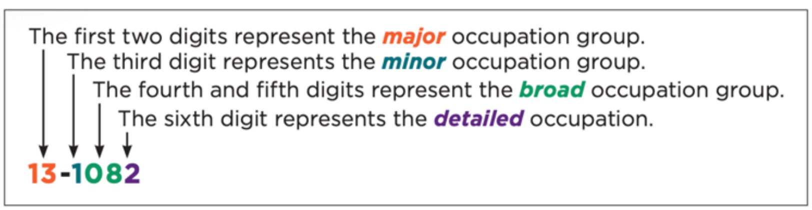

Figure 20. 6-digit Standard Occupational Classification schema.

(Source: U.S. Census Bureau 2020)

2.3 Collection of Industry and Occupation Data in the United States

In March 2020, the U.S. Census Bureau published a report summarizing how industry and occupation data are collected and summarized across the multiple household Census Bureau surveys, including the ACS, summarized in Section 2.5. When respondents define their industry and occupation on a U.S. Census Bureau survey, responses are coded to Census Industry Code (CIC) and a 6-digit Census Occupation Code (COC), respectively. The current (2017) CIC list consists of 271 industry codes and descriptions and is an aggregated version of

NAICS codes. The current (2018) COC list includes 570 occupation codes titles. These correspond to an aggregate list of the 2018 SOC codes. Unlike NAICS and SOC codes, corresponding CIC and COC digits do not have hierarchical structure or other significance. They only serve to distinguish between industries and occupations as they are grouped at the time of survey and have changed over time. Every COC has a corresponding SOC code. For example, census occupation code 2205, “postsecondary teachers”, crosswalks to the SOC minor group 25-1000 with the same title.

2.4 The National Institute for Occupational Safety and Health’s Industry and Occupation Computerized Coding System

The National Institute for Occupational Safety and Health (NIOSH) has developed the NIOSH Industry and Occupation Computerized Coding System (NIOCCS) that can be used for singular or batch-coding of industry and occupation data from surveys and patient records to corresponding NAICS and SOC codes for analyses (Centers for Disease Control and Prevention n.d.). This service can be used to convert between CIC and COC codes, NAICS and SOC codes. It can also be used to crosswalk between historical SIC codes and among previous versions of NAICS and SOC codes. After receiving a file or single record to code, NIOCCS outputs a list of codes corresponding to the records submitted, by order of confidence level of the match (ranked as a percentage). The current iteration (NIOCCS V4) was released in February 2021, providing a code for all industry and occupation records submitted and more accurate, consistent coding overall than V3 (January 2018).

Performance evaluations of V4 were not publicly available at the time of this report. For comparison, in their evaluation of V3, Schmitz and Forst found 84% agreement (kappa 0.84 with 95% CI 0.79-0.88) between the consensus codes agreed by two hand-coders and the high-confidence NIOCCS (90% match or above) codes at the 2-digit level (“major occupation group”) for n=338 records (Schmitz and Forst 2016). Agreement at the more granular, 4-digit level (“broad occupation group”) was lower, with a kappa of 0.58 (95% CI 0.52-0.63) for n=337 records. In analyses performed as part of this dissertation, estimations of COVID-related risk by occupation will utilize NIOCCS to categorize occupations at the 2-digit level, consistent with existing reports summarized in Sections 3.2 and 3.3.

2.5 Quantifying Populations of Workers with the American Community Survey

The American Community Survey (ACS) is a national survey conducted annually by the U.S. Census Bureau. It employs random, address-based sampling and includes six questions to collect industry and occupation data using 2018 census codes. The ACS is referenced in many of the COVID-19 surveillance reports reviewed in the next section and is the only survey estimating number of workers by occupation group specifically for the city of Chicago. Both 2018 and 2019 ACS data were used to estimate the number of NHNCW classified as 1b/1c during vaccination rollout in Chicago, as well as the distribution of essential workers for calculation of Chicago’s CCVI (Section 1.6.1). At the time of this report, the most recent estimates of Chicagoans by industry and occupation are from 2019. Though city-level quality metrics are unavailable, the Census Bureau publishes state-level ACS response rates (U.S. Census Bureau n.d.). The 2019 response rate in Illinois was 85.3%.

2.6 Definitions of Critical Infrastructure (“Essential”) Workers

This section overviews the Cybersecurity and Infrastructure Security Agency (CISA) definition of Essential Critical Infrastructure workforces in the U.S., commonly referred to as “essential workers during the pandemic. On March 19, 2020, the Cybersecurity & Infrastructure Security Agency (CISA) published the first iteration of Guidance on the Essential Critical Infrastructure Workforce. The goal was to help “state, local, tribal, and territorial governments making time-sensitive decisions about who could access worksites during periods of quarantine and reduced movement” in response to COVID-19 (Cybersecurity & Infrastructure Security

Agency n.d.). The USA Patriot Act of 2001 (42 U.S.C. 5195c(e)), describes critical infrastructure as:

> "systems and assets, whether physical or virtual, so vital to the United States that the incapacity or destruction of such systems and assets would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters".

CISA designated 16 critical infrastructure sectors: communications, chemical, commercial facilities, critical manufacturing, dams, defense industrial bases, emergency services, energy, finance, food and agriculture, government facilities, healthcare and public health, information technology, nuclear reactors/materials and waste, transportation systems, and water. These sectors were also prioritized for vaccination by ACIP (Section 1.8.2). In September 2020, the CDC issued interim guidance exempting these industries from population-level quarantine recommendations. At the time, the general recommendation was for all individuals to quarantine for 14 days after a known exposure to SARS-CoV-2. Critical infrastructure workers could work on-site if they adhered to pre-shift and regular symptom screening, workplace masking for at least 14 days after exposure, physical distancing of at least six feet from others, and routine disinfection of work spaces (Centers for Disease Control and Prevention 2020b). In November 2020 this guidance was refined to emphasize that quarantine exemptions should only be used 'as a last resort', when facility closures due to quarantine would pose a serious threat to public safety.

3. COVID-19 AMONG NON-HEALTHCARE NON-CONGREGATE WORKERS: REVIEW OF EXISTING LITERATURE

In this section, I review how industry and occupation-related COVID-19 risk have been estimated and evaluated over the course of the pandemic. I summarize how industry-specific projections were generated to inform initial infection control and prevention guidance for workplaces, given evolving knowledge of SARS-CoV-2 transmission dynamics, and in the absence of surveillance data. I describe how real-world surveillance data have since been used to validate these early definitions of at-risk industries and occupations, and how the national framework for occupation-related risk estimation has been refined to incorporate evolving knowledge of SARS-CoV-2 transmission dynamics. Existing reports of workplace-related COVID-19 surveillance are outlined, and the remaining knowledge gaps described. This dissertation and remainder of this literature review refer to “Non-Healthcare, Non-Congregate Workers and Workplaces”, abbreviated as NHNCW. The increased workplace-related risks of COVID-19 among those working in healthcare and congregate or residential settings (homeless shelters, corrections facilities, senior and assisted living facilities, educational institutions, first responders) have been well-established, including by methods summarized in the following sections. Specialized public health guidance, investigation criteria and other response efforts are implemented nationally and locally for prevention and mitigation of COVID-19 in these settings. In the context of this dissertation, NHNCW refers to workers not represented in those groups.

3.1 Projections of COVID-19 Risk by Industry and Occupation Using O*NET

Before COVID-19 was declared a pandemic, Baker et al. approximated workplace-related COVID-19 risk by quantifying general exposure to infection or disease among U.S. workers by industry sector (Baker, Peckham, and Seixas 2020). This estimation was not specific to SARS-CoV-2, as transmission dynamics were still being determined. Following the process of

Doubleday et al. (Doubleday et al. 2019), Baker merged counts of U.S. workers per industry sector from the U.S. Bureau of Labor Statistics with exposure estimates from the worker-facing O*NET survey (U.S. Department of Labor), to extrapolate the number of workers exposed to (any) infection at least monthly.

The O*NET survey, conducted online and via phone, represents workers in over 1,000 occupations and was last updated in 2019 (U.S. Department of Labor. n.d.). Worker-reported frequencies of various workplace characteristics and activities are converted to percentages, producing standardized descriptions of occupations. “Occupational experts” are also employed to improve the validity and representativeness of frequencies of job characteristics described by the survey tool. A search for assessments of validity of these self-reported measures did not yield any summary reports specific or non-specific to O*NET. Measures of interest can be utilized as relevant for diverse purposes including occupational health research. Baker et al. grouped occupations by 2-digit SOC into the 22 major non-military industry sectors, enabling calculation of “average” frequencies of workplace exposures by industry sector.

Utilizing the O*NET measure: "How often does your current job require you to be exposed to diseases or infections?", Baker et al. estimated that as of May 2018, among the 144.7 million workers in professions counted by the BLS, 18.4% are exposed to infection at least monthly, and 10% at least weekly. Most of these workers are in healthcare sectors. Non-healthcare workplace sectors with the highest frequency of exposure to infection or disease include protective service (police, firefighters, transportation screeners), personal care and service workers, each with 52% of workers exposed at least monthly. Community and social services occupations (including corrections officers) are also considered at higher risk (32% exposed monthly), as well as educational (23%) and building, grounds cleaning and maintenance workers (21%).

In March of 2020, when physical distancing measures were introduced to limit SARS-CoV-2 transmission, Hicks et al. utilized O*NET survey data specifically to estimate the likelihood or ease of physical distancing by occupation (Hicks, Faulk, and Devaraj, n.d.). Measures of frequency of “working with others” and “physical proximity to others” were included in this broader analysis of industries likely to suffer ‘negative demand’ shock due to distancing guidance. Healthcare and public sector jobs such as teaching were excluded, and industries impacted by patrons’ need to socially distance (e.g., restaurant workers, travel agents, flight attendants, taxis drivers) were included. This analysis estimated that 28.1 million (1 in 6) US workers hold occupations at risk of negative demand shock due to distancing mandates, with a mean weighted annual salary of $32,774. This application of the O*NET survey data may seem tangential to discussions of COVID-related risk estimation methodology. However, as described in the following sections, these results align with industry-specific COVID-19 risk projections and surveillance findings of workplaces considered ‘higher-risk’ for COVID-19, in part due to prolonged proximity to others.

Zhang expanded on these estimations of occupation-related risk, in the first published study utilizing O*NET survey measures alongside real-world COVID-19 surveillance data (Zhang 2021). At that time, Washington State had reported on 26,799 laboratory-confirmed cases of COVID-19 residents through June 2020, for which 10,850 (41%) had occupation data. These were grouped into industry sectors by SOC and, with state estimates of workforce population size by industry, used to estimate COVID-19 prevalence by occupation in Washington State. Zhang used measures from O*NET’s “Work Context” survey category (Interpersonal Relationships, Physical work Conditions, Structural Job Characteristics) to assign average values for 57 job-related factors to each occupation group. Factors that could plausibly influence COVID-19 infection based on current knowledge of SARS-CoV-2 transmission were evaluated using a bivariate correlation matrix; the most likely predictors were included in multiple linear regression models of occupation-related factors of prevalence by occupation. The analysis identified six potential occupational predictors of COVID-19 risk:(1) contact with others, (2) cramped workspace or awkward work conditions, (3) work week duration, (4) exposure to disease or infection, (5) face-to-face discussion and (6) physical proximity. Ultimately, disease exposure and physical proximity predicted 47.5% of the variance in COVID-19 prevalence by occupation.

Unsurprisingly, healthcare practitioners had the highest average frequency of exposure to disease (80%) and face-to-face-discussion (85%). In recursive estimations of specific high-risk occupations, Zhang's model predicted the dental field as the highest-risk for COVID-19 infection. For example, dental hygienists were found to have a predicted prevalence ratio [PPR] of 2.7 (95% CI 1.28-4.13). Non-healthcare occupations at highest predicted risk were: flight attendants (PPR 2.34, 95% CI 1.02-3.68), firefighters (PPR 2.21, 95% CI 0.94-3.5), non-EMT ambulance drivers (PPR 2.17, 95% CI 0.90-3.43), barbers (2.1, 0.90-3.43) and kindergarten teachers (PPR 2.0, 95% CI 0.81-3.28). As previously reported by Baker et al., other high-risk NHNCW occupations included jailers, special education teachers, transportation security screeners, septic tank servicers and sewer pipe cleaners, social and human service assistants, and those directly exposed to SARS-CoV-2 (morticians and embalmers). The following sections summarize how cross-sector and industry-specific reports of COVID-19 burden among NHNCW have since validated validate these estimations.

3.2 **Cross-sector Reports of COVID-19 Risk among Non-Healthcare, Non-Congregate Workers**

The Council of State and Territorial Epidemiologists (CSTE) has defined COVID-19 outbreaks among NHNCW as "two or more laboratory-confirmed COVID-19 cases among workers at a facility with onset of illness within a 14- day period, who are epidemiologically linked, do not share a household, and are not listed as a close contact of each other outside of the workplace during standard case investigation or contact tracing" (Council for State and Territorial Epidemiologists 2020).

In response to identification of COVID-19 cases in several meat and poultry processing plants early in the pandemic, the CDC released a report of risk assessment findings and COVID-19 incidence among 115 such facilities in 19 states through April 2020 (Dyal 2020). The total numbers of cases among all workers across all affected plants were reported by state, along with total number and proportion of deaths among cases. 4,913 confirmed COVID-19 cases were identified among 130,578 workers (an estimated incidence rate of 3.7%), with an overall case fatality rate of 0.4% (20 deaths). An update was released in July 2020 summarizing data from 124 more facilities and 4 more states (Waltenburg et al. 2020). Combining data from both assessments, 91 COVID-related deaths among 17,358 cases were identified among employees of the animal slaughtering and processing industries through May 2020 in 23 states. The updated overall case fatality rate (0.5%) was similar to that of the earlier report. Fourteen states reported total worker populations of affected facilities, enabling estimation of incidence rates ranging from 3.1% to 24.5% per facility.

A more extensive update was published in January 2021, including aggregate COVID-19 incidence and mortality data from 382 meat processing facilities across 30 states, and 742 other food manufacturing and agricultural facilities in 31 states over this period (March through May 2020) (Waltenburg et al. 2021). The incidence rate among workers in the meat processing industry (beef, bison, lamb, pork, poultry, veal or other) was 11.4%, with a 0.5% case fatality rate (CFR). Incidence among other food and agricultural industry workers was lower (8.2%), with a CFR consistent with earlier reports (0.6%). Since these industry-specific reports, several jurisdictions have reported surveillance data among NHNCW, in industry-specific and broader summaries cross-sector summaries. These are described in the next two section of this review.

In August 2020, Bui et al. described COVID-19 cases and outbreaks identified among NHNCW by industry sector in Utah (Bui et al. 2020), using the CSTE criteria. Through June 5, 2020, three quarters (210/277, 76%) of all outbreaks reported by Utah's Department of Health occurred in these non-healthcare, non-congregate settings, and comprised 12% of all confirmed COVID-19 cases in Utah (1,389/11,448). Half (49%) of outbreaks and over half of all associated cases (58%) were in three industries: manufacturing (20% of outbreaks), construction (15%) and wholesale trade (14%). Hospitalization rates were similar among outbreak versus non-outbreak-associated cases (6 versus 7.6% of cases, respectively) and case-fatality rates among outbreak and non-outbreak-associated cases did not differ (0.7 versus 0.6%). Notable advantages to this report were comparisons of outbreak-associated cases versus other cases (not outbreak-associated) and overall demographics of workers by industry sector. Hispanic-Latino and other non-White workers comprised 73% of outbreak-associated cases across all sectors, but an estimated 24% of workers across these sectors. As the authors described, studies by occupation, as planned in this dissertation, would shed additional light on disproportionate risks among workers by race and ethnicity.

Murti et al. described workplace outbreaks identified in Ontario from January 21- July 28, 2020, including details of household transmission (Murti et al. 2021). Workplace outbreaks were classified by NAICS into one of 20 non-healthcare industry sectors, and household cases were identified for exclusion from outbreak counts using matching algorithms based on natural-language processing. In sensitivity analyses, all cases with shared workplaces were included in outbreak definitions regardless of shared households. Of 199 workplace outbreaks and 1,245 associated cases identified through June 2020, 9 industry sectors had 3 or more outbreaks. Manufacturing (45%), agriculture, forestry, fishing and hunting (12%) and transportation and warehousing (11%) comprised the greatest share of outbreaks. The proportion of outbreak cases with a corresponding household case varied by sector from as low as 7% (construction) to as high as 40% (accommodation and food services).

Sensitivity analyses resulted in a 42% higher caseload when including all household cases as outbreak-associated. The authors noted that agriculture workers may have been over-represented in this analysis due to dominance of the farming industry and mass surveillance testing conducted among farming workers in Southwest Ontario. They also posited that shared break areas (e.g., rest stops) and movement through areas with greater community transmission caused increased transmission among truck drivers in the transportation and warehousing industry. While the CSTE outbreak definition in the beginning of this section was being employed across U.S. jurisdictions, the criteria for defining non-healthcare workplace outbreaks as having two or more associated cases were not issued regionally in Ontario until June 11. Before then, outbreak investigations were initiated at the discretion of local health department based on assessments of potential occupational risk. Though further details of these early criteria were not provided, investigators reported that 50 investigations initiated before June 11 had only one case and that excluding these did not appreciably change the distribution of outbreaks by sector.

In July 2021, Contreras et al. described workplace outbreaks identified from March 19 – September 30, 2020 in Los Angeles County, California, classified by NAICS code (Contreras et al. 2021). Like that of Bui et al., this analysis utilized average county-level quarterly employment data from the Census of Employment and Wages to estimate incidence rate by industry (per 100,000 workers). Almost 60% of all outbreaks occurred in three industries: manufacturing (26.4%), retail trade (19.6%), transportation and warehousing (10.5%). These sectors were also found to have the highest industry-specific incidence rates (980.9 in manufacturing, 425.1 in transportation and warehousing). Contreras et al. classified outbreaks further by industry subsector, finding that most outbreaks occurred in food and beverage stores (10.7%), food manufacturing (10.0%), food services and drinking places (9.2%). The three subsectors with highest incidence rates per 100,000 population were food manufacturing (3,779), warehousing and storage (2,853, and apparel manufacturing (2,186). This was the first cross-industry report to suggest higher case burden in “non-essential” workplaces like bars and restaurants, likely reflective of local re-opening of such workplaces later in 2020.

Spearman’s correlation coefficient assessed the magnitude and direction of association between workforce size and outbreak size and duration, confirming that size of on-site workforce was positively correlated with outbreak size (rho = 0.49) and duration (rho = 0.54). For example, the arts, entertainment, and recreation industry had the largest median number of staff at outbreak sites (302, ranging from 134 to 1,500), highest median number of associated cases (22, ranging from 3-38 per site), and also the longest median outbreak duration (41 days, ranging from 13-62). However, only three outbreaks were reported in this industry (0.4% of all), Transportation and warehousing had the second largest median number of staff at outbreak sites (255, with a range of 4-2,083 on-site workers per site), with median of 9 associated cases (range 3-125) and median outbreak duration of 23 days (range 0-158 days).

Contreras initially used a more conservative outbreak definition for workplaces than those in Utah (Bui), of five or more suspected or confirmed COVID-19 cases within any 14-day period. As capacity for COVID-19 response increased, the threshold was lowered to three or more laboratory-confirmed cases over the same period. Quarterly employment data from L.A. County included residents of Pasadena and Long Beach who were considered out of jurisdiction for tabulations of COVID cases reported to the Los Angeles County Department of Public Health, potentially causing underestimations of industry-specific burden. Authors countered that this had little influence in the most impacted essential industries, with smaller proportions of workers in these outside jurisdictions compared to other industry sectors.

Bonwitt et al. described the approach and findings of NHNCW outbreak investigations conducted by Public Health-Seattle and King County from June 15 through November 2020 (Bonwitt 2021). Their team adopted a prioritization scheme for responding to all reports of workplaces that one or more workers attended while infectious, based on features associated with increased spread and severe outcomes. For example, workplaces that met one of the following criteria could be considered high priority: (1) two or more laboratory confirmed COVID-19 cases within 14 days, (2) health department awareness of other cases within the workplace,

(3) interviewed workers with no contact information for exposed coworkers or contacts, (4) workers reporting to work while infectious. These workplaces were considered high priority if also meeting at least one of the following criteria: (1) at least five potential workplace or customer contacts, (2) a high-density or high-traffic workplace, (3) a disproportionate number of workers at high-risk for severe outcomes, or (4) workers' concern about infection control practices in the workplace. A high-density workplace was defined as one in which workers have long shifts (8 hours or more) and prolonged contact with each other; examples include agriculture and produce packing, construction, fishing, food and non-food manufacturing. Public health response included cooperation with businesses to complete a COVID-19 risk assessment, and ascertainment of all known cases; universal testing was not uniformly implemented.

Among 2,850 workplace reports triaged over five months, 1,770 (62%) were classified as high priority. 45.1% of high-priority investigations met outbreak criteria, versus 16.1% of others. Most investigations (56%) were initiated through review of routine case investigation and contact tracing data, versus self-report by the business (24%) or other means (20%). This suggests that most investigations among NHNCW would have gone un-identified if relying only on workplaces and others to report to the health department versus incorporating active methods of surveillance, as discussed further in Section 4.2.

A report of workplace outbreaks investigated by the Wisconsin Department of Health Services from March 4 – November 16, 2020 (Pray et al) was the first to stratify analyses of industry-specific burden by time period and levels of "non-essential" workplace operations (Pray 2021). Pray et al. distinguished between outbreaks occurring (1) before and during the state's stay-at-home ("Safer-at-Home") order March 4 –May 12, (2), over Summer and as schools and non-essential businesses were resuming (May 13 –September 23), and (3) and during the subsequent surge in COVID-19 cases (September 3-November 16, 2020).

Over all periods, 5,757 outbreaks and 57,991 associated cases were identified, comprising 18.3% of 316,758 cases in the state. Of NHNCW, outbreaks in manufacturing and food processing were found to have the largest proportion of cases (2,146 or 47.1% combined) during “Safer-at-Home”. The proportion of workplace outbreaks that occurred in these sectors deceased to 19.8% over the second period (re-opening). At the same time, the proportion of workplace outbreaks associated with bars and restaurants increased from 1.8 to 12.1%, and the proportion among retail and public establishments increased from 1.0 to 6.0%. During the third period (Fall surge), outbreaks in congregate settings (schools, correctional facilities and long-term care) comprised the majority of outbreak-associated cases (67.3% combined). This reflects the higher-risk nature of these environments. However, authors also described a need to re-allocate outreach teams and other resources away from NHNCW settings in response to surges in these congregate settings. Fewer investigators conducting follow-up and analyzing surveillance data among NHNCW may have resulted in decreased case ascertainment among workplaces perceived as “lower risk” compared to congregate settings.

3.3 <u>Industry-specific Reports of COVID-19 Burden among Non-Healthcare Workplaces</u>

Further industry-specific reports of workplace-associated COVID-19 in the United States have shed light on occupational risk factors, and shaped infection-prevention and control guidance for higher-risk congregate workplaces. For example, in 2020, CDC-facilitated investigations of 13 outbreaks among workers in Alaska’s seafood processing industry informed revised quarantine and testing recommendations for these and other high-density, congregate settings (Porter et al. 2021). From all outbreaks investigated, 20% (132/677) of cases were contained among workers in entry quarantine (off-site locations in which workers were held prior to joining the on-site workforce). An estimated 539 outbreak-associated cases were identified later (80% of all on-site cases), the majority of which could not be identified as contracted from workers entering from quarantine. These findings informed restrictions of the size of pre-entry quarantine group to minimize spread among workers, eliminated the option of work during pre-entry quarantine. They also led to pre-transfer testing requirements and recommendations of serial testing of on-site workers, dependent on the level of community transmission.

In their report of cases associated with outbreaks among 3,635 employees of meat and processing facilities in South Dakota between March and April of 2020, Steinberg et al. estimated a cumulative attack rate of 26% (n=929 cases) among workers across all sites (Steinberg et al. 2020). Rates were as high as 30% within each of the harvest (126/478 workers), cut (266/882) and conversion departments (173/575); three types of areas that all require employees to work in close contact. Rates were much higher among non-salaried employees (26%, 890/3,372 workers) than among salaried employees (15%, 39/263) who are not typically in close contact for extended periods of time. These findings emphasized need for interventions that mitigate risk between close contacts as described in Section 1.2, such as physical barriers, and speak to the disparities in risk that can exist within industry sectors between workers of different occupations.

A later study of COVID-19 risk among meat processing employees in Nebraska augmented these findings by estimating the effectiveness of facility-level measures to prevent the spread of COVID-19 among workers. From April through July 2020, 5,002 COVID-19 cases among meat processing industry workers had been reported in Nebraska, an attack rate of almost 1 in 5 (Herstein et al. 2021). Herstein et al. compared COVID-19 incidence among workers in periods before and after implementation of facility-level controls (universal masking and/or installation of physical barriers) across thirteen facilities that received risk mitigation assistance from the University of Nebraska Medical Center (UNMC).

Most (84% or 11/13) facilities installed both physical barriers (mostly plexiglass partitions on production lines and cafeteria tables) and implemented workplace masking. Of these, 8/11 (73%) saw significantly decreased incidence rates post-intervention (at $p \leq 0.05$). Among these, the pre-intervention incidence rates ranged from 2.2 to 17.2 cases per 1,000 person days with percentage decreases ranging from 49% (1.3 cases down from 2.5 per 1,000 person-days) to as much as 97% (0.06 cases down from 2.2 cases). The two facilities that instituted masking alone had similar pre-intervention incidence rates (3.2 and 3.3 cases per 1,000 person-days) and did not see appreciable reductions in case rates post-intervention (10% and 3% reductions at $p=0.75$ and $p=0.94$, respectively).

These findings substantiate the implications of reports from South Dakota, that facility-level interventions in high-density workplaces can reduce risk of SARS-CoV-2 transmission during prolonged close contact among workers. They also emphasize the necessity of strategies that do not rely entirely on worker adherence (e.g., proper use of facemasks). UNMC's prior survey of 443 meatpacking workers in Nebraska in May of 2020 found that while 83% said masks were required in their workplaces, only 44% said they had received information on how to wear and care for face masks (Ramos, Athena 2020).

In May 2020, Rubenstein et al. conducted a survey to define factors associated with differential case burden among foreign versus U.S. born poultry facility workers (Rubenstein et al. 2020). Among 359 workers surveyed across two Maryland facilities, 135 (38%) were foreign-born. Despite being a smaller proportion of the workforce than U.S. born-workers, foreign-born workers were almost five times as likely to work in areas involving cutting (OR 4.8, 95% CI 2.3-10.0), almost 4 times as likely to work in evisceration (harvesting) (OR 3.5, 95% CI 1.5-8.5), and over 4 times as likely to be working in cold-temperature areas (OR 4.4, 95% CI 2.1-9.2), though temperatures of work areas were not specified in this report. As described by Steinberg et al. and Günther et al., these environments have been found to be the highest-risk for workplace-acquired infection within meat processing facilities. This is another report that speaks to differential occupational risk encountered among workers of different demographic and occupation groups within the same industry, and potential compounding of occupation with individual-level risk among NHNCW.

This study also speaks to the value of employer-initiated, culturally appropriate guidance on how to reduce COVID-19 risk among employees. Work was the third most frequently cited source of information about COVID-19 prevention (31%) after television news (72%) and the internet (34%) among all workers surveyed, with no difference observed between U.S. and foreign-born workers. However, foreign-born workers were more likely to report carpooling with others outside their household (OR: 1.9, 95% CI 1.2-3.0), and also reported a higher median number of household members (4.0, ranging from 3.0-5.0, versus 3.0, ranging from 2.0-4.0 among U.S.-born workers, p <0.001), suggesting that incorporating messaging about reducing risk outside the workplace might serve to reduce risk of community-acquired COVID-19 among this subgroup of NHNCW.

3.4 Studies of Severe COVID-19 Outcomes among Non-Healthcare, Non-Congregate Workers in the United States

Hawkins et al. published the first analysis of COVID-19 mortality by occupation in the U.S., utilizing surveillance and death data from Massachusetts and O*NET classifications to identify occupational characteristics associated with increased mortality. They analyzed vital records from 555 COVID-related deaths among non-military working age (ages 16-64) Massachusetts residents between March and July 2020, to identify industries and occupations with the highest COVID-related mortality rates. Cases were classified into 22 non-military occupation groups using NIOCCS, and workforce distribution data from the 2018 ACS were used to estimate age-adjusted mortality rates by industry.

Consistent with previous studies of factors associated with increased COVID risk, this analysis found that occupations requiring frequent close contact with the public and potentially ill people had the most elevated mortality rates. Half of the defined occupation groups had higher mortality rates than those for all workers (healthcare support; transportation and material moving; food preparation and serving; building and grounds cleaning and maintenance;

production; construction and extraction; installation, maintenance, and repair; protective service; personal care and service; arts, design, entertainment, sports, and media; and community and social service). The overall COVID-related mortality rate across all sectors was estimated to be 16.4 deaths per 100,000 workers from March through July 2020 (<0.2%). Deaths were found to be highest in April and May, the peak of the first wave of COVID-19 in Massachusetts; authors attributed the decrease in mortality to implementation of lockdowns, partial shutdowns, other community- and workplace-based measures after that period, and improved treatment practices for severe COVID. Hispanic and Black workers with COVID-19 were found to have age-adjusted mortality rates over four times those of White workers (53.4 and 50.4 versus 10.7 per 100,000), and higher rates than white within the same occupation group. These findings suggest exacerbation of occupation-related COVID-19 risk by sociodemographics among NHNCW as described in Section 1.5.2.

Two studies from California have estimated COVID-19 mortality by occupation. Both used death certificates as a source of occupation information for cases, autocoding free-text field for “usual occupation” into major occupation subgroups using NIOCCS. The first study by Chen et al. estimated excess mortality related to COVID-19 in the first nine months of the pandemic, stratified by major occupation group overall (Chen et al. 2021). Time-stratified analyses compared mortality rates over three time periods over which public health guidance presumably impacted occupational risk: (1) March – May, (2) June - August, and (3) September - November 2020 approximated periods of sheltering in place, non-essential business re-opening and non-essential business closure in California. This study found that from March through November 2020, California experienced an excess mortality rate of 22% (46 excess deaths per population) due to COVID, with the highest rates among workers in food/agriculture (39% relative excess; 75 excess deaths per 100,000), transportation/logistics (31%; 91 per 100,000), manufacturing (24%; 61 per 100,000), and facilities (23%; 83 per 100,000). Excess mortality rose across all these essential sectors during the March through May shelter-in-place period but not among non-essential sectors.

The second report by Cummings et al. described disparities in COVID-related fatalities among working Californians. This retrospective study of laboratory-confirmed COVID-19 deaths occurring in January – December of 2020 estimated that 8,050 (9.9%) of 81,648 fatalities among working-age Californians (ages 18-64) were COVID-related, and that the overall age-adjusted COVID-related mortality rate was 30 deaths per 100,000 workers (Cummings et al. 2021). Eight NHNCW occupational groups had mortality rates higher than the overall rate (all in rates per 100,00 workers): farming, fishing and forestry (78.0, 95% CI 68.7-88.2), material moving (e.g. – industrial truck and tractor operators, 77.8, 95% CI 70.2-85.9), construction and extraction (62.4; 95% CI, 57.7-67.4); production (60.2; 95% CI, 55.7-65.0), transportation (57.2; 95% CI, 52.2-62.5); installation, maintenance, and repair (55.2; 95% CI, 49.3-61.7); building, grounds cleaning, and maintenance (46.9; 95% CI, 42.7-51.5); food preparation and serving-related (46.0; 95% CI, 41.2-51.1). Disparities in mortality rates by occupation could not be explained by demographic differences alone: high-risk groups still showed increased mortality when controlling for sex, race and ethnicity. For example, as authors report, the mortality rate among female workers in farming, fishing and forestry was more than double the rate among all female workers (38.0%, 95% CI 27.7-51.1, versus 15.9% with 95% CI 15.2-16.8).

3.5 **Summary of Remaining Knowledge Gaps**

To-date, reports of workplace-associated COVID-19 surveillance among NHNCW have been subject to two principal limitations: focus on industry-specific outbreaks, and restriction to pre-vaccination and pre-Omicron phases of the pandemic. Given high case burden among workers in food production and processing, these and other 1b/1c workplaces have received increased attention. Comparatively less is known about workers in “non-essential” industries that resumed operations in mid-2020, some of which have frequent and close interactions with colleagues and patrons (e.g., those in bars and restaurants, gyms, salons). Data are lacking on COVID-19 burden among workers subject to these environments, including after vaccine eligibility, masking requirements, and resulting changes in COVID-19 exposure in these settings.

This dissertation will expand on previous reports and analyses of industry- and occupation-specific COVID-19 burden, by summarizing how workplace investigations have varied over time with changes in key guidance, and as workers and patrons became eligible for vaccination. The WHO's database of Public Health and Social Measures (World Health Organization n.d.), which tracks changes in guidance at national, state and local locals, will be referenced alongside a working list of the City's COVID-related health orders to define dates of guidance changes affecting workplace operations, masking and vaccination.

By aiming to describe demographics and trends among all NHNCW with COVID-19 in Chicago, the planned analyses will be more comprehensive than previous studies of COVID-19 among NHNCW that have focused on characterizations of outbreak-associated cases. Workers and workplaces without the means of reporting cases to the health department, or who have reduced access to laboratory-confirmed COVID-19 testing are likely to be under-represented in outbreak reports: reporting criteria include a threshold number of laboratory-confirmed cases, and sufficient details of epidemiologic links among cases that cannot be gathered without workplace cooperation. The broader analyses that incorporate data from additional NHNCW cases identified through routine interviews with CDPH are still subject to non-response bias, in that NHNCW not reached for interview or choosing not to share industry or occupation data are not represented. However, they provide more information about COVID-19 burden among NHNCW than reports of outbreak-associated cases alone.

Since the initial estimations of occupational risk and use of O*NET for estimation of workplace-related COVID-19 risk as summarized in this section, CSTE's Occupational Health Subcommittee has developed the SARS-CoV-2 Occupational Exposure Matrix (SOEM), a pathogen-specific framework for estimation of risks of COVID-19 transmission in the workplace. This framework expands on the methods employed by Zhang et al. to yield a single measure of potential workplace exposure. Based on 2 questions estimating frequency of public-facing work, 5 measures of working indoors and 3 of working in proximity to others, occupations can be rated as high, medium or low-risk for COVID-19. This dissertation will include novel applications of this updated framework using real-work surveillance data from NHNCW cases in Chicago.

An additional limitation of the existing characterizations of risk among occupational environments is that they do not account for the hierarchy of workplace controls since recommended by OSHA and described in Section 1.2 of this report. Publicly available data regarding adherence to these controls among workplaces have since been limited. This dissertation will address this by summarizing results of workplace assessments issued to NHNCW workplaces through May 2022 to estimate the proportion reporting adherence to OSHA-recommended infection control measures. Though these surveys will be subject to reporting bias, they will provide some estimates of compliance with hierarchy of controls by industry sector and over time to begin to address a lack of existing data on this topic.

While studies summarized in this section have helped define occupational and industry subgroups at increased risk of workplace-acquired COVID-19, they have not described the prevalence of neighborhood-level demographic factors among these workers that may contribute to a disproportionate risk of severe outcomes among these workers. Analyses for this dissertation will include composite variables to help estimate the distribution of these among NHNCW based on CCVI of and HCEZ of residence. These will help control for confounding of the associations between work-related risk and COVID-19 outcomes by sociodemographic and community-level vulnerabilities, in models exploring the underlying mechanisms of disproportionate burden observed among NHNCW in Chicago.

4. COVID-19 SURVEILLANCE AMONG NON-HEALTHCARE, NON-CONGREGATE WORKERS IN CHICAGO: DATA SOURCES AND METHODS

This section describes how cases of COVID-19 are reported in Chicago. Requirements for reporting to health departments are outlined, including those specific to NHNCW. In addition to passive surveillance channels (reliance on individuals and workplaces to report to CDPH), active surveillance approaches (in which CDPH conducts outreach to workplaces for case ascertainment) are explained.

4.1 COVID-19 Reporting and Investigation Compliance in Chicago

All positive SARS-CoV-2 tests are reportable to state and local health departments based on CARES Act Section 18115 (Centers for Disease Control and Prevention, n.d.). In Illinois, providers and testing centers enter positive lab results into I-NEDSS as “Novel Coronavirus 2019”. Requested testing and demographic data are outlined on the national case report form established by the CDC (Centers for Disease Control and Prevention, n.d.). This form requests but does not require occupation and industry data. Under the Illinois Communicable Disease code (Centers for Disease Control and Prevention, n.d.), individuals and workplaces are required to comply with IDPH and local health departments during COVID-19 outbreak investigations. The first COVID-specific reporting mandate applying to NHNCW in Chicago was issued in October 2020, in contrast to congregate settings such as schools, homeless shelters, and healthcare facilities, with preexisting guidance. Effective October 1, Chicago re-issued Public Health Order 2020-2 (City of Chicago 2023) . As specified in Section 4: Any business or establishment licensed or required to be licensed under Title 4 of the Municipal Code of Chicago shall immediately report the following to CDPH: (1) any suspension in operations due to COVID-19 cases among employees or patrons; or (2) any instance in which the business learns that five or more employees or patrons have tested positive for COVID-19 occurring within 14 calendar days of each other. (p.2) Prior to this guidance (in

March 2020), CDPH established a COVID call center, e-mail address, and an outpatient case report form to facilitate reporting of one or more COVID-19 cases by businesses or individuals. Incoming reports are routed to respective response units for triage and outreach. I-NEDSS is cross-referenced for verification of laboratory results. Cases not found to be classified as probable or confirmed in I-NEDSS are considered suspect.

4.2 **Case Investigation and Contact Tracing for Workplace COVID-19 Surveillance**

Case investigation and contact tracing (CICT) interview data supplement direct reports to CDPH. In Chicago, all probable and confirmed cases are currently imported from I-NEDSS into the city's CICT Salesforce interface ("Chicago CARES") for follow up and contact tracing. Cases not reached in 5 days are assigned a status of 'administrative closure' ('unreachable'). Interviews include elicitation of close contacts (individuals who may have been within 6 feet of an infectious person for at least 15 minutes within any 24-hour period) (Centers for Disease Control and Prevention 2020c)and the following data informing workplace response: symptom onset date, specimen collection date, employer name, occupation, employer address, and last day worked on-site. Free-text fields collect any additional details on workplace exposure, workplace cases, or other interviewee/interviewer concerns related to the workplace.

The existing protocol for CICT teams at CDPH requests that single cases are escalated to the NHNCW unit when interviewees report multiple cases within two weeks at the same workplace, or workplace practices that may be encouraging workplace transmission (such as requiring employees to return to work before full recovery, refusal to comply with COVID-19 infection control guidance). Since Summer of 2020, Chicago's unit for NHNCW has been using data mining to supplement these methods, with the goal of improving timeliness of cluster identification and outreach to workplaces regarding current preventive measures and known cases. Workplace data are extracted from Chicago CARES and aggregated in SAS for cleaning; workplaces corresponding to other congregate settings (healthcare settings, senior, youth and behavioral facilities, corrections, homeless shelters, educational facilities) are routed to appropriate units for follow-up and excluded from further review in SAS. Interviewees with incomplete work site location information or who specify working remotely are also excluded.

In SAS, dates of specimen collection and any reported symptom onset for individual cases are compared any reported last day of on-site work, to identify employees who may have worked during their infectious period, and workplaces with two or more workers who may have exposed others on-site. These analyses maximize the efforts of CICT by identifying exposures that may not be found during routine interviews. For example, interviewees with a common workplace may be exposed to SARS-CoV-2 without knowledge of one another, or without choosing to disclose colleagues' information to interviewers. Given the volume of interviews required across CICT teams during Chicago's COVID-19 response, especially during surge periods, communicable disease investigators may work on separate response teams, without awareness of concomitant or related workplace cases mentioned across interviews.

Non-response and low rates of interview completion among cases are major limitations to methods relying on CICT. Internal performance metrics (i.e., not publicly available) from CDPH suggest that the proportion of cases successfully interviewed in 2021 decreased from a peak of 50% (in July of 2021, when case rates were very low) to below <10% in the final weeks (the onset of the current Omicron surge). Preliminary analyses of recent interview data indicate that in calls to 28,742 working-age cases who tested positive from June through November 2021, 10,521 (37%) were successfully interviewed. Of those, 5,006 (48%) reported any information on occupation, job title or employer name. Table V compares the number and demographics of working-age cases who were and were not successfully interviewed with any workplace data and suggests that data may thus be biased toward improved detection and outbreaks among White, non-Latinx cases, though distributions of complete and incomplete interviews by age and region are similar.

TABLE V.DEMOGRAPHICS OF WORKING-AGE CHICAGOANS TESTING POSITIVE FOR COVID-19 BY INTERVIEW COMPLETION, JUNE THROUGH NOVEMBER 2021 (N=28,742)

	completed and provided workplace data (n=5,006)		incomplete or missing workplace data (n=23,736)	
	n	%	n	%
Age Group				
17-29	1613	32.2	8027	33.8
30-39	1649	32.9	6908	29.1
40-49	956	19.1	4227	17.8
50-59	601	12.0	3262	13.7
60-69	187	3.7	1312	5.5
Race/Ethnicity				
Latinx	1200	24.0	3732	15.7
Black, non-Latinx	1359	27.2	5402	22.8
White, non-Latinx	1763	35.2	6307	26.6
Asian, non-Latinx	98	2.0	241	1.0
Other, non-Latinx	136	2.7	741	3.1
Unknown	450	9.0	7313	30.8
Region				
Northwest	1071	21.4	4969	20.9
North	1044	20.9	4683	19.7
West	806	16.1	3565	15.0
Southwest	653	13.0	3013	12.7
Far South	585	11.7	2662	11.2
South	445	8.9	2351	9.9
Central	359	7.2	1818	7.7
Unknown	43	0.9	675	2.8

4.3 **Criteria for Workplace COVID-19 Investigations in Chicago**

Workplace investigations may be initiated when either of these criteria are met: (1) Reports or CICT data indicate two or more employees with COVID-19 may have been at the same physical work site during their infectious periods within 14 days of one another (with infectious period defined as 2 days prior to or within 10 days after the earlier of onset or positive test date); (2) Reports or CICT data indicate concern of significant workplace spread or nonadherence to workplace-based infection and prevention control measures; (3) the number of cases reported from one workplace exceeds the number expected based on routine reports or level of community transmission. Workplaces in which the only cases are known to share a mailing address are excluded, as spread is presumed to have occurred in the household. Cases among patrons and secondary cases (i.e., sharing a household and becoming sick later) are not consistently ascertained or documented as outbreak-associated.

Outreach is usually initiated the same day that a potential cluster is identified. Employers are provided with a case report template and asked to report individual-level data on all known employee cases, including of any known epidemiological links among cases (e.g., work locations, shifts, carpooling, shared households). A workplace assessment is conducted to assess prevention and control measures currently in place and inform follow-up with employers. CDPH provides tailored guidance in response to the completed assessment and any additional concerns.

On October 26, 2020, weeks after region-wide surges in case counts and positivity rates, IDPH changed the threshold for definition of a COVID-19 outbreak among NHNCW from two to five probable or confirmed cases within 14 days. At CDPH, the surveillance unit for NHNCW has continued to respond to alerts of 2-4 cases but categorized these smaller investigations as “clusters”, aligned with the CDC definition of a cluster as “a number of cases that is greater than expected for a certain location and period” (CDC 2020b). The classification of ‘outbreak’ has since been reserved for investigations of five or more cases sharing the epidemiologic linkage defined by CSTE. Investigations meeting IDPH's criteria for a workplace outbreak are reported to the Illinois Department of Public Health through the State-maintained ORS (Outbreak Reporting System). Investigations remain open for identification of further cases until at least 28 days (2 incubation periods) have elapsed since the first day of illness for the last known associated employee case. They are then considered 'closed', the number of associated cases is finalized, and, if an outbreak has been reported to IDPH, the report is updated and closed.

4.4 Knowledge Gaps Related to COVID-19 Surveillance among Non-Healthcare, Non-Congregate Workplaces in Chicago

To date, publicly available data have described COVID-19 outbreaks among NHNCW in by workplace type in Illinois. They have not explicitly summarized Chicago's investigations and associated cases identified using the processes described here, or trends by industry in the context of non-essential re-opening guidance, infection control guidance or vaccination. As described in this section and among summaries of surveillance from other jurisdictions, incorporation of methods such as single-case escalation and aggregate analyses of CICT data substantially increase the number of clusters and outbreaks identified among NHNCW. To-date, however, differences in how investigations are most frequently identified by industry have not been described. Furthermore, most cases interviewed by CDPH are not part of cluster or outbreak investigations but may still provide valuable data on COVID-19 occupation that have not yet been more broadly described. This dissertation proposes a broader characterization of all interviewed cases reporting occupation data and estimation of incidence rates by occupational sector. This analysis will provide a more representative estimate of relative COVID-19 burden among NHNCW than quantifying and describing only the cases found to be associated with outbreaks and clusters.

4.5 **Changes to COVID-19 Surveillance in the United States**

As national and local COVID-19 response strategies evolve, a shift away from case-based surveillance measures is imminent. In January 2022, CSTE issued a statement that, based on two years of global SARS-CoV-2 surveillance, public health agencies expect the virus will continue to circulate globally for the foreseeable future; public health agencies should be preparing to treat COVID-19 as an endemic, potentially seasonal illness such as influenza (Council for State and Territorial Epidemiologists 2022). As such there is a need to reduce ongoing burden of managing this disease on public health agencies. Furthermore, uptake of self-administered and other unreported rapid testing has increased substantially in 2021, decreasing effectiveness of surveillance practices driven by laboratory-confirmed test results. The CSTE statement recommended that public health agencies increase communication and education strategies encouraging the public to self-manage COVID-19 infections, including notification of close contacts, and that health departments begin to focus on other forms of more sustainable and effective population-level surveillance. This impending shift emphasizes the need to empower workplaces to report COVID-19 concerns directly to CDPH, and the value of these dissertation findings in identifying types of workplaces most in need of this outreach.

5. VACCINE HESITANCY: DEFINITION OF TERMS AND ESTABLISHED MODELS

The final sections of this review shift from discussions of COVID-19 surveillance to vaccine hesitancy, including among Chicagoans, and ways employers can encourage vaccination among NHNCW. First, this section provides an overview of the WHO's definition and established frameworks for vaccine hesitancy, for reference during subsequent summaries of existing studies of COVID-19 vaccine hesitancy among NHNCW (World Health Organization 2014).

The WHO Working Group on vaccine hesitancy defines **vaccine hesitancy** as "delay in acceptance or refusal of vaccines despite availability of vaccine services" (World Health Organization 2014)This phenomenon is described as complex and time-varying, with underlying explanations dependent on place, context and vaccines being considered. Accordingly, the studies reviewed in Section 6 focus on trends in hesitancy towards COVID-19 vaccination among NHNCW only, which, like distributions of disease (Section 3 of this review), have been relatively under-studied compared to trends among healthcare workers. The WHO uses two models to describe factors of vaccine hesitancy. The first model, summarized in Figure 21 below, categorizes factors of vaccine hesitancy as either **contextual, individual, or group-influenced, or specific to the COVID-19 vaccine itself.**

The reasons for vaccine hesitancy evaluated in interviews of COVID-19 cases and contacts in Chicago (see: Section 7.2) are more readily categorized and interpreted using a second "3C's model". This model categorizes factors as related to Complacency, Convenience and Confidence. Briefly, **vaccine complacency** exists when individuals do not perceive vaccination against SARS-CoV-2 to be necessary for them because they feel that their risk related to contracting COVID-19 is low. Ironically, successful vaccination programs have been found to increase vaccine complacency when those who have not yet been vaccinated feel that uptake among the rest of the population has sufficiently reduced their own personal risk (the "free rider" phenomenon). **Convenience**-related factors of COVID-19 vaccine hesitancy intuitively include proximity and access to vaccine, but also consist of ability to understand immunization guidance (i.e., health literacy) and perceived quality of immunization services provided. **Confidence**-related factors include trust not only in the efficacy and safety of COVID-19 vaccines, but also in the health professionals administering them, and motivations of policymaking bodies such as the CDC and FDA as they continue to recommend priority groups and strategies for vaccination against COVID-19.

CONTEXTUAL INFLUENCES Influences arising due to historic, socio-cultural, environmental, health system/institutional, economic or political factors	**a.** Communication and media environment **b.** Influential leaders, immunization program gatekeepers and anti- or pro-vaccination lobbies. **c.** Historical influences **d.** Religion/culture/ gender/socio-economic **e.** Politics/policies **f.** Geographic barriers **g.** Perception of the pharmaceutical industry
INDIVIDUAL AND GROUP INFLUENCES Influences arising from personal perception of the vaccine or influences of the social/peer environment	a. Personal, family and/or community members' experience with vaccination, including pain b. Beliefs, attitudes about health and prevention c. Knowledge/awareness d. Health system and providers-trust and personal experience. e. Risk/benefit (perceived, heuristic) f. Immunisation as a social norm vs. not needed/harmful
VACCINE/ VACCINATION–SPECIFIC ISSUES Directly related to vaccine or vaccination	a. Risk/ Benefit (epidemiological and scientific evidence) b. Introduction of a new vaccine or new formulation or a new recommendation for an existing vaccine c. Mode of administration d. Design of vaccination program/Mode of delivery (e.g., routine program or mass vaccination campaign) e. Reliability and/or source of supply of vaccine and/or vaccination equipment f. Vaccination schedule g. Costs h. The strength of the recommendation and/or knowledge base and/or attitude of healthcare professionals

Figure 21. World Health Organization determinants of vaccine hesitancy matrix.

(Source: World Health Organization, 2014)

6. COVID-19 VACCINE HESITANCY AMONG NON-HEALTHCARE, NON-CONGREGATE WORKERS: REVIEW OF EXISTING LITERATURE

This section describes current knowledge of reasons for vaccine hesitancy specifically among NHNCW during the COVID-19 pandemic, and frequency of vaccine encouragement strategies reported by employers. These will inform surveys of non-healthcare workplaces in Chicago as part of this dissertation. Findings published by The Kaiser Family Foundation (KFF) COVID-19 Vaccine Monitor in April, 2021 have remained among the most-widely cited references regarding COVID-19 vaccine hesitancy among NHNCW specifically (Kaiser Family Foundation 2021). This ongoing survey, conducted through random-digit dialing in the U.S., reached a nationally representative sample of 1,862 adults between March 15-March 22, 2021. This survey found non-healthcare essential workers to be two to three times as likely as non-essential non-healthcare workers or unemployed adults to say they would definitely not be vaccinated (21% of non-health essential workers, compared to 7% of non-essential, non-healthcare workers and 9% of unemployed respondents). Such findings highlight a need for evidence-based interventions to reduce persisting hesitancy among NHNCW, as Aim 3 of this analysis aims to inform.

Among the 53% of non-healthcare essential workers from the KFF study who were not already vaccinated or planning to be vaccinated, the most frequently cited reason was concern for side effects (66%) followed by concerns of having to miss work due to side effects (53%). When asked how they would respond to employer incentives to be vaccinated, 23% of essential workers said that they would be more likely to be vaccinated if their employer provided on-site vaccine; 41% said that monetary incentive would increase their likelihood of vaccinating.

Harvard University’s nation-wide Shift study, conducted over a period of broader vaccine eligibility, assessed reasons for vaccine hesitancy among workers in the service sector by surveying large firms in the grocery, retail, food service and delivery industries in March through

May of 2021 (Evelyn Bellew et al. 2021). Among 9,000 respondents, 48% reported not having received any COVID-19 vaccine. Among the 78% who had not tried to make an appointment, the most frequently-cited reason was concern for side effects (49%) followed by complacency (27% were not worried about COVID); and 17% cited being busy. This study found vaccination rates to be much higher in workplaces that encouraged vaccination: 68% among those that provided vaccine, 63% among those that provided time off to recover from side effects, 60% among those who provided time off to get vaccinated, and 56% among those that offered monetary or other incentives. In comparison, the vaccination rate among workplaces that reported not offering any of these types of encouragement was 39%. These findings suggest that employer encouragement can make a substantial impact in workforce vaccination rates and that the frequency of these practices among NHNCW in Chicago should be evaluated.

Both the KFF and Harvard studies indicate that safety is a priority topic for messaging to address vaccine hesitancy among NHNCW. However, given increased uptake since these studies, strengthened vaccine recommendations during the Omicron surge, and mandated vaccination for some indoor spaces, more updated and localized assessments of residual hesitancy are needed. Furthermore, the Shift study focuses on workers from large firms; their surveyed population may be better-resourced to offer employees encouragement than other businesses. This dissertation will address these limitations by surveying smaller businesses in Chicago and analyzing interview data that are more reflective of recent hesitancy attitudes. The surveys issued to workplaces as part of this dissertation will ask about the practices assessed in the Shift study. Use of similar survey language will aid comparison with results from other studies informed by the CDC's COVID-19 Workplace Vaccination Program guidance (Centers for Disease Control and Prevention 2021c) or CISA Insights on Vaccination Hesitancy within the Critical Infrastructure Workforce (Cybersecurity & Infrastructure Security Agency 2021). Both recommend these strategies for reducing risks of low vaccination among NHNCW.

7. COVID-19 VACCINE HESITANCY AMONG CHICAGOANS

The final section of this review summarizes how hesitancy to receive COVID-19 vaccine has been evaluated among Chicagoans to-date, existing knowledge gaps and how the analyses in this dissertation will address these.

7.1 Collection of Vaccine Hesitancy Data in Chicago

In May of 2021, CDPH added questions probing vaccination hesitancy to its CICT platform. All cases and contacts interviewed May 28, 2021, and later are asked whether or not they had received **any** doses of COVID-19. Those who respond that they have not yet received any doses are asked to specify their primary reason for not vaccinating, and provided the following options: Safety concerns, medical conditions or provider advice, previous infection with COVID-19, being busy or not making time, religious objections, or other mistrust, skepticisms or anxiety; individuals can also cite perceived cost, transportation or issues finding an appointment, or can indicate that they are still unsure, planning to vaccinate, or do not want to specify a reason. They can also specify an 'Other' reason, in which case other provided details for not initiating vaccination are captured in free text.

To describe trends in vaccine hesitancy in Chicago, CDPH extracts demographic details and these reported vaccination details for processing in SAS, where free-text options are reviewed and re-categorized. Frequency of reported vaccination status is summarized by interviewee type (case or contact), stratified by age group, race/ethnicity, and geographic region, aligning with the HCEZ described in previous sections of this review. Reasons for hesitancy are also analyzed over time by these demographics.

7.2 Analyses of Vaccine Hesitancy in Chicago: Findings-to-Date

Results from vaccine hesitancy analyses among working-age case and contacts interviewed in January,2022 are shown in the following figures. As shown in Figure 22 below, a total of 8,623 interviewees provided vaccination data over this 30-day period, and approximately 1 in 4 (24%, or 22% of cases and 43% of contacts) reported not yet having received any doses of vaccine at time of interview. Over half (65%) of interviewed cases reported being fully vaccinated or boosted, a finding reflective of the ability of the Omicron variant to evade existing immunity as described in Section 1 of this review.

When reasons for vaccine hesitancy reported by unvaccinated cases and contacts interviewed in January and early February of 2022 were examined overall and by race/ethnicity (Figure 23), 48% of working-age interviewees (ages 18-64) who reported not having received vaccine did not specify a reason. The most frequently cited reason for not initiating vaccination was concerns about safety (25% of all interviewees). This held across all race/ethnicity groups of interviewees and is consistent with the findings of previously summarized national studies.

To-date, the focus of hesitancy analyses in Chicago and for the purposes of this dissertation will remain around reasons for not initiating **any** vaccination, given that the overwhelming majority of COVID-related hospitalization or deaths in Chicago have been among the unvaccinated. As such, these summaries of interview data from CDPH do not distinguish between fully-vaccinated (but not boosted) interviewees by time since vaccination, to estimate the proportion of vaccinated who have not been boosted simply because they are not yet eligible. This is a limitation that will be addressed in the aims of this dissertation, since dose dates will be collected and can be compared to interview dates. Finding a high proportion of interviewees who are not boosted despite being eligible would identify NHNCW at increased risk of infection due to potential waning immunity, and a need for messaging not only around initiation of vaccination but also remaining up to date on vaccines. Further limitations to these hesitancy analyses are described in Aim 3 of the Methods section of this report.

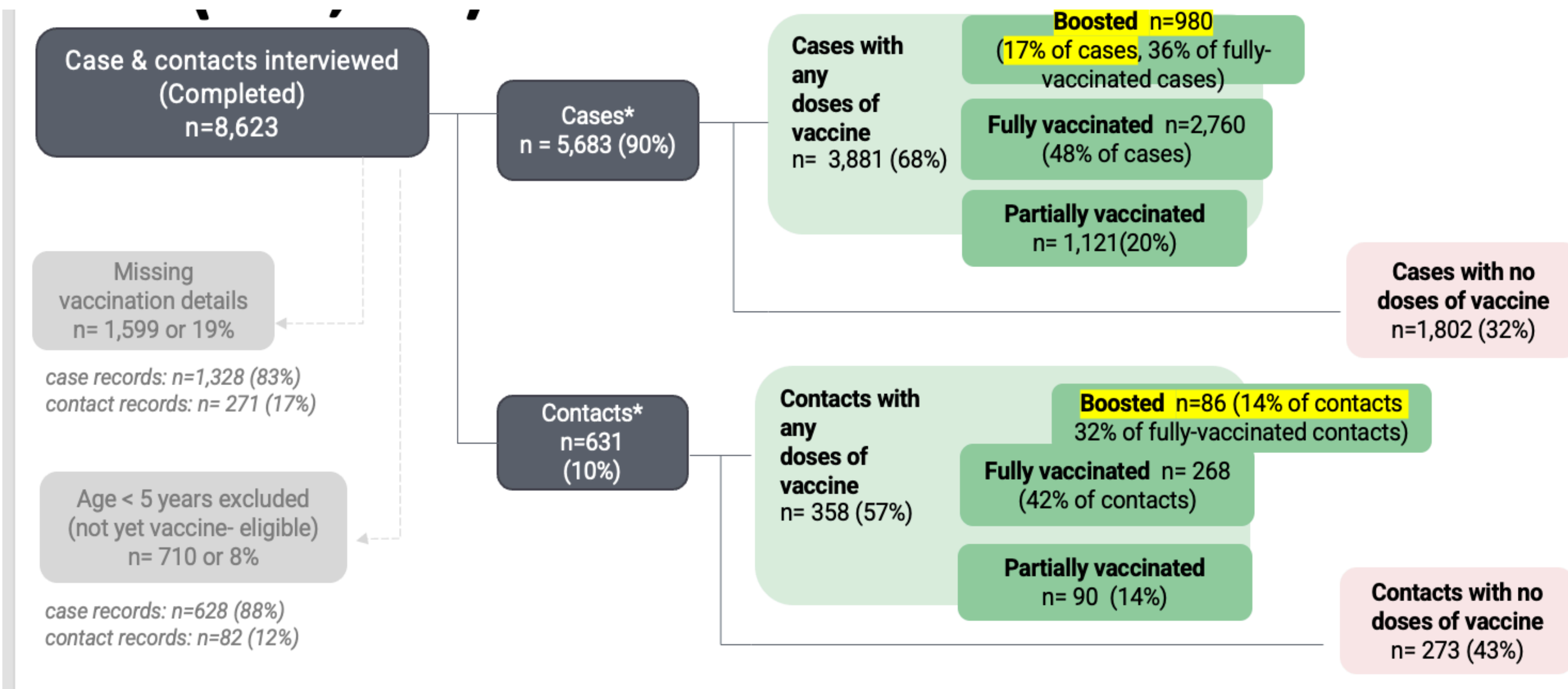

Figure 22. COVID-19 cases and contacts interviewed by CDPH, January 9 through February 5, 2022 by vaccination status (n=8,623).

(Source: Chicago Department of Public Health, 2022)

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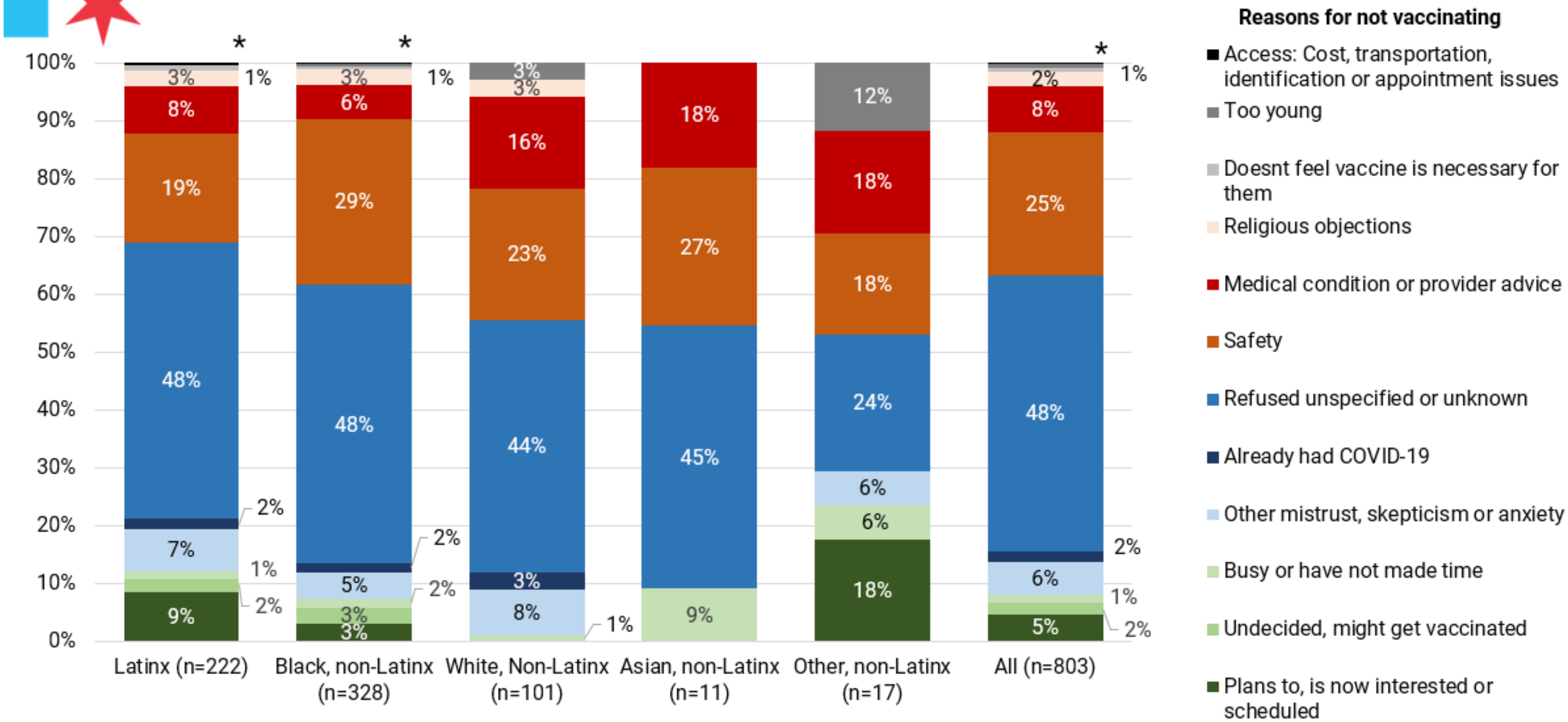

**Reasons reported by <1% of interviewees not labeled. Interviewees of unknown race/ethnicity comprise 15% of unvaccinated, included in 'All' column only.*

Figure 23. Reported reasons for vaccine hesitancy among working-age COVID-19 cases and contacts interviewed in Chicago: January 9 – February 5, 2022 (n=803)
(Source: Chicago Department of Public Health, 2022)

8. **SPECIFIC AIMS**

Aim 1: Characterize the demographics, neighborhood risk factors and outcomes of NHNCW with COVID-19 in Chicago, from early through post-vaccination phases of the pandemic (March 2020 – May 2022) and compare by industry and occupational sectors. (1A) Characterize cluster and outbreak investigations of workplace-associated COVID-19 NHNCW cases in Chicago: by industry sector, number of cases, demographics, and severity of associated cases. (1B) Characterize trends in individual and neighborhood-level demographics, hospitalizations, and deaths among NHNCW cases in Chicago overall, and compare by occupational sector and level of occupational risk. (1C) Identify opportunities to mitigate COVID-19 transmission among NHNCW by analyzing levels of workplace-reported compliance with OSHA's recommended hierarchy of controls.

Aim 2: Explore factors associated with being unvaccinated among NHNCW in Chicago. Stratify by vaccine eligibility phase, level of estimated occupational risk, individual and neighborhood-level COVID risk factors, in models of cases in pre- and post-Omicron periods. Evaluate effect modification by race/ethnicity, CCVI and HCEZ.

Aim 3: Describe workplace-reported COVID-19 vaccination rates, requirements and encouragement practices, and persisting vaccine hesitancy among NHNCW workers. (3A) Generate primary data by conducting workplace-level survey of NHNCW businesses in Chicago through July 2022, to report rates of vaccination among workers and frequency of vaccine encouragement practices (as recommended by CISA and WHO to reduce vaccine hesitancy among workers). Stratify results by industry sector, vaccine eligibility, business size (number of on-site employees) and HCEZ. (3B) Summarize reasons for vaccine hesitancy among unvaccinated NHNCW interviewed by CDPH from June 2021 through May 2022. Describe frequency distributions of reasons for not initiating vaccination among NHNCW. Report distribution of race/ethnicity, sex, and age group of interviewed NHNCW by vaccine eligibility phase.

9. METHODS

9.1 Aim 1. Characterizations of COVID-19 among Workers and Workplaces

Aim 1 is to characterize the demographics, neighborhood risk factors and outcomes among NHNCW with COVID-19 in Chicago, from early through post-vaccination phases of the pandemic (March 2020 – May 2022) and compare by industry and occupational sectors. To-date, most analyses of COVID-19 among NHNCW have been limited to outbreak investigations during the pre-vaccination period of the pandemic. Few have contextualized COVID-19 burden by defining sectors that have been highly impacted (i.e., have seen the most outbreaks and associated cases, and increased rates of severe infection and mortality) before and after changing mitigation measures (e.g., opening and closing of 'non-essential' businesses, masking and vaccination requirements). Understanding how these preventive measures affect levels of workplace-related risk, including among specific industry and occupational sectors of NHNCW, is essential for planning targeted public health guidance, facilitating a return to pre-pandemic operations while minimizing risk among NHNCW.

9.1.1 1A. Characterizations of Workplace COVID-19 Clusters and Outbreaks

Aim 1A is to characterize cluster and outbreak investigations of workplace-associated COVID-19 NHNCW cases in Chicago: by industry sector, number of cases, demographics, and severity of associated cases. The first hypothesis is that, given gradual resumption of non-essential businesses in June 2020, outbreaks will be limited to essential sectors in March through May 2020, and that the proportion of outbreaks among non-essential sectors will then increase beginning in June. The second is related to number and severity of cases associated with cluster and outbreaks among NHNCW: the median number of investigation-associated cases, rates of hospitalization and death are expected to decrease over time, especially after the introduction of vaccination among 1b/1c workers in January 2021.

Aim 1A will utilize workplace-level COVID-19 data from 4 sources. As described in Section 4, individual-level COVID-19 case data (for Aims 1A and 1B) will be derived from I-NEDSS and supplemented by: (1) corresponding interview data gathered through CDPH's case-investigation and contact tracing platform, (2) workplace-reported case data (see Section 4.1), and (3) facility-level investigation data collected by CDPH's workplace response unit. For inclusion in Aims 1A and 1B, COVID-19 cases among NHNCW in Chicago must have a probable or confirmed laboratory result on file in I-NEDSS. Cases reported to CDPH by workplaces but without corresponding laboratory results in I-NEDSS will be excluded from all analyses. Cases with a potential shared workplace will be identified following the surveillance practices summarized in Section 4.

Potential workplace contact and transmission among employee cases are determined through outreach to workplaces. When employees have contact outside work (e.g., carpooling, shared household or spending other time together off-site), only the first case (earliest onset or test date) will be counted as associated with a workplace-associated cluster or outbreak; subsequent are assumed to be acquired outside the workplace. This convention was adopted by the workplace response unit because transmission is more likely through prolonged community or household exposures in absence of masking and workplace controls (distancing, physical barriers, increased hand hygiene and disinfection, ventilation). This is consistent with transmission dynamics and risk (Section 1 of this report). Investigations of clusters and outbreaks among NHNCW will be initiated and classified according to the methodology described in Sections 4.2 and 4.3.

The workplace response unit at CDPH uses collapsed categories informed by NAICS coding by industry sector, with some groups collapsed given small numbers of investigations and similarities in services provided. The following categorizations informed by NAICS coding of workplace names will be used for this analysis: Food Production and Processing, Factory and

Manufacturing, Warehouse/Distribution, Grocery, Bars and Restaurants, Construction, Retail, Hotel, Office Settings, Personal Care and Service, Janitorial, Transportation and Other. Reason for investigation will be categorized as 'cluster' (report of at least 2 potentially associated cases among workers), 'outbreak' (report of 5 of more epidemiologically-linked cases), or 'other' (a single-case report or other report requiring public health response due to concerns of increased spread or noncompliance, after which a cluster or outbreak could was not definitively identified).

The Chicago Department of Public Health documents the identification source for all workplace investigations. Clusters and outbreaks identified by means other than direct report from businesses, CICT direct referral (single case escalation), review of CICT exposure data or complaints comprise an estimated 5% of all investigations through January 2022 and will be collapsed for the purposes of this analysis into an 'Other' category for identification source. The variable for identification source will have four values: Direct report, CICT, Complaint, and Other. Complaints also comprise a small proportion of all investigations (8%) but will be examined by industry sector over time, for insight into ability of public health prevention and surveillance measures to mitigate infection control concerns that would otherwise lead to complaints. Single case escalation and aggregation of interview data in SAS (described in Section 4) will be collapsed to quantify any identification through data obtained by CICT. This categorization helps interpret the impact of ending universal case investigation for COVID-19 as a public health practice, summarized in Section 4.5.

Region (Healthy Chicago Equity Zone) of workplaces investigated for COVID-19 clusters and outbreaks will be determined by zip code as follows, following conventions by CDPH. While HCEZ are defined by Community area as described in Section 1.6.2, CDPH maintains a crosswalk for estimating HCEZ by zip code, for ease of comparison with other geospatial data based on zip code, as follows:

- North Central – 60613,60614,60625,60626,60640,60645,60657,60659,60660, 60601,60602,60603,60604,60605,60606,60610,60611,60654,60661
- Northwest - 60618,60630,60631,60634,60639,60641,60646,60647,60656,60666,60707
- Southwest - 60609,60621,60629,60632,60636,60638,60652
- Near South - 60609,60621,60629,60632,60636,60638,60652
- Far South - 60617,60620,60628,60633,60643,60655,60827

COVID-related hospitalization will be defined using a binary variable in CDPH's COVID-19 dataset. This indicates hospitalization following COVID-19 diagnosis, aggregating data from self-report, provider entry into I-NEDSS, and inpatient syndromic surveillance data reported by IDPH. Hospitalization status is primarily hand-entered by providers when reporting cases to I-NEDSS. Additionally, IDPH sends CDPH weekly updates of any syndromic surveillance data from the CDC's BioSense platform that correspond to [I-NEDSS] State Case Numbers for COVID-19 cases among Chicagoans; data include inpatient encounters coded for COVID or COVID-like Illness (CLI). Syndromic surveillance data are limited to hospitalizations within 14 days following these diagnoses. Self-reported and provider-reports of hospitalization after illness are not bound to this timeframe (i.e., records can be updated if data are received > 14 days from diagnoses). If, after 7 days, a person with COVID-19 is not known to be hospitalized, their status is classified as 'not hospitalized'. Unrelated hospitalizations are excluded when details are known.

COVID-related death will also be defined using a binary variable in the Chicago cases dataset, based on the national Vital Records Criteria for reporting. From May 26, 2020, through August 31, 2021, probable and confirmed COVID-19 cases were considered COVID-related deaths given any of the following:

1. Death within 30 days of symptom onset, diagnosis, positive laboratory specimen collection OR during hospitalization, without another fully explanatory alternative cause of death unrelated to SARS-CoV-2 infection, (e.g., accident, homicide)
2. Clinical history consistent with COVID-19, without complete recovery (return to baseline health) after the COVID-19 diagnosis
3. Autopsy findings consistent with COVID-19
4. COVID-19 or SARS-CoV-2 or an equivalent term listed on death certificate as an immediate or underlying cause of death, or significant condition contributing to death.

On September 1, 2021, criteria were revised to include only: (1) COVID-19 or SARS-CoV-2 or an equivalent term listed on death certificate as an immediate, underlying, or significant condition contributing to death (2) other evidence from local health departments (e.g., clinical history, medical records, or autopsy findings) on a case-by-case basis.

Six time periods will be defined, for examination of trends in identification of new COVID-19 cases among NHNCW, overall and by industry/occupational sectors:

1. March through June 2, 2020 (before Chicago's "Phase 3" re-opening of offices, hotels, restaurants, non-essential retail, personal services, construction at limited capacity in Chicago)
2. June 3, 2020 through January 24, 2021 ("Phase 3" reopening, to the day before NHNCW first became eligible for vaccination)
3. January 25 through June 10, 2021 (date on which NHNCW ("1b") first became eligible for vaccination), through lifting of masking guidance (May 18) the day before "Phase 5" broad reopening in Chicago
4. June 11, 2021 through December 14, 2021 - date on which Chicago businesses entered Phase 5, until the estimated onset of the Omicron wave in Chicago
5. December 15, 2021 – through May 31, 2022 - beginning Of Chicago's Omicron wave, through end of universal case investigations/contact tracing in Chicago.

Masking and vaccination requirements for patrons (for example, in bars, restaurants, fitness centers) decrease exposure for employees among these settings. With the caveat that patron cases are not included in quantifications of outbreaks and clusters among NHNCW (to estimate simultaneous changes in burden among patrons or potential patron-to-employer transmission), comparing the frequency of outbreaks identified among employees in these settings before and after requirements were in effect (e.g., before and during masking guidance re-instatement during “Period 5” above (August 2021) may help approximate the impact of these changes in guidance. Additional periods will be defined as needed, based on changes in major guidance and pandemic inflection points.

From March 2020 through January 2022, 503 workplace-related clusters and outbreaks were identified among NHNCW. Given decline in case rates and pending end to universal CICT practices, the number of investigations initiated after this period is not expected to increase significantly. It is expected that the number of new investigations identified between February and May 2022 will be significantly lower than the number initiated during the same period in 2021.

Distribution of investigations classified as clusters or outbreaks through May 2022 will be compared, including by investigation type and identification source (direct report to CDPH, case investigation/contact tracing, other source). Results will be stratified by period, comparing distribution by identification source using Fisher’s exact test for difference in proportions. Distributions by industry sector will not be compared by period, as these are expected to be different, given City-level regulations on closure of non-essential businesses through June 2020. We will report the median number of associated cases with interquartile range, overall and stratified by period to examine changes in magnitude of investigations after changes in public health guidance. Finally, we will calculate and report hospitalization and mortality rates among laboratory-confirmed cases, overall and by period.

Aim 1A analyses are subject to misclassification bias related to categorization of cases as investigation-associated. When workplaces and interviewees do not disclose exposures and interactions among coworkers outside the workplace, cases are considered workplace-associated by default, a misclassification bias that could either over-estimate investigation size (number of associated cases, including potential erroneous classification of a cluster as an outbreak by CDPH conventions). Conversely, inclusion of only the earliest-known case among workers with contact outside work could underestimate the degree of workplace transmission. The proportion of employee cases who also share a household or other community exposure has not been uniformly collected over time, precluding a sensitivity analysis of differences in measured COVID-19 burden among workers when relaxing this assumption.

Not all workplaces provide an accurate estimate of total number of on-site employees especially in environments where the number of on-site employees varies due to telework. This precludes accurate analyses of COVID-19 attack rates among on-site workers by industry sector. Another limitation to investigation-based analyses of Aim 1A is that when businesses are contacted for investigation, they do not consistently report occupations of individual cases. This prevents description of the occupations disproportionately affected by outbreaks within industries, a need that has been identified in existing studies of COVID-19 among NHNCW. To help address this limitation, Aim 1B will include broad analyses of all NHNCW cases by occupation (in addition to industry), including by estimated level of associated workplace risk (defined by O*NET).

Chicago's methods for identification of clusters and outbreaks among NHNCW rely heavily on CICT and direct reports from businesses. If industry or occupation data were consistently included in laboratory results, analyses of interview completeness by industry or occupation be conducted among lab-confirmed cases, to measure under-representation among NHNCW in Chicago who are not interviewed. However, as described in Section 4, employment data are very rarely documented I-NEDSS, so this assessment cannot be conducted. As described in section 4.5, CDPH anticipates that the current practice of contacting all individuals with lab-confirmed COVID-19 will end in 2022, and that case-based surveillance will focus on older and other high-individuals, and settings such as congregate living and skilled nursing facilities. It is expected that fewer investigations will be identifiable through investigation and contact tracing of laboratory-confirmed cases. Though the timeframe for the end of routine case investigation is unknown, it is expected this change will occur before May 2022 and potentially require abbreviation of the study period for case and workplace-based investigations.

9.1.2 **1B. Characterizations of Non-Healthcare, Non-Congregate Workers with COVID-19**

Aim 1B is to characterize trends in individual and neighborhood-level demographics, hospitalizations, and deaths among NHNCW cases in Chicago overall, and compare by occupational sector and level of occupational risk. This aim will characterize cases associated with clusters and outbreaks among NHNCW investigated in 1A, by individual and neighborhood demographics. Data on additional (i.e., not cluster/outbreak-associated) cases reporting industry or occupation to CDPH during routine case interview will be incorporated into this analysis, to achieve overall and time-stratified comparisons of outbreak and non-outbreak-associated cases by demographics, outcomes and industry sector, and a broader characterization of all NHNCW with available occupation data by demographics, outcomes, level of occupational risk and occupational subgroup. Characterization of NHNCW cases by both industry and occupation over time will shed light on the potential impact of industry-specific public health guidance on COVID-19 among NHNCW over time, while examining burden by occupation and level of occupational risk to validate the O*NET framework for defining high-risk occupations. The first hypothesis of this aim is that cases classified as “essential” (1b/1c sector) have greater odds of being part of outbreaks than cases in “non-essential” (Group 2) industry sectors. The second hypothesis is that overall proportion of cases in ‘low risk’ occupations will increase over time.

Prior to October 2020, CDPH's case investigation and contact tracing (CICT) interview data were collected in REDCap; in October 2020, CDPH transitioned to a Salesforce-based platform. Because demographic and occupation-related fields are similar across platforms, data from both instances will be merged and included in these analyses to maximize sample size.

Sex will be included as a three-level categorical variable, as defined in CDPH's case datasets: sex is recorded as 'sex at birth' and superseded 'sex at onset' as reported in I-NEDSS, and categorized as: Male, Female or Other/Unknown. Age at time of positive test will be re-defined categorically (18-29, 30-39, 40-49, 59-59, 60-64), for comparability to existing COVID-19 surveillance data and vaccine recommendations by age group.

Race and ethnicity are derived from the values reported in I-NEDSS and will be analyzed as a composite variable for consistency with other analyses conducted by the City. CDPH categorizes any case reporting Hispanic ethnicity as Latinx. All cases not categorized as Latinx are categorized into one of 4 race-ethnicity categories, with missing or incomplete data resulting in assignment of 'Unknown' race-ethnicity: White, non-Latinx, Black, non-Latinx, Asian, non-Latinx, Other, non-Latinx (includes Native Hawaiian or Pacific Islander, Native American or Alaskan Native). In CICT interviews at CDPH, ethnicity is collected first (Hispanic, non-Hispanic, or Unknown) using the following question: "Do you identify as Hispanic, Latino or Latina? You may decline to answer". Race is collected second ("Which race do you identify as?") with 8 options: (Asian, including South Asian, Native Hawaiian or Pacific Islander, Black, including African American or Afro-Caribbean, Native American or Alaskan Native, White, Unknown, Other, and "I do not identify as any of these races"); interviewees may specify additional details, which are captured as free text. In these analyses, responses not corresponding to the 4 groups specified above, including after processing free-text details, are categorized as 'Other, non-Latinx'.

The CDPH-constructed composite variable of CCVI will be included to reduce unmeasured confounding of associations between workplace-related risk and COVID-19 among

NHNCW due to differential access to healthcare, income, other socioeconomic demographics and level of community COVID burden. Like HCEZ, CCVI was constructed based on city Community areas, as described in Section 1.6.1. However, CDPH also provides a publicly available crosswalk that incorporates weighted estimates of the community areas represented by zip code in Chicago, allowing estimation of CCVI by zip code (City of Chicago n.d.).

As also described in Section 1.6.1, CCVI has been presented by tercile (low, medium, high risk). However, when planning requires more precise definition of highest-vulnerability areas, the top quintile (15 highest CCVI) are defined as 'Very High' separately from the remaining 11 'High CCVI' areas. The remaining two-thirds (51) are described as 'Not High CCVI'. This dissertation will use the latter three-level categorization, since modeling the associations among high CCVI vs. other CCVI would yield more specific and actionable results. Furthermore, since these classifications are dependent on both community COVID burden and proportion of essential workers, very high CCVI areas are expected to have a disproportionate number of cases, despite comprising only a fifth of all community areas. This may help pre-empt any issues arising due to comparing data from very few zip codes to the remainder of the city. CDPH has designated these zip codes as very high and high CCVI:

- "Very High" CCVI: 60621, 60623, 60632, 60636, 60639
- "High" CCVI: 60609, 60617, 60620, 60628, 60629 ,60636, 60644, 60651

We will categorize all other zip codes as "not high CCVI" for purposes of this analysis.
HCEZ of cases will be determined by zip code, following methods for determining HCEZ of workplaces in Aim 1A.
This aim will include all the cases known to be associated with the investigations described in Aim 1a, classified by industry of their employer. Additional cases between ages 18-64 who are interviewed by CDPH March 2020 – May 2022 will be included, pending classification of any industry or occupations reported. Classifications will be determined using NIOCCS: all cases interviewed during this period will be extracted from REDCap and Salesforce with

corresponding industry and occupation data and submitted to NIOCCS for coding by industry and occupation. Those with data on industry will be categorized as in Aim 1a. Those with data on occupation will be categorized using major occupation (SOC) codes. Cases will be classified as cluster or outbreak-associated following the methods outlined in 1A.

Occupation-associated COVID-19 risk will be estimated for all cases reporting occupation, based on the SOEM released by CSTE in 2021 (CSTE Occupational Health Subcommittee 2021). In brief, occupations are classified as higher risk when scoring highest on two of three measures representing exposure to the public or other coworkers. Lower risk occupations are those in which workers are outdoors, not close to one another and not public facing, and medium risk are those in all remaining exposure classifications. Examples of high, medium and low-risk occupations are shown in Table VI.

The total number of outbreak-associated cases among NHNCW as identified during workplace investigations March 2020 through January 2022 is 1,706. The total number of interviewed cases with available occupation or industry data is expected to be a low proportion of all working-age cases over this period, as described in Section 4, but much larger than the number of outbreak-associated cases alone. For example, preliminary reviews and processing of case interview data suggest that approximately 3,000 interviewed cases reported industry or occupation between June and November 2021 alone.

TABLE VI. EXAMPLES OF OCCUPATIONS BY COMBINED EXPOSURE CATEGORIES

High		Medium		Low	
51-3023	Slaughterers and Meat Packers	45-2092	Farmworkers and Laborers, Crop, Nursery and Greenhouse	11-1011	Chief Executives
35-2011	Cooks, Fast Food	47-2031	Carpenters	11-3121	Human Resources Managers
33-2011	Firefighters	47-2111	Electricians	15-1131	Computer Programmers
33-3051	Police and Sheriff's Patrol Officers	41-9021	Real Estate Brokers	27-3043	Writers and Authors
35-3011	Bartenders	53-4041	Subway and Streetcar Operators	53-7021	Crane and Tower Operators

Code for power calculations for association between vaccine eligibility phase and likelihood of association to a known outbreak is included in Appendix A. The sample size estimations for these (unadjusted) models were generated using PROC POWER in SAS v9.4 with assumptions of 80% power, $\alpha = 0.05$, while varying both mean probabilities of association to a known outbreak and measures of association. The estimated distribution of NHNCW cases by vaccine eligibility phase was calculated based on the distribution of outbreak-associated cases only by vaccine eligibility phase as of January 2022 (data not shown): distributions of all working-age cases among NHNCW by vaccine eligibility phase are not available, a knowledge gap that this dissertation aims to address. Mean outcome probabilities were informed by preliminary analyses of all laboratory-confirmed cases in Chicago through mid-January 2022 (data not shown): approximately 4% of cases in I-NEDSS from March 16, 2020 through January 16, 2022 were identified as being associated with a known outbreak. This estimation includes cases of all age groups; given the high number of outbreaks reported among higher-risk, congregate settings such as schools and daycares, senior living and skilled nursing facilities, 4% is likely an overestimation of outbreak-associated cases among NHNCW alone. Given overrepresentation of 1b and 1c workers in large outbreaks early in the pandemic, the lowest specified test OR of 1.2 is expected to be lower than the OR observed in Aim 1B modeling results. Assuming 1 in 100 cases among NHNCW across groups is outbreak-associated, sample size estimates are n=2,591 for a test OR of 2.0 and n=402 for a OR of 5.0 (Table VII).

TABLE VII. SAMPLE SIZE ESTIMATIONS: MODELING OUTBREAK ASSOCIATION AMONG NON-HEALTHCARE, NON-CONGREGATE WORKERS WITH COVID-19

	Test OR		
Probability of Outbreak Association	**1.2**	**2.0**	**5.0**
1 in 20 (cases)	7,518	546	91
1 in 100	36,148	2,591	402
1 in 1,000	358.39	25,614	3,895

Demographic distributions of NHNCW workers with available industry data will be described overall and by known association to a workplace outbreak. Frequency of reported sex, age group, race/ethnicity, CCVI and HCEZ of residence will be reported. Distribution by major industry sector and vaccine eligibility phase (1b, 1c, 2) will also be reported. Statistical testing for differences between groups (e.g., Pearson chi-squared test) will not be used: groups are expected to be different over time, given changes in operations of essential and non-essential businesses and vaccine eligibility.

Logistic regression will model odds of being associated with an outbreak among all NHNCW cases reporting industry. A full model will include all variables described in Step 1, with industry sector categorized by vaccine eligibility (1b, 1c, 2) as the primary exposure, approximating workplace-related risk. This model will also include interaction terms to examine effect modification of workplace-related risk by race/ethnicity and socioeconomic risk factors for adverse health outcomes using CCVI and HCEZ. While this risk is better approximated using CCVI (as described previously), differences in associations by HCEZ may point to disparities in resources by region that can be targeted in cooperation with the lead public health collaborators designated by HCEZ as described in Section 1.6.2.

Because COVID-19 prevention and outreach initiatives differ by HCEZ in Chicago, it is plausible that the magnitude of association between HCEZ and outbreak status may vary significantly by HCEZ, and that the relative associations between other case characteristics and outbreak status would also differ across HCEZ. For example, if the Far South (but not North-Central) HCEZ had implemented widespread workplace safety programs to help prevent outbreaks among NHNCW, the effect of HCEZ on outbreak status among cases in Far South HCEZ could be greater in magnitude than the effects of other case demographics or industry sector. In contrast, HCEZ would not be as influential in predicting outbreak status among cases from North-Central, where other demographic characteristics could be more strongly associated with outbreak status. The Hausman specification test will be used to evaluate whether allowing parameter estimates to vary across HCEZ (including HCEZ as a random effect) results in a more efficient model than assuming the parameter estimates are the same across all levels of HCEZ (including HCEZ as a fixed effect). A small test statistic would suggest that the standard error when including HCEZ as a random effect is smaller than when including as a fixed effect, and that inclusion of HCEZ as a random effect improves model efficiency.

One counterargument to specifying HCEZ as a random effect is heterogeneity of CCVI, within individual HCEZ. Another is that all HCEZ are represented in the data, but not uniformly (see Table V); there is likely an uneven distribution of outbreak-associated workers by vaccine eligibility and demographics across HCEZ, which could lead to issues of small cell size in a demographically adjusted model. Because HCEZ were not defined until 2021, it is plausible that regionally specific COVID prevention initiatives would not differentially impact the effect estimates for vaccine eligibility phase or case demographics by HCEZ until later in the study period, if at all. These considerations also hold true for models of breakthrough infection (vaccination status) among NHNCW who contract COVID-19 (Aim 2), namely because significant vaccine outreach was conducted by CCVI (not HCEZ) early in 2021 (Section 1.8.3).

Backward elimination with likelihood ratio testing will be employed to select a best-fitting model of the association between industry sector and outbreak association, when adjusting for individual and neighborhood-level COVID-19 risk factors. Industry sector will be modeled using the collapsed 1b, 1c and 2 categories to (1) help adjust for vaccination status among workers and (2) mitigate issues with small cell size that may arise when restricting models by time period. Since these categories were designated during vaccine prioritization by estimated level of workplace-associated risk for COVID-19, use of the collapsed variable rather than modeling by more granular industry sectors also helps approximate occupational risk in absence of occupation data of associated cases. (Outbreak-associated cases will all have complete data on industry level based on characterization of their respective workplace, but the occupation of outbreak-associated cases is not consistently reported.)

Demographic distributions of NHNCW workers with available occupation data will be described overall and by level of occupational risk (low, medium, and high). Distributions of cases by reported sex, age group, race/ethnicity, and HCEZ /CCVI of residence will be characterized. Fisher's exact test will compare the distributions of cases by demographics across groups of low, medium and high occupational risk. Finally, distributions of all NHNCW cases with either industry or occupation data will be reported by sex, age group, race/ethnicity, HCEZ and CCVI in results stratified by time periods outlined in Aim 1a, corresponding to business opening and closures, vaccine availability and emergence of the Omicron variant.

A major limitation to Aim 1 is missingness of industry and/or occupation data among individuals with COVID-19 in Chicago. These is no data source describing all city-licensed businesses that fall into NHNCW sectors, against which the sample of businesses assessed in this and other aims could be compared, to assess the degree to which subgroups of NHNCW businesses are under-represented in this dissertation. ACS data do not provide mutually exclusive, demographically adjusted estimates of workers by occupational subgroups at the city level. Incidence rates by industry and occupational sector cannot be estimated, given a lack of 'denominator' estimates enumerating NHNCW subgroups stratified by age, race/ethnicity, and sex in Chicago.

The use of CCVI as a composite indicator of unmeasured neighborhood and individual-level risks for COVID-19 has some limitations. The first is that it assumes the socioeconomic indicators constructed using ACS and Healthy Chicago survey data have not changed appreciably since these data were collected in 2018-2019. Second is the assumption that relative COVID-19 burden by region has remained similar throughout pandemic, since incidence, morbidity and mortality estimates by region are based on data through December 2020. Protect Chicago subsequently prioritized these high-burden areas for mobile vaccination and other outreach based on CCVI, as described in Section 1, such that infection, hospitalization, and mortality rates due to COVID no longer have the same distribution.

9.1.3 **<u>1C. Descriptive Analyses of Workplace Safety Assessments for COVID-19</u>**

Aim 1C is to identify trends in workplace-implemented infection control practices, and opportunities to mitigate COVID-19 transmission among NHNCW by analyzing levels of reported compliance with OSHA's recommended hierarchy of COVID-19 controls. This analysis will summarize responses to workplace safety questionnaires issued by CDPH to NHNCW workplaces during investigations of COVID-10 cases among employees, April 2020 through May 2022. Characteristics of businesses (industry sector, business size, HCEZ, reason for investigation) will be described and compared with those of non-respondents to assess representativeness of the survey sample. Frequency of public health practices that have been mandated during the pandemic (paid sick leave, masking, vaccination) will be assessed overall, and in time periods before and after guidance changes, to examine differences due to instatement of masking mandates, vaccination requirements. These practices are listed and categorized in the next section. Frequency of these workplace controls will be examined by period, and stratified by industry sector, business size, reason for investigation, and HCEZ of reporting businesses, to identify trends in preventive practices, industry sectors with low rates of prevention practices, or findings characteristic of workplaces reporting outbreaks. In contrast to their use at the time of investigation (to inform intervention), assessment data can also be described in aggregate, for insight into the practices reported by businesses over time. This may help contextualize results from descriptive analyses of COVID-19 burden among NHNCW by industry sector over time as done in 1A and 1B.

This aim will analyze responses to workplace investigation and safety questionnaires, collected using REDCap during CDPH's investigations of COVID-19 among employees. The questionnaire is primarily self-completed by workplace points of contact, with subsequent evaluation by CDPH, but may also be completed by CDPH with workplaces via phone. Workplace representatives are often occupational health staff (public health nurses), corporate human resources personnel, or management personnel. Before creation of the REDCap project

(December 2020), these questionnaires were only issued to workplaces via phone interview with responses recorded on paper; inclusion of data from March through November 2020 will be contingent on access to hard-copy surveys, and legibility of documentation by infection control staff. This analysis will focus on quantification of practices that are specifically mandated in public health guidance at the city or state level due to evidence of preventing spread of COVID-19: sick leave for employees, mandated masking, and vaccination. Implementation of physical barriers/distancing will also be included, given potential for these controls to mitigate spread among workers (Section 1).

Industry type, vaccine eligibility group, workplace size, reason for investigation, and region (i.e., Healthy Chicago Equity Zone) of workplaces will be defined as described in Aim 1A. Workplace size is currently collected as a continuous variable (number of employees), but will be categorized as a three-level variable: (a) fewer than 100 employees, (b)100-500 employees, and (c) greater than 500 employees. This enables interpretation of results in the context of federal workplace vaccination mandates proposed in 2021 (among businesses of 100 employees or greater), as well as dissemination of actionable data to small business outreach organizations in Chicago, since Illinois defines “small businesses” as having 500 employees or fewer. Workplace-level COVID-19 controls will be defined dichotomously (Yes/No): (1) Do you require employees to be fully vaccinated? (Added May 28, 2021) (2) Do you check vaccination status of employees? (Added May 28, 2021) (3) Do you have a sick leave policy for ill workers? (4) Is work environment configured for 6 feet spacing? (5) Are physical barriers (e.g., partitions) used when 6 feet spacing is not possible? (6) Are masks provided to employees? Responses to the question about masking among workers will be dichotomized for analyses of mandated universal masking over all periods: Who do you require to wear masks in your facility [all workers regardless of vaccination status, unvaccinated workers, or neither]?

Trends will be interpreted according to public health guidance in effect at the time of survey. For example, between May 8 and August 19, 2021, masks were required only among un-vaccinated workers in NHNCW. Beginning August 20, 2021 and through the period of this report, masks have been required of all workers regardless of vaccination status.

As of February 25, 2022, 354 questionnaires have been completed. Though this aim plans to analyze any surveys administered through May 2022, the survey period may be truncated given falling case rates and ending of universal CICT (as described elsewhere), a primary method of identifying facilities in need of outreach. Characteristics of responding workplaces (industry sector, workplace size, reason for investigation, workplace region (by HCEZ), CCVI) and distribution by period of assessment will be reported. Characteristics of businesses who do not respond will also be summarized and compared to responding businesses to assess non-response bias. Pearson chi-squared tests will be used to compare distributions of responding and non-responding businesses. Frequency of reported COVID-19 prevention and control practices (vaccination requirements, sick leave policy, universal masking among employees, physical distancing and installation of physical barriers between workers) will be described overall and compared by industry sector and over time, and among businesses with versus without identified outbreaks.

As of January 2022, 354/439 (80%) workplaces investigated for COVID-19 clusters and outbreaks have completed assessments with CDPH's workplace unit. An estimated 57/354 assessments (16%) were completed prior to October 2020 on paper. Paper surveys with no legible responses will be excluded. Most of these were collected in Spring of 2020, so businesses interviewed during the first wave could be under-represented. Under the assumption that all facilities are issued an assessment at time of outreach, it's possible to assess the magnitude of non-response bias introduced by missing survey responses. These analyses are subject to selection bias, in that workplaces are chosen for assessment by CDPH based on reports or identification of potentially workplace-associated COVID-19 cases. This precludes ability to model or otherwise compare factors associated with workplace transmission among businesses who do and do not have identified cases among workers. Limitation to only cluster and outbreak-associated facilities also prevents use of the survey to identify businesses where workplace spread is occurring before cases are reported to the health department.

The workplace assessment questions are worded for consistency with OSHA's assessments for critical infrastructure workers. While this facilitates comparison with existing and future research about COVID-19 among NHNCW, the phrasing of questions poses some limitations. For example, the question asking about sick policy does not distinguish between quarantine and isolation policies, so issues related to inability of workers to take paid leave for either reason cannot be disentangled. Vaccination questions do not ask specifically about booster vaccinations among employees, a limitation that the survey of NHNCW businesses planned as part of Aim 3 will help address. Results are also subject to social desirability bias, in that workplaces may under-report non-compliance with recommended infection control measures and overstate enforcement of masking, distancing, and other infection-control practices.

The conditions and practices reported by businesses found to have workplace-associated cases or transmission may not be representative of conditions at the time of workplace-transmission among cases, particularly if (1) corrective action has been taken between time of transmission and time of survey in response to known cases or (2) businesses have been contacted multiple times by CDPH, due to detection of multiple clusters or outbreaks over the course of the pandemic; the survey is not re-issued. Temporality of infection control measures and workplace transmission cannot be measured to deduce causality. Longitudinal analyses of the impact of corrective actions on workplace transmission and incidence rates cannot be conducted.

Proportions of represented (union), contract or temporary employees on-site are not consistently reported in these questionnaires, though policies may not apply uniformly to these (versus non-represented and/or full-time) workers. For example, when paid leave is available to full-time workers but not contract or temporary workers, employees' ability to quarantine or isolate is over-estimated. This limits the ability to draw inferences about behaviors causing transmission in a workplace from the questionnaire data alone, among businesses with staff that are not full-time. The survey planned in Aim 3 to evaluate vaccination rates and encouragement will assess practices among contract, temporary or part-time staff to avoid similar limitations. Workplace size is defined as a three-level variable aim to maximize usefulness of findings. For example, examining COVID-19 burden among small businesses specifically (500 employees or fewer) can inform targeted COVID-19 prevention outreach in cooperation with Chicago's Department of Business Affairs and Consumer Protection (BACP), which has established a Small Business Center providing resources to these businesses.

At the time of this report, proposed federal vaccination mandates (for businesses with 100 employees or more) do not have sufficient legislative support to be enacted. Nonetheless, the planned analyses can help estimate potential impact of these public health policies. The same categories will be used to describe respondents to the Aim 3 survey of practices of employer encouragement for vaccination. However, they do not speak to workplace density, a key factor for spread of COVID-19 as defined in Section 1 of this report. This precludes stratification of data on workplace practices by environmental risk (e.g., comparing COVID-19 prevention strategies reported among high versus low-density workplaces), and limits the conclusions that can be drawn about behaviors contributing to spread among workplaces surveyed. Evaluation of patron-to-employee transmission is beyond the scope of this dissertation, other than inclusion in the CSTE conceptual framework for workplace risk (SOEM). Therefore, frequency of masking and vaccination policies for patrons will not be reported. The influence of these can be approximated by stratifying analyses to time periods before and after relevant changes in public health guidance.

Practices reported among businesses with multiple locations or completed by off-site personnel may not be fully representative of workplace environments of cases (e.g., when human resources, occupational health or other contacts are responding on behalf of employers and reporting typical or recommended practices). A lack of data to describe facilities who do not respond (other than industry, which can be determined by CDPH through case interviews, business websites and other sources) precludes further characterization of businesses who are under-represented due to non-response. The survey is only conducted in English, limiting CDPH's ability to conduct successful evaluation among minority and foreign-owned workplaces without English-speaking contacts. The Aim 3 survey to collect vaccination requirements and encouragement practices reported by workplaces will be translated into Spanish to help improve representativeness among NHNCW in Chicago.

9.2 Aim 2. Associations between COVID-19 Risk and Vaccination Status among Non-Healthcare, Non-Congregate Workers

Aim 2 is to explore associations between vaccination status and occupational risk among all NHNCW cases since the availability of vaccines for NHNCW in Chicago (January 2021 and later), including in logistic regression models restricted to pre- and post-Omicron periods. Since most reports of COVID-19 among NHNCW were published before availability of vaccine, breakthrough infections and disparities in vaccination among this population have not been comprehensively characterized. A lack of industry and occupation data collected at vaccination precludes general estimations of vaccination coverage by industry or occupation sector among NHNCW. Examining the vaccination status of cases by industry and occupation sectors over time, and factors associated with being unvaccinated at time of infection may help triangulate persisting coverage gaps among NHNCW subpopulations. Resulting data may help optimize vaccination outreach and messaging in Chicago, as further informed by analyses of reasons for vaccine hesitancy among NHNCW, outlined in Aim 3.

Analyses for this aim will combine the datasets utilized in Aim 1 (I-NEDSS case surveillance data with Salesforce interview data) with records of COVID-19 vaccinations administered among Chicagoans from the State immunization record (I-CARE). Chicago maintains a joint dataset combining COVID-19 case data and available COVID-19 vaccine administration data for all individuals with a lab-confirmed COVID-19 infection. The dataset of all NHNCW cases defined by industry or occupation in Aim 1B will be restricted to the period after which vaccines became available for 1b/1c workers citywide (January 2021 and later). Modeling analyses will be restricted to the time after which all industry groups were eligible for vaccination (June 2021 and later).

Demographics of cases (sex, age group, race/ethnicity, CCVI, HCEZ), and frequency of severe outcomes will be defined as in Aim 1. For the subset of cases with industry data, industry sector and vaccine eligibility phase will be categorized as described in Aim 1a. Similarly, for the subset of cases with occupation data, occupational sector and level of occupational risk will be categorized as described in Aim 1B. Definition of additional variables related to vaccination are described below. For this analysis, a breakthrough case is defined as a probable or confirmed case record in I-NEDSS, indicating onset or positive SARS-CoV-2 test at least 14 days after an individual's second dose of mRNA vaccine or first dose of J&J. Breakthrough cases will be categorized by brand of initial vaccine series received: Pfizer, Moderna, J&J or Other. Receipt of any booster doses of vaccine will be captured as a dichotomous variable for receipt or no receipt among those eligible, based on time since vaccination and original series received, aligned with current CDC guidance.

Months since full vaccination will be calculated for all NHNCW who are fully vaccinated at COVID-19 infection. This helps contextualize findings alongside available efficacy data (described in Section 1.8 of this report), and CDC's time-based recommendations for booster dosing, reported in months. Breakthrough cases with test dates through October 2021 will be considered part of the 'pre-Omicron' time period. Those occurring November 2021 and later will be considered part of the Omicron time period.

Seasonality has been observed among COVID-19 incidence data as illustrated in Section 1 of this report (Figures 1-4). Each of the pre- and post-Omicron models will be subset to compare data by season, and likely collapsed during modeling depending on distribution of data. Descriptive analysis of pre-Omicron data will be subset into two periods: June through August 2021, and September through December 14, 2021. This allows comparison of cases during the time of relaxed masking restrictions and lower community transmission to those during reinstated restrictions and Chicago's Fall surge, prior to Omicron predominance in Chicago. Descriptive analyses during the Omicron period will also be stratified into two periods: December 15, 2021 through January 2, 2022 (greater mobility and gathering through the holidays, Chicago's Omicron surge and before any vaccination requirements), and January 3, 2022 and later (Omicron predominance in Chicago, including an early period of mandated indoor vaccine requirement for some businesses). Variables for seasonality of cases (early and late) in each period may be included in models depending on the distribution of the data.

Preliminary calculations of sample size after exclusion of cases not classified as NHNCW yielded an estimated 3,000 working age cases (June through October 2021). The number of cases November 2021 and later is expected to be comparable or lower: despite the surge in overall cases during the Omicron wave, a small proportion have been interviewed due to lack of confirmatory testing; the study period will be truncated if routine case interviews end. The code from power calculations for association between level of occupational risk and likelihood of being unvaccinated at time of COVID infection are shown in Appendix A.

Sample size estimations for these models were generated using PROC POWER in SAS v9.4, with assumptions of 80% power and $\alpha = 0.05$, while varying mean probabilities of being unvaccinated and test odds ratios (Table IIX). The distribution of workers by occupational risk was estimated using the distribution of outbreak-associated cases by vaccine eligibility group as done in Aim 1B. The estimated mean outcome probabilities were based on preliminary analyses of case interview data from Salesforce (June 2021 through January 2022). Just under half (45%) of working-age cases interviewed June through September 2021 reported not having received any vaccine, a proportion that was much lower among cases interviewed between

December 2021 and January 2022 only (25%). The lowest specified (exploratory) probability of 1 in 100 being unvaccinated is likely an underestimation. Conversely, the highest specified test OR of 5.0 is expected to be higher than the OR observed in Aim 2 modeling results. Assuming 1 in 3 cases among workers across groups is unvaccinated, sample size estimates are n=119 for a test OR of 2.0 and n=52 for a test OR of 3.0.

TABLE VIII. SAMPLE SIZE ESTIMATIONS: MODELING VACCINATION STATUS AMONG NON-HEALTHCARE, NON-CONGREGATE WORKERS WITH COVID-19

	Test OR		
Probability of Being Unvaccinated	**1.2**	**2.0**	**3.0**
1 in 10 (cases)	3,957	291	117
1 in 3	1,585	119	52
2 in 3	1,512	106	45

Bivariate analyses will characterize all NHNCW cases from June 2021 through May 2022 by vaccination status (fully vaccinated versus not vaccinated). Distributions of demographics from pre- versus post-Omicron time periods (early and late as described above) will be compared by sex, age group, race/ethnicity, CCVI and HCEZ. For cases with available data on each: industry sector, vaccine eligibility phase, occupational sector and level of occupational risk will be characterized. Frequency of severe outcomes will be summarized for all cases. Breakthrough cases will be characterized overall, by the periods described above and by: initial vaccination (brand) received, frequency of booster receipt, and months since vaccination.

For cases occurring June through October 2021, logistic regression will model associations between level of occupational risk and vaccination status among NHNCW cases, with occupational risk (low, medium or high) as the primary exposure of interest, and vaccination status as the outcome. The model will include individual and neighborhood level covariates as in Aim 1 (sex, age group, race/ethnicity, HCEZ and CCVI) and interaction terms to assess for modification of the association between occupational risk and vaccination status by race/ethnicity, CCVI and HCEZ. As described in the Aim 1 methods (see 9.1.2), the Hausman specification test will be used to evaluate the efficiency of including HCEZ as a random versus fixed effect in these models. These modeling steps will be repeated among all cases occurring November 2021 and later, to compare results in pre- vs. post-Omicron phases.

For cases occurring through October 2021, logistic regression will be used to model associations between industry (vaccine eligibility phase) and being unvaccinated (versus fully-vaccinated) among NHNCW cases, with eligibility phase (1b, 1c, 2) as the primary exposure of interest, and being fully-vaccinated as the outcome. The model will include individual and neighborhood level covariates as in defined previously. These steps will be repeated among all cases occurring November 2021 and later, for comparison of results in Omicron and post-Omicron phase with those from pre-Omicron phase.

A major limitation to the breakthrough analyses described here is the lack of routine capture of occupational data in the state vaccination record. This precludes calculations of breakthrough infection rates among all vaccinated NHNCW and related modeling (e.g. time to breakthrough infection among all vaccinated NHNCW by level of occupational risk, rates of infection among vaccinated NHNCW compared to those among workers in other industry sectors (healthcare, congregate settings). The data source for vaccinations among NHNCW in Chicago also carries some limitations: I-CARE is not a comprehensive vaccination record, as it does not receive data from federal vaccine registries (e.g., Department of Veteran's Affairs). It also does not capture vaccinations administered out of state. As such, the proportion of cases who have received vaccination may be under-estimated through reliance on I-CARE alone.

Several sources of residual confounding remain despite planned adjustment by individual and neighborhood-level covariates. The underlying distribution of health status by occupational risk group may differ, including comorbidities associated with decreased immune response. If breakthrough infections occur earlier differentially in higher-risk occupation groups due to a greater prevalence of comorbidities, then the measures of association between occupational risk and vaccination status among NHNCW cases will be biased away from the null. Furthermore, these analyses cannot adjust for time-varying workplace characteristics and vaccination status among the colleagues of cases, both of which change level of occupational risk.

9.3 **Aim 3. COVID-19 Vaccination Requirement, Encouragement and Barriers among Non-Healthcare, Non-Congregate Workers in Chicago**

Aim 3 is to describe workplace-reported COVID-19 vaccination rates, requirements, and encouragement practices, and persisting vaccine hesitancy among NHNCW workers. Available data on employer-reported vaccine encouragement strategies and attitudes toward vaccination among NHNCW are primarily from surveys of large firms during periods of early vaccine availability (Spring 2021). Data generated as part of this aim will provide novel insights into practices implemented among both small and large businesses and persisting reasons for vaccine hesitancy through the Omicron surge in Chicago.

9.3.1 **3A. Survey of Non-Healthcare, Non-Congregate Workplaces in Chicago**

Aim 3A is to generate primary data by conducting a workplace-level survey of NHNCW businesses in Chicago through July 2022. We will report employee vaccination rates and frequency of recommended vaccine encouragement practices, stratified by industry sector, vaccine eligibility, business size (number of on-site employees) and HCEZ. There are two hypotheses for these analyses: (1) all types of encouragement strategies will be more frequently reported among larger businesses (>500 employees), especially if categorized as 1b/1c workplaces, and (2) fewer workplaces will report incentivizing or requiring boosters compared to initial vaccine series.

Industry types for prioritization will be informed by surveillance data from Aims 1 and 2. The NHNCW workplace unit will compile a list of businesses that have been contacted for COVID-19 surveillance and vaccine-related outreach, all of whom will be sent this survey:

- Workplaces who have reported COVID-19 cases directly to CDPH
- Other workplaces contacted by CDPH for completion of workplace assessments
- Workplaces that have completed the vaccine self-certification survey for CDPH 's Protect Chicago Plus campaign
- Workplaces that have been contacted by CDPH for mobile vaccination efforts during early-phase (1b/1c) vaccine rollout in Chicago

Additional channels may be utilized for broader recruitment, such as Chicago's Department of Business Affairs and Consumer Protection (BACP), the Illinois Restaurant Association (ILRA), and Illinois Unidos We will apply for exemption from review by the Institutional Review Boards (IRB) at CDPH and if necessary UIC, citing criteria for Category 2 exemption:

"Research that only includes interactions involving educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior (including visual or auditory recording)",

generating data that

"is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects".

The survey will be constructed and maintained within IDPH's REDCap instance, with content outlined below. The survey will also be translated into Spanish in cooperation with the Chicago Department of Public Health after receipt of IRB approval. An outline of the survey and coded responses is included in Appendix B. Industry sector ("Type of Business"), business address and zip code, and total number of employees will be collected from all respondents, for classification by vaccine eligibility (1b, 1c, 2), business size and HCEZ and defined as in Aim 1.

Percentage of workforce currently off-site or teleworking will be collected using categories defined in the City's outpatient case report forms: 0%, 1-25%, 26-50%, 51-75%, 76-99%, 100%. Number of contract or temporary employees will be collected as a continuous variable, for calculation of proportion of total number of employees that are contract or temporary workers. Primary languages spoken by employees will be collected in categories consistent with the workplace assessment summarized in Aim 1C: English, Spanish, or Other (with free text field). The number and proportion of businesses that report offering health insurance for full-time and/or other types of employees will be calculated, since health insurance facilitates access to vaccination.

Requirement and verification of vaccination will be evaluated for full-time and, separately, any other (contract, temporary or part-time) employees as applicable. In brief, the survey will ask if workplaces require employees to be vaccinated and, if so, how this is verified. The survey will include questions derived from CISA guidance for encouragement of vaccination among essential workers, and the Harvard Shift Project. Employer encouragement strategies will be evaluated in a checklist format, so that employers can specify strategies for (a) full vaccination and/or (b) boosting, and whether any incentives are also offered to any workers who are not full-time. The survey will assess frequency of the following: offering paid time off for vaccination or side effects, offering monetary or other incentive for vaccination, use of social media or other communication tools to promote vaccination, training for staff to serve as vaccine ambassadors, and townhalls or information sessions to promote vaccination among workers.

The survey will remain open through July 2022 and the response rate will be estimated using the proportion of directly contacted businesses who responded to the survey. Characteristics of all workplaces contacted will be summarized to compare the responding and non-responding workplaces and assess potential for non-response bias. Descriptive statistics will characterize frequency of reported encouragement strategies by business characteristics (industry sector, vaccine eligibility group, business size, proportion of on-site staff, proportion of contract/temporary staff and Healthy Chicago Equity Zone of the business). Mean vaccination rates will be reported by business characteristics listed in Step 3. Mean vaccination rates among businesses that do versus do not report each encouragement practice will be compared, for insight into any strategies differentially used by workplaces with higher vaccination rates. Thematic analyses of free-text responses of workplace-level vaccine encouragement practices, successes and potential barriers to implementation will be conducted. A deductive approach will be used, in that the “3C’s” model of factors associated with vaccine hesitancy (complacency, confidence and convenience), as described in Section 5, will be referenced for categorization of any barriers to vaccine encouragement and uptake among employees. Businesses who report willingness to participate in more detailed discussions of workplace-level vaccine encouragement practices, successes and potential barriers to implementation may be re-interviewed either individually or as part of an organized focus group, depending on the capacity of CDPH to conduct follow-up outreach.

These analyses have some limitations. Longitudinal data are not collected to analyze change in practices or changes in reported vaccination rates over time among NHNCW. Causal associations between employer encouragement practices and vaccination rates cannot be analyzed. The influence of community-based vaccination efforts on vaccination rates among employees cannot be determined. Findings indicating higher rates among businesses in specific HCEZ can inform further investigation into any hyperlocal vaccination efforts that may have led to increased vaccination rates in these areas and could be implemented to improve vaccination in areas with lower reported vaccination rates. It is possible that respondents may not have complete information on employer encouragement strategies practiced by their workplace, either due to time passed since promotion of vaccination or because they were not part of the workplace when strategies were implemented. Findings are subject to recall bias. At the time of this report, COVID-19 case rates are decreasing, and vaccine requirements for some businesses and patrons in Chicago may soon be lifted; there may be less incentive for businesses to participate or engage in efforts to improve vaccination among employees than in previous phases of the pandemic.

9.3.2 **3B. Analyses of Individual-level Vaccine Hesitancy Data from Non-Healthcare, Non-Congregate Workers**

Aim 3B summarizes reasons for vaccine hesitancy among unvaccinated NHNCW interviewed by CDPH from June 2021 through May 2022. Report frequency distributions of reasons for not initiating vaccination among NHNCW, including by vaccine eligibility phase, race/ethnicity, sex, and age group of interviewed NHNCW. For this sub-aim we hypothesize that among NHNCW interviewed, frequency of not being vaccinated will be higher among Phase 2 (‘non-essential) workers than 1b/1c workers in Chicago and that, like findings among all Chicagoans as described in Section 7.1, safety will be the predominant reason for not initiating vaccination among NHNCW. This sub-aim will analyze Salesforce records from all cases and contacts ages 18-64 who have completed interviews with CDPH in Chicago CARES from June 2021 through May 2022 and reported industry or occupation data classifying them as NHNCW according to the NIOCCS classification process described in Aim 1B. Vaccination details are gathered as described in Section 7.1; interviewees without complete vaccination details will be excluded.

Reported vaccination status for each interviewee will be calculated based on the number, dates and brands of vaccine doses reported. Following CDC guidance at the time of this report, full vaccination is defined as receipt of two two-dose COVID-19 vaccines or at least 1 dose of J&J vaccine at least 14 days prior to date of interview. This includes individuals who have received two-dose vaccines other than Pfizer or Moderna as recognized by the CDC’s vaccination requirement for entry into the United States. Among individuals who initially received Pfizer or Moderna vaccines, those who report receipt of more than two doses of vaccine will be categorized as ‘boosted’. Among J&J recipients, those who report more than 1 dose of vaccine will be categorized as boosted. Individuals who report receipt of any vaccine but do not meet criteria for full vaccination will be categorized as partially vaccinated. As described in Section 7.1, individuals who report not having received any vaccine are asked about their primary reason for not having initiated vaccination and provided with the following options, and opportunity to specify another reason. Pre-specified categories and free-text responses will be categorized based on the “3C’s” model for hesitancy referenced in Section 5, with examples in Table IX at the end of this chapter.

Between January 2 and February 5, 2022, 803 cases and contacts of working age who were not vaccinated reported their reasons for not having received any vaccine. Data from June 2021 onwards will be analyzed for this aim. An estimated 10, 983 working-age cases and contacts reported not having received any vaccine between June 2021 and March 4, 2022 in Chicago CARES. The sample size for this aim is expected to be lower given that a small proportion of these will report industry or occupation data to be classified as NHNCW, as described in discussions of limitations to workplace-based surveillance and reliance on CICT data.

Frequency of reported vaccination status among NHNCW will be summarized by month and record type (case versus contact) from June 2021 through May 2022. Reported reasons for not initiating vaccination will be re-categorized consistent with Table IX. Individuals who cite multiple reasons in free-text with any mention that they are now planning to be vaccinated are classified as “planning to be vaccinated”. Those who are still considering or want to wait are classified as ‘unsure’. This decision was meant to distinguish these populations from those who still need outreach and encouragement due to persisting hesitancy. Coding efficacy separately from safety, as ‘other mistrust, skepticism or anxiety’, helps distinguish between portions of the population who may benefit from education and messaging about vaccines working to prevent severe illness, including during Omicron, or vaccines being safe despite potential side effects. This also enables comparison of vaccine skepticism before and after emergence of the Omicron variant. As the proportion of individuals who offer ‘Other’ reasons for not initiating vaccination is relatively low (e.g., 125/803 or 16% between 1/5 – 2/5/22), decisions regarding classification of these individuals have only a small impact on findings. However, some coding decisions that are expected to affect significant proportions of re-coded responses are described in the Limitations section. Distribution of reasons for not being vaccinated will be summarized overall (among cases and contacts combined), by industry sector and vaccine eligibility phase, time period (pre- and post-Omicron, or June 2021 through November versus November 2021 and later) and case demographics (age group, race/ethnicity group, CCVI, HCEZ). Given that only 5,006 of 10,521 working-age cases interviewed between June and November 2021 (48%) provided any data on industry or occupation, restricting hesitancy data only to interviewees who can be classified as NHNCW will further decrease a sample that is already limited by the non-response to interview or disclosure of vaccination details. However, inclusion of interview data from both cases and contacts will offer some improvement in sample size over analyses of data from cases alone.

As 21% of recently completed interviews were missing data on vaccination status (see: Section 7.2), non-response and missing data pose the greatest limitations to drawing inferences from these data. Additionally, interviewees can only choose one primary reason for not vaccinating. As most interviewees who provide data on vaccine hesitancy specify a pre-selected option during interview (e.g., 673/803 or 84% of interviewees summarized in this section), examination of free-text responses only provides a small amount of additional insight. The large proportion of respondents who do not want to specify a reason for not vaccinating (48% in the past month of interview data) further limits the ability to recommend strategies for addressing low vaccination rates based on analyses of vaccine hesitancy alone. Surveying employers about their vaccination requirements and encouragement strategies may help address these limitations, by identifying workplace-level motivators that are common among workplaces reporting high rates of vaccination, or barriers to implementation that can be addressed.

Because questions about vaccine hesitancy were not captured until broad vaccine availability (June 2021), earlier attitudes about vaccine hesitancy among unvaccinated NHNCW working in 1b1/c industry sectors will not be represented. Distribution of interviewees by reported vaccination status is not representative of the overall vaccination status of Chicagoans, though interview data will be compared to existing data on citywide coverage among adults during interpretation. Reported vaccination status will not be confirmed using I-CARE.

Some individuals report that their ‘Other’ reason for not being vaccinated is that they already have or had COVID-19. These are grouped with the existing, pre-defined category of ‘already had COVID-19” in absence of other details, originally offered to capture those who feel they are not at risk due to naturally acquired immunity. This category is ambiguous, especially during interviews of cases. This category could represent not vaccinating due to other reasons including perceived immunity, or planning to be vaccinated, despite being in isolation. Related misclassification bias impacted a small proportion (2%) of all interviews conducted from in January of 2022 (See: Section 7.2).

Despite these limitations, these analyses will help address a lack of data on factors of vaccine hesitancy among NHNCW in Chicago. Surveys of businesses will provide insight into how vaccination is being enforced and encouraged among NHNCW by industry and, potentially, barriers to vaccination t that can be addressed. Any trends observed by geography could also be of value to small business outreach organizations that provide cross-sector outreach to NHNCW in specific city regions that have been disproportionately impacted by the COVID-19 pandemic.

TABLE IX. PLANNED CATEGORIZATION OF VACCINE HESITANCY DATA

Theme	**Collapsed and pre-specified categories**	Example of other free-text reasons and **pre-specified categories** to be collapsed
Confidence	• **Safety** • Medical condition **or** Provider advice	• Too many side effects • I have had bad reactions to vaccines • I am undergoing chemotherapy • **Provider advice** • **Medical contraindication**
	• **Other mistrust, skepticism, or anxiety**	• Vaccine doesn't work • Vaccine was developed too quickly • Don't trust the government • Don't trust traditional medicine • **Philosophical objections** • **Religious objections**
Convenience	• **Busy or have not made time**	• I am working long hours
	• Access	• Could not use online scheduling • Vaccines are far from my house • **Cost** • **Transportation** • **Need for Identification** • **Could not find an appointment**
Complacency	• **I don't feel the vaccine is necessary for me**	• I don't get sick very often • I never leave the house • COVID-19 won't make me very sick
	• **Already had COVID-19**	• I was going to be vaccinated but then I got COVID

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10. **AIM 1 FINDINGS: COVID-19 CLUSTERS AND OUTBREAKS AMONG NON-HEALTHCARE, NON-CONGREGATE WORKERS IN CHICAGO**

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10.1 **Introduction**

The COVID-19 pandemic took a disproportionate toll on essential workers (Dyal 2020; Waltenburg et al. 2021), supporting national recommendations for vaccine prioritization by industry (Dooling 2021). Despite establishment of work environment as a key determinant of COVID-19 risk, occupation, industrial sector, and employer information are not required to be collected during case reporting and interviewing (Centers for Disease Control and Prevention 2020a). Successful strategies for workplace surveillance for COVID-19 have not been widely documented. This is especially true for workers in non-healthcare, non-congregate workplaces (NHNCW). Those in healthcare and congregate settings (e.g., long-term care facilities, educational and childcare settings, shelters, and correctional facilities) have more frequently implemented measures such as screening, testing, point prevalence sampling and routine reporting to counteract increased risks of transmission and severe outcomes among individuals in these environments (Illinois Department of Public Health n.d.; Centers for Disease Control and Prevention n.d.; Illinois Department of Public Health 2021; Centers for Disease Control and Prevention 2020b).

Chicago followed national prioritization strategies for COVID-19 vaccination, beginning distribution to the earliest “1a” group (long-term care and residential healthcare facilities, healthcare workers) on December 15, 2020 (City of Chicago n.d.). On January 24, 2021, “1b” Chicagoans became eligible (those age 65 and older, those in non-healthcare residential settings, and frontline essential workers). On March 29, 2021, working-age Chicagoans with other essential occupations or underlying medical conditions became eligible (as group “1c”) and all other working-age residents became eligible on April 19, 2021 (group “2”). Also in March 2021, the Chicago Department of Public Health (CDPH) began mobile outreach dedicated to vaccination of employees at non-healthcare essential businesses that had experienced the greatest proportions of workplace-associated outbreaks. These included sectors related to the food supply chain (such as agriculture and food processing) and general manufacturing, warehousing, and distribution of goods. To-date, COVID-19 surveillance reports about NHNCW have largely been limited to pre-vaccination phases of the pandemic. As Omicron variants of SARS-CoV-2 have proven their potential to escape both natural and vaccine-induced immunity (Andrews et al. 2022), the persisting burden of COVID-19 among workers by vaccination status bears investigation.

This report aims to address knowledge gaps related to (1) the utility of different surveillance practices for identifying COVID-19 clusters and outbreaks among NHNCW over time, and (2) the number, size and distribution of workplace clusters and outbreaks among NHNCW in Chicago, including through vaccine availability and the first Omicron surge (ending in early 2022). Such findings can inform the planning of effective public health surveillance systems, immunization and intervention strategies to protect workers at increased risk of occupational exposure to disease-causing agents.

10.2 Methods

10.2.1 Surveillance of COVID-19 Cases, Clusters, and Outbreaks among Non-Healthcare, Non-Congregate Workers

Since March 2020, COVID-19 cases in Chicago have been reported to CDPH through electronic laboratory reporting (ELR) feeds or manual entry into the Illinois National Electronic Disease Surveillance System (I-NEDSS). Through May 2022, CDPH conducted universal case investigation and contact tracing (CICT), calling all Chicago residents identified as being in close contact with or having probable or laboratory-confirmed cases of COVID-19 reported in I-NEDSS (Centers for Disease Control and Prevention 2021b). (This practice was ended following the Council of State and Territorial Epidemiologists (CSTE) recommendations to prioritize outreach to the highest-risk populations (Council for State and Territorial Epidemiologists 2022)). Interviews included a standardized questionnaire collecting occupation, employer name and address, and dates of symptom onset, positive COVID-19 test, and last on-site work. These interview data were used to help identify workplace-related cases in two ways. First, starting in June of 2020, case investigators were instructed to notify CDPH’s dedicated "workplace response unit" when an interviewee reported significant workplace spread or employer non-compliance with infection prevention guidance. Second, in July of 2020, CDPH began supplementing this “single-case escalation” with review of all CICT data to improve identification of employee exposures. For all interviewees aged 16-64 years not reporting healthcare or congregate workplaces, onset and test dates were compared with last dates worked on-site to identify employees who may have worked during their estimated infectious periods (2 days before through 10 days after the earlier of onset or positive test); employer name and address data were analyzed to identify workplaces with multiple cases. Case interviewees mentioning being exposed or potentially exposing others at the same work location in any 14-day period were identified for evaluation as a cluster or potential outbreak of COVID-19 cases.

At the time of this report, COVID-19 outbreaks among NHNCW in Chicago were defined by the Illinois Department of Public Health (IDPH) as “five or more epidemiologically-linked cases within 14 days at a common worksite” (Illinois Department of Public Health n.d.). Clusters were defined following the CDC definition, as “a number of cases that is greater than expected” in one 14-day period (CDC 2020b) with no known close contact outside the workplace. Clusters could consist of as few as 2-4 epidemiologically linked cases, or more when an epidemiologic link could not be confirmed. To investigate potential outbreaks or clusters, CDPH’s workplace response unit called work locations to request individual-level data on recent employee cases, including known epidemiological links (work locations, shifts, carpooling, shared households). Details of current COVID-19 mitigation measures and controls put forth by the Occupational Safety and Health Administration (OSHA) were also requested (Occupational Safety and Health Administration 2021). Investigations meeting outbreak criteria were reported to IDPH through the State-maintained Outbreak Reporting System (ORS). All investigations remained open until at least 28 days (2 incubation periods) elapsed since the first day of illness for the last known associated case.

Chicago also maintained a call center, e-mail address, and public-facing survey (via REDCap (Harris et al. 2009; 2019) to facilitate reporting of COVID-19 cases, including "direct reports” by businesses, in compliance with Chicago’s Public Health Order 2020-2: in October 2020, the City of Chicago mandated that non-healthcare businesses self-report when (1) operations were modified due to COVID-19 among employees, or (2) businesses became aware of 5 or more cases within any 14-day period among employees or patrons (City of Chicago 2023). Employees and other members of the public could use the same channels to report concerns about businesses’ non-compliance with COVID-19 infection prevention and control measures; these types of notifications are referred to as “public concerns” throughout this report. Aside from CICT methods, direct reporting and public concerns, a comparatively small proportion of workplace investigations for COVID-19 were initiated by referrals from other

City departments or jurisdictions, healthcare providers, news, and social media, collectively referred to as “other sources” in this analysis.

10.2.2 **Inclusion and Exclusion Criteria**

This report describes clusters and outbreaks identified by CDPH’s workplace response unit from March 2020 through May 2022. Healthcare, congregate settings (schools, residential senior/youth/behavioral facilities, homeless shelters, corrections, and protective service workers), and government workplaces were excluded, due to differences in COVID-19 surveillance, reporting requirements, and response in Chicago. All analyses were conducted using SAS v9.4.

10.2.3 **Classifications of Clusters and Outbreaks**

Clusters and outbreaks among NHNCW were classified by workplace industry in alignment with IDPH’s outbreak reporting conventions and collapsed further by vaccine eligibility phase as early frontline essential (“1b”) or other eligibility. While essential workers not included in 1b may have been vaccinated in the “1c” phase that preceded broad “Phase 2” eligibility in Chicago, 1c and 2 workers are grouped together for the purposes of this report: in Chicago, most of these populations were vaccinated in a similar time period (May – June 2021) (City of Chicago n.d.), later than most mobile outreach and other efforts targeting 1b workers (March and April 2021). Thirteen industry sector classifications were used for this analysis, including four 1b groups (Food Production and Processing, Manufacturing, Warehouse/Distribution, Grocery) and nine others (Bars and Restaurants, Construction, Retail, Hotel, Office Settings, Personal Care and Service, Janitorial, Transportation and Other). Due to sparsity and aligned with approaches used in other jurisdictions, other categories were collapsed for industries with small numbers of investigations (Bonwitt 2021; Silver et al. 2020). Finally, all investigations were categorized by method of identification (CICT, direct report from the workplace, public concern, or other sources).

10.2.4 **Descriptive Analyses of Workplace COVID-19 Clusters and Outbreaks**

The frequency distribution of investigations classified as clusters or outbreaks was reported by industry, vaccine eligibility phase, city region and identification method, overall and by period of investigation. Five time periods were defined, aligned with Chicago's non-essential business shutdown under the "Restore Illinois" plan, and industry-based vaccine eligibility timelines (City of Chicago n.d.)

1. Shutdown, March through June 2, 2020: Shutdown of non-essential businesses, and "Stay at Home" Executive Order issued in Phases 1 and 2 of "Restore Illinois".
2. Partial re-opening and pre-vaccine, June 3, 2020 through January 24, 2021: re-opening of offices, hotels, restaurants, non-essential retail, personal services, construction at limited capacity ("Phase 3") until the day before frontline essential workers first became vaccine-eligible

3. Partial re-opening, with vaccine rollout, January 25 through June 10, 2021: vaccine eligibility begins for frontline essential workers, other essential workers (March 29), and all working-age adults (April 19), until the day before non-essential businesses could re-open at full capacity

4. Full re-opening and pre-Omicron, June 11 through December 14, 2021: Full capacity ("Phase 5") re-opening of non-essential businesses, until the onset of the Omicron wave

5. Omicron, December 15, 2021 through May 31, 2022: beginning of Chicago's Omicron wave, until the end of universal CICT.

Median numbers (with interquartile range) of cases included in (1) clusters and (2) outbreaks were calculated overall and by period. Frequencies and distributions of clusters, outbreaks, and all investigation-associated cases by status (laboratory-confirmed versus suspected) were reported overall and by period for insight into trends in testing and reporting among NHNCW. Frequencies and distributions of investigations by cluster/outbreak status, workplace type, region and time period were reported overall and by identification method.

10.2.5 **Descriptive Analyses of Cases Associated with Clusters and Outbreaks**

Demographic data for all laboratory-confirmed cases among Chicago residents were derived from I-NEDSS and reported overall and by period. Cases reported as having any Hispanic or Latino ethnicity were classified as Latinx. Those not reporting any Hispanic or Latino ethnicity were classified as: Black non-Latinx, White non-Latinx, Asian non-Latinx, Other (including more than one race), or Unknown race-ethnicity. Cases were also described by sex at birth (male/female), by age group (18-29, 30-39, 40-49, 50-65), and by city region of residence as determined by zip code (North Central, Northwest, Southwest, Near South, Far South). Hospitalization and COVID-related mortality among all cases, also determined from the city's I-NEDSS extract, were reported overall and by period. Vaccination status at illness was determined from the Illinois Comprehensive Automated Immunization Registry Exchange (I-CARE) via a CDPH-maintained dataset that matches individuals' COVID-19 case data to their immunization history on file with the State. Laboratory-confirmed cases among NHNCW working in but living outside Chicago were included in investigation-level analyses but excluded from case-level analyses; their records are not included in the demographic and outcomes datasets extracted from I-NEDSS and maintained at CDPH.

10.3 **Results**

10.3.1 **Characteristics of COVID-19 Investigations**

From April 2020 through January 2022, 496 COVID-19 investigations among NHNCW businesses identified 444 clusters (89% of all investigations) and 54 outbreaks (11%) as shown in Table X. None were identified February – May 2022. The sizes of outbreaks decreased from a median of 21 associated cases (IQR 8 - 36) during the 2020 shutdown, to 11 cases in the one outbreak identified during the 2021 Omicron wave. Conversely, clusters increased from a median of 3 cases (IQR 2-11) during the shutdown, to 5 (IQR 3 - 6) during Omicron. During the shutdown, most investigations were outbreaks (69%), and among frontline essential industries such as food production and processing (47%) and manufacturing (25%) (Figures 24 and 25). These and other “1b” industries made up over 78% of all investigations conducted, the remainder (22%) among other essential businesses. Most investigations were among workplaces in Southwest (44%) or Northwest (28%) city regions (Figure 26) and were initiated by direct report from the workplace (31%) or public concern (41%) (Figure 27).

In the second time period (partial re-opening, pre-vaccine), the number of workplace investigations increased dramatically (to 213 from 32 in the previous period), driven by a nearly twenty-fold increase in the number of clusters identified. Bars and restaurants (20%), office settings (16%) and retail (13%) became the most frequently investigated. Distribution by region changed substantially, with most investigations among workplaces in the North-Central neighborhoods of Chicago (43%). This period also marked a shift to the use of CICT data to identify issues of workplace spread (51% of investigations) and a decrease in the number of investigations initiated by a public concern (9%). In the third time period (during vaccine rollout, before full re-opening), the overall number of investigations and number of outbreaks among NHNCW began to decrease. Interview data became the primary means of identification of clusters and outbreaks (81% of all investigations in January through June of 2021).

TABLE X. CHARACTERISTICS OF COVID-19 CLUSTERS AND OUTBREAKS IDENTIFIED AMONG NON-HEALTHCARE, NON-CONGREGATE WORKERS IN CHICAGO, MARCH 2020 – JANUARY 2022 (N=496)

	Full study period (N=496)[a]	Non-essential business closure, "Stay at Home" (n=32)	Partial re-opening, pre-vaccine (n=213)	Partial re-opening, vaccine rollout (n=118)	Full re-opening, pre-Omicron (n=74)	Omicron phase[a] (n=59)
	3/11/20-1/31/22	3/11/20 – 6/3/20	6/4/20 – 1/23/21	1/24/21 – 6/10/21	6/11/21 – 12/14/21	12/15/21 – 1/31/22[a]
Investigation Type (n, %)						
Outbreak[b]	54 (10.9)	22 (68.8)	19 (8.9)	7 (5.9)	5 (6.8)	1(1.7)
Cluster	442 (89.1)	10 (31.3)	194 (91.1)	111(94.1)	69 (93.2)	58 (98.3)
Lab-confirmed cases (n, %)						
All investigations	1,698 (67.1)	481 (66.4)	749 (83.3)	281 (80.1)	142 (53.4)	45 (15.6)
Outbreaks only	776 (76.3)	459 (70.6)	209 (96.3)	60 (78.9)	43 (68.3)	5 (45.5)
Clusters only	922 (61.0)	22 (29.7)	540 (79.2)	221 (80.4)	99 (48.8)	40 (14.4)
Outbreak Sizes (Median, IQR)						
Total cases	11.5 (6, 20)	21.5 (8,36)	8 (5,16)	9 (6,14)	15 (7,17)	11 (11,11)
Lab-confirmed	9.5 (5,16)	14 (6, 31)	8 (5, 16)	8 (5, 14)	7 (5, 13)	5 (5, 5)
Cluster Sizes (Median, IQR)						
Total cases	2 (2, 4)	3 (2, 11)	2 (2, 4)	2 (2, 3)	2 (2, 3)	5 (3, 6)
Lab-confirmed	2 (1, 2)	2 (0, 2)	2 (2, 3)	2 (2, 2)	1 (1, 2)	0 (0, 1)
Frontline Essential Workplaces (n, %)	125 (25.2)	25 (78.1)	62 (29.1)	26 (22)	8 (10.8)	4 (6.8)
Identification Source (n, %)						
CICT data	250 (50.4)	1 (3.1)	108 (50.7)	95 (80.5)	40 (54.1)	6 (10.2)
Direct report	164 (33.1)	10 (31.3)	77 (36.2)	12 (10.2)	21 (28.4)	44 (74.6)
Public concern	43 (8.7)	13 (40.6)	18 (8.5)	6 (5.1)	5 (6.8)	1 (1.7)
Other	39 (7.9)	8 (25)	10 (4.7)	5 (4.2)	8 (10.8)	8 (13.6)

[a]*No investigations were identified from February through May 2022.*

[b]*Outbreaks are defined by the Illinois Department of Public Health (IDPH) as "five or more epidemiologically-linked cases within 14 days at a common worksite and no other known close contact outside the workplace". Clusters are defined as "a number of cases that is greater than expected" in one 14-day period within the workplace and no other known close contact outside the workplace; clusters can consist of as few as 2 cases.*

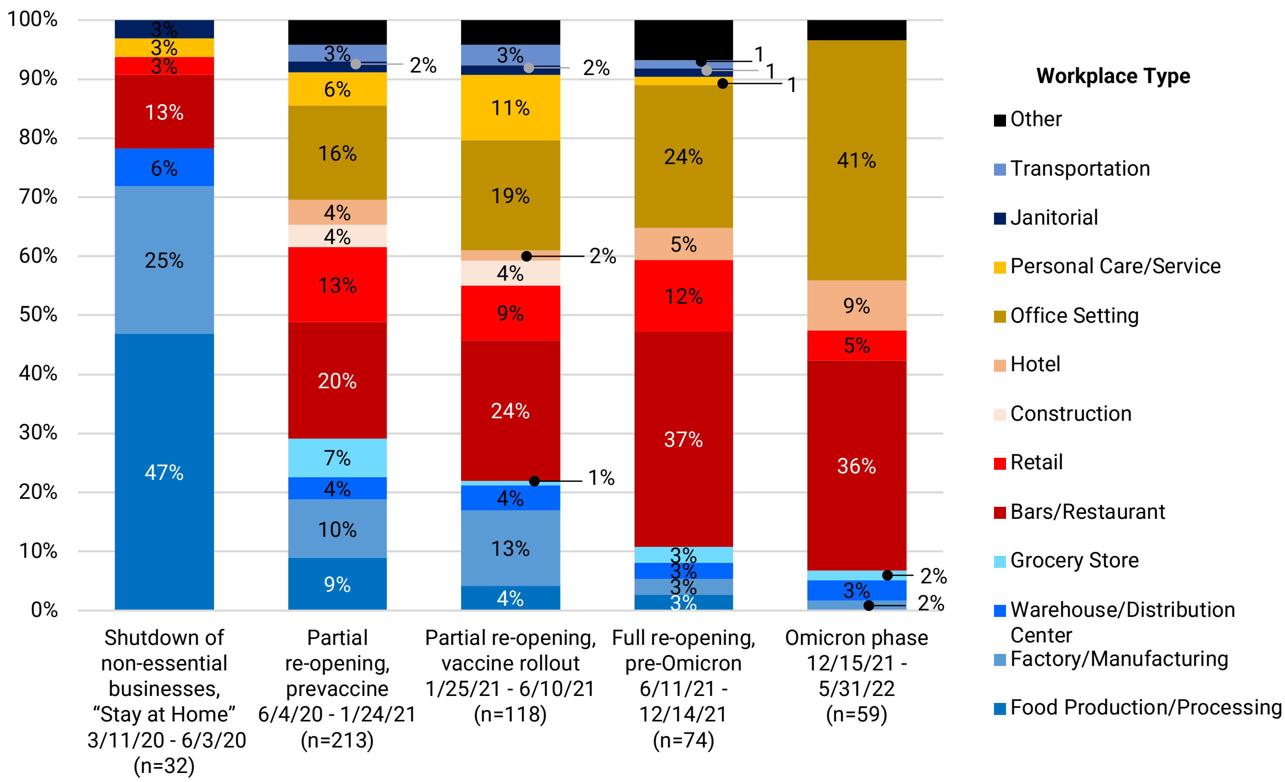


Figure 24. Distribution of COVID-19 clusters and outbreaks among non-healthcare, non-congregate workers in Chicago, April 2020 to January 2022 by period of identification and workplace type

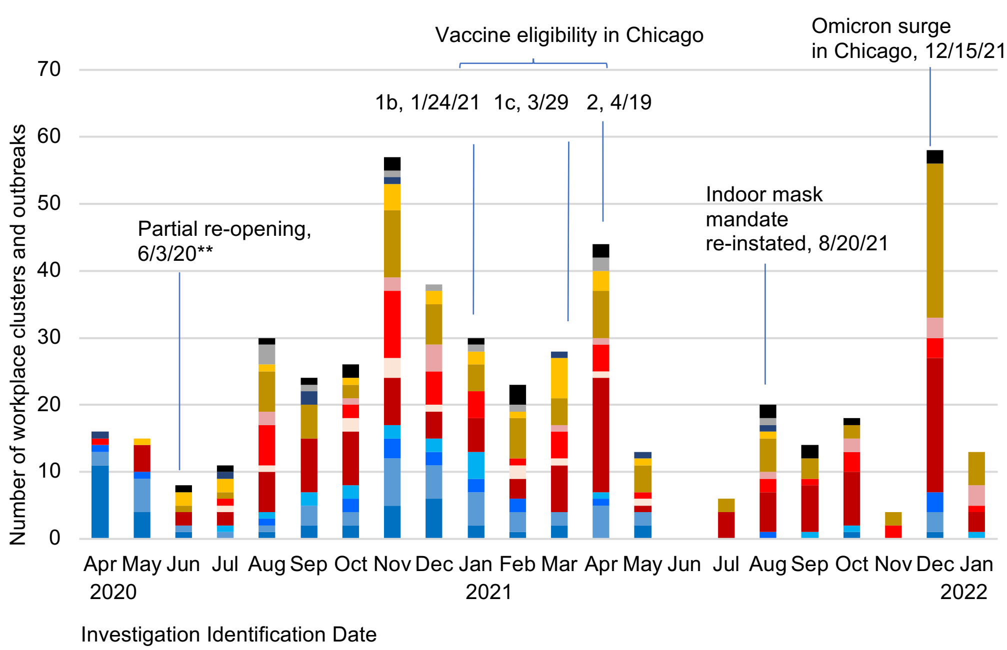


Figure 25. Clusters and outbreaks among non-healthcare, non-congregate workers in Chicago, April 2020–January 2022, by workplace type (N = 496)

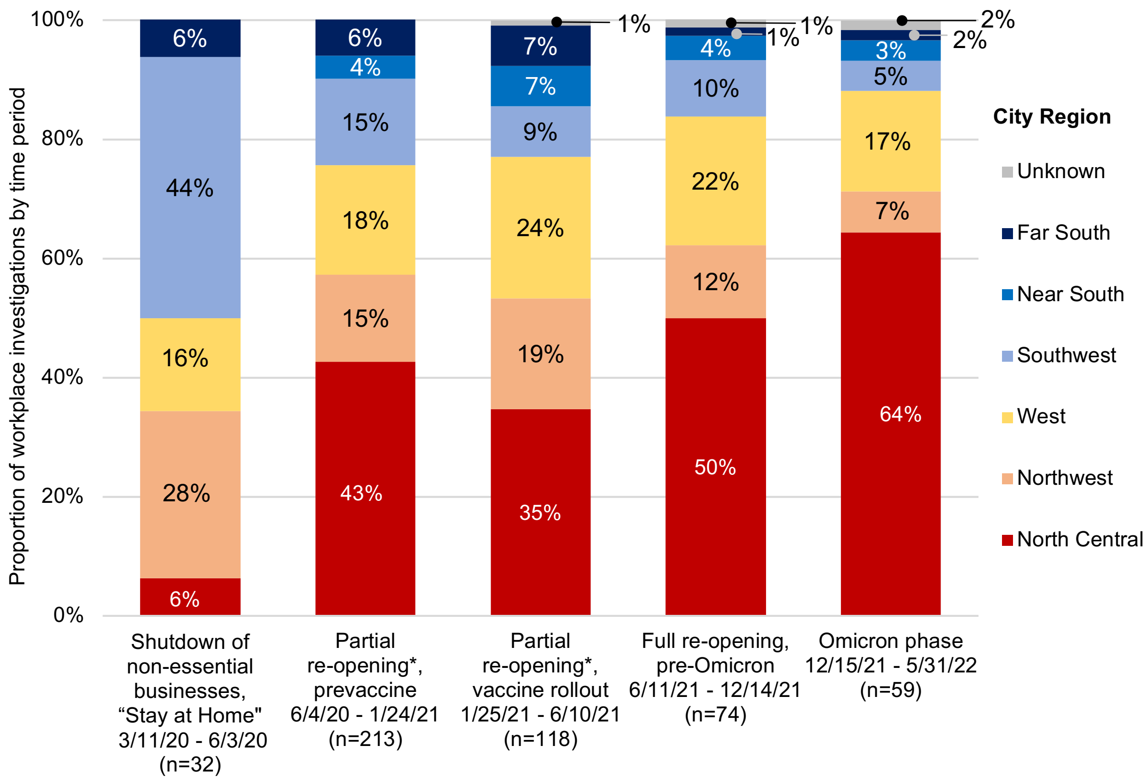


Figure 26. Distribution of COVID-19 clusters and outbreaks among non-healthcare, non-congregate workers in Chicago, April 2020 to January 2022 by period of identification and city region (N = 496)

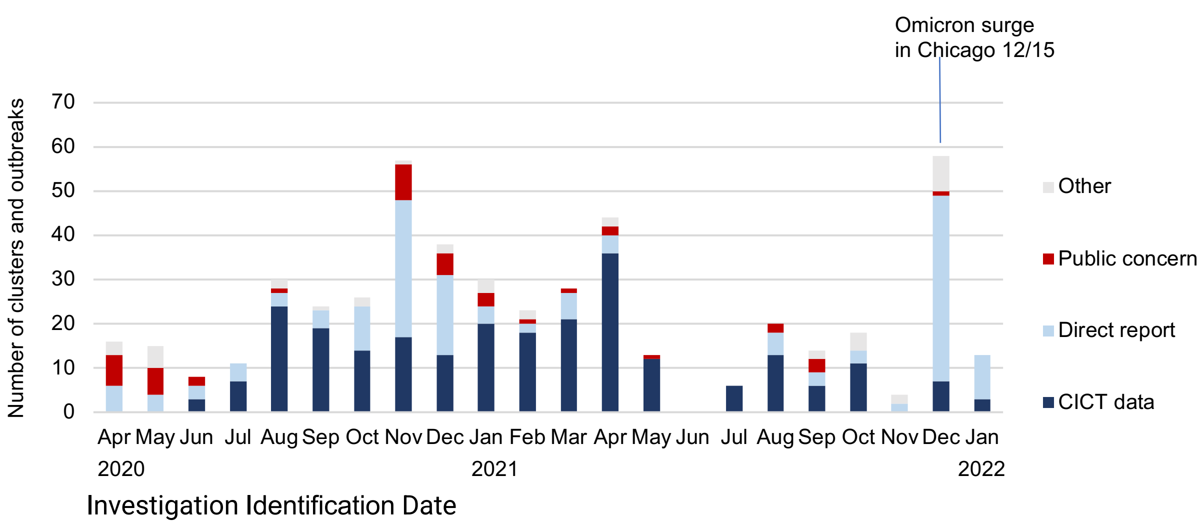


Figure 27. Clusters and outbreaks among non-healthcare, non-congregate workers in Chicago, April 2020 – January 2022 by identification source (N=496)

In the fourth time period (full re-opening), the proportion of investigations among 1b (frontline essential) workplaces decreased by half (11% of all investigations compared to 22% in the previous period). More investigations were conducted among bars and restaurants (37% compared to 24% previously). Fewer investigations were initiated through review of CICT data (54%), and more were prompted by direct reports from workplaces (28% compared to 10% in the previous period).

In the fifth and final period (during the Omicron wave), fewer clusters and outbreaks were identified than in any period since the first few months of the pandemic (59 total), with just one investigation meeting outbreak criteria. No investigations were identified from February through May 31, 2022. Office settings surpassed bars and restaurants as the most-investigated workplace type (41%, increased from 24% in the previous period). The fewest investigations were conducted among frontline essential businesses (7% combined). Investigations conducted among workplaces in North-Central Chicago increased further (64%) as those in the Southwest, Far South and Near South sides became decreasingly represented (~10% of all investigations combined). For the first time during the pandemic, most investigations were initiated based on direct reports from employers (75%). The proportion identified through CICT decreased to just 10% of investigations. Overall, outbreaks were more common among workplaces investigated because of public concerns (30%) than because of direct reports (11%) or CICT alerts (6%) (Table XXI, Appendix C). Half of all public concerns were about frontline essential workplaces (51%), which comprised fewer CICT alerts (28%) or direct reports (15%). Workplaces in West Chicago were also over-represented among public concerns (30%) and under-represented among direct reporters (12%). Almost one-third of direct reporters were offices (30%) and most (59%) were in North-Central Chicago.

10.3.2 **Individual-Level Characteristics of Investigation-Associated Cases**

Of the 2,529 associated cases found to be associated with workplace clusters or outbreaks, 1,698 (67%) were lab-confirmed. The distribution of laboratory-confirmed cases by workplace type over time is shown in Figure 34, Appendix C. While the number of investigations increased through 2020 as described previously, the number of associated cases decreased overall after the surge in November of 2020. The proportion of all investigation-associated cases that were found to be lab-confirmed decreased consistently when after the shutdown ended, from 83% in June 2020 to 16% in December 2021 (Figure 35, Appendix C).

Of the 1,698 laboratory-confirmed cases, 1,221 (72%) were among Chicago residents; their demographics are summarized in Table XXII, Appendix C. The proportions of NHNCW cases that were among workers living outside Chicago did not vary appreciably over time and ranged from 25% to 32% of cases per period (28% over all periods, data not shown). During the shutdown, 50–64-year-olds comprised 31% of investigation-associated Chicago cases, compared to 9% during the Omicron wave, when younger age groups were more likely to be represented: Young adults (18–29-year-olds) comprised 15% of cases during the shutdown and 47% during Omicron. Distributions by race/ethnicity also changed over time. Latinx Chicagoans were over-represented in essential workplace outbreaks during the shutdown period (62%) compared to during Omicron (15%), when proportions of cases increased among Black, non-Latinx (from 6 to 27%) and Asian, non-Latinx workers (from 9% to 27%). During the Omicron wave, 68% of investigation-associated cases had a record of being fully vaccinated against COVID-19. No hospitalizations were reported, compared to 70 (6%) among cases over all periods before vaccine rollout. All but 1 of the 10 deaths occurred in periods before vaccine became available.

10.4 **Discussion**

This analysis is the first to illustrate the changing burden of COVID-19 among NHNCW in Chicago through post-vaccination phases of the pandemic. It also demonstrates that by using a combination of direct reporting and CICT, CDPH identified more COVID-19 clusters and outbreaks among NHNCW over time than were detected by either method alone, and that these methods contributed to the success of Chicago's workplace surveillance system to varying degrees over time.

Workplace types varied by identification source, reflecting (1) concomitant changes in business operations and surveillance practices in Chicago and (2) greater frequency or capacity of some workplace types to self-report to CDPH. It is unsurprising that outbreaks were most common among investigations initiated because of public concerns, and that most public concerns were among frontline essential businesses. Most public concerns (72%) were received during pre-vaccination periods, and CICT and direct reporting processes were not fully established during non-essential shutdown. As described in Table X, most outbreaks (69%) occurred prior to Chicago's outbreak reporting requirement for non-healthcare workplaces (October 2020), potentially helping explain why so few were identified by direct report. Workplaces who reported directly to CDPH became over-represented during Omicron, when CICT data became less effective at identifying potential instances of workplace transmission. Through 2020, direct reporters comprised about one-third (36%) of all clusters and outbreaks CDPH identified. Investigations initiated solely through review of CICT data in 2021 (after this became the predominant source of cluster and outbreak information) would have missed nearly half (45%) of all clusters and outbreaks, including 90% of those identified during the Omicron wave. The conclusion that layered methods improve sensitivity of workplace-based COVID-19 surveillance is echoed by Bonwitt et al., who reported that through June-November 2020, a combination of CICT data (used to identify 56% of investigations), direct report (24%) and other means (20%) was more effective at identifying issues of workplace transmission among NHNCW than any one methodology alone (Bonwitt 2021).

The decreases in number and size of workplace outbreaks beginning in June 2020 – as non-essential businesses re-opened– speak to the importance of masking and distancing in resuming safe workplace operations. The substantial increase in clusters investigated over that time may reflect improved surveillance practices that maximized CICT data and informed proactive outreach to facilities. It is possible these practices, compared to reliance on direct reporting alone, led to earlier intervention and identified clusters that would not otherwise have been reported.

The large outbreaks identified early in the pandemic among food production, processing and manufacturing workers are consistent with reports by other jurisdictions (Dyal 2020; Waltenburg et al. 2021; Murti et al. 2021; Contreras et al. 2021; Herstein et al. 2021; Rubenstein et al. 2020), and national recommendations to prioritize these workers for vaccination (McClung 2020). Increased investigations among bars and restaurants after Chicago's re-opening are comparable to reports from other jurisdictions. Contreras et al. found that from March through September 2020, 20% of all workplace outbreaks were in food and beverage stores (11%) or bars and restaurants (9%) (Contreras et al. 2021). Pray et al. were among the first to report time-stratified data, delineating 'stay at home' periods and business operations in Wisconsin through November 2020 (Pray 2021). They reported increased outbreaks in bars and restaurants (2 to 12%) and retail (1 to 6%) after re-opening. At the time of this report, summaries of COVID-19 among NHNCW after vaccine availability and Omicron dominance have not been published.

Identification of clusters and outbreaks decreased dramatically during the Omicron surge, despite record numbers of cases reported from every Chicago community at the time. This finding demonstrates how increases in at-home rapid testing and decreases in lab-based testing reduced CDPH's ability to verify cases and workplace transmission events. No clusters or outbreaks were identified after January 2022, further emphasizing the decreasing sensitivity of surveillance processes driven by laboratory data. As fewer cases were interviewed and fewer investigations initiated using CICT data, workplaces with more resources to seek confirmatory testing or self-report to CDPH (offices, hotels) became overrepresented, resulting in surveillance bias. This inference may be supported by the finding that less vulnerable demographic groups (White, non-Latinx and North Central Chicago residents) comprised greater proportions of workplace-associated cases over time.

While most Chicago regions can be characterized as a mix of business and residential, the City has designated industrial corridors concentrated mostly in South, Southwest and West-side regions and a Central business district that is primarily commercial (City of Chicago n.d.; 2022). These differences are reflected in the contrasting representation of these regions and corresponding industries in earlier versus later phases of the pandemic (Figures 24 and 26). Overall, 61% of all investigations conducted in the Southwest were among manufacturing, food production and processing workplaces, while 64% of those conducted in North and Central Chicago were among bars, restaurants, and offices. Understanding the distribution of COVID-19 outbreaks by region is important not only for protecting those workers, but also for stemming outbreaks in their surrounding communities. For example, there is evidence that workplace outbreaks in the meatpacking industry were the source of community outbreaks and affected some of the poorest counties in the U.S.(U.S. Department of Agriculture 2021). As indicated by our supplemental data, trends in the geographic distribution of Chicago’s workers associated with COVID-19 clusters and outbreaks were like those among the workplaces investigated: Northwest and Southwest regions became decreasingly represented during Omicron, despite citywide surges in cases. This is particularly important in a city as segregated as Chicago. These regions include many of the communities considered highly vulnerable to adverse COVID-19 outcomes according to CDPH’s COVID-19 Community Vulnerability Index (CCVI), which incorporates distributions of racial and ethnic minority groups, essential workers, socioeconomic indicators and early-pandemic COVID-19 hospitalizations and deaths (City of Chicago n.d.). During Omicron, both testing and workplace reporting became biased toward low-vulnerability communities, hindering the ability of workplace surveillance to identify businesses and workers most in need of outreach through local support networks.

10.4.1 **Strengths and Limitations**

These analyses have some limitations. First, investigations of clusters and outbreaks among NHNCW in Chicago do not assess cases among patrons of public workplaces or patron-employee transmission dynamics. However, interpretation of surveillance data from workers, alone, in the context of Chicago’s operational guidance provides insight into changes in worker risk related to patron exposure. For example, it is unsurprising that investigations of bars, restaurants, and personal care and service settings (such as salons) increased when these businesses re-opened fully and masking guidance for patrons was relaxed. The overall declines in laboratory-confirmation of investigation-associated cases and in investigations identified by CICT were consistent with changes in community testing behavior and decreased case investigation in Chicago. However, the degree to which employer-based testing options contributed to confirmatory testing and subsequent identification of workplace transmission events over time is unknown.

The dramatic decrease in investigations among essential workplaces after their eligibility for vaccine suggests that prioritizing workers at increased occupational risk of contracting COVID-19 was an effective strategy for immunization of working-age populations. However, demographically adjusted comparisons of incidence over time among vaccinated and unvaccinated workforces could not be conducted, due to a lack of population-level industry and demographic data. Industry and occupation data are not collected as part of the State immunization record, and data describing distributions of working Chicagoans by both industry and race-ethnicity groups are not available at the city level. Similarly, workplaces investigated for COVID-19 clusters and outbreaks did not consistently report numbers of employees working on-site, so attack rates could not be calculated or compared by industry or over time.

Among employees reported to have contact outside work (e.g., carpooling, shared household or spending other time together off-site), cases were not considered workplace associated. As a result, the number or sizes of clusters and outbreaks among NHNCW may have been underestimated. This convention adopted by the workplace response unit at CDPH assumes that transmission is more likely through prolonged community or household exposures, including shared living, sleeping, and eating spaces in absence of masking and workplace controls (distancing, physical barriers, increased hand hygiene and disinfection, ventilation). The proportion of employee cases who also share a household or other community exposure has not been uniformly collected over time among cases in Chicago, precluding a sensitivity analysis of differences in measured COVID-19 burden among workers when relaxing this assumption.

A major limitation to CICT-based surveillance was that most working-age interviewees did not specify complete employer information. Chains, franchises, and other multi-location workplaces in particular may have been under-represented when employees did not specify a worksite address, used by CDPH to corroborate common work sites and inform outreach. Completeness of employer and occupation information among CICT data decreased over time, further decreasing the sensitivity of the surveillance system. For example, the proportion of working-age interviewees missing all fields on employer or occupation increased from 35% in the second time period to 60% during Omicron (data not shown).

The data sources used to describe case demographics, vaccination status and outcomes as part of this report are limited to Chicago residents. Vaccinations administered out-of-state are not captured in I-CARE unless updated by in-state providers. Therefore, those who work but do not live in Chicago or who were vaccinated outside Illinois are under-represented.

The COVID-19 pandemic has highlighted the importance of incorporating occupational health standards into infectious disease surveillance systems. However, the workplace classification schemes used by city and State health departments, as described here, do not conform to industry classification frameworks used by other branches of government public health. CDPH's methods align with State outbreak reporting requirements, including employer name and in, some cases, indication of workplace environment versus industry (e.g., "Office Setting", compared to ''financial", "legal" or "management"). Collection and standardized classification of industry data, including use of the North American Industrial Classification System (NAICS) (U.S. Census Bureau n.d.), could have enabled characterization of impacted sectors, more targeted closure policies, subsequent dissemination of risk mitigation approaches, and synthesis of findings with those from other jurisdictions.

Furthermore, workplace and case interviews did not consistently include data on occupations of NHNCW. While analyses by workplace and industry are appropriate for exploring the impact of sector-based vaccine strategies, risk for workplace-acquired COVID-19 has been more precisely defined by exposure and proximity among workers, which can vary among job types within the same workplace (Hawkins, Davis, and Kriebel 2021; Zhang 2021). As acknowledged in existing literature (Baker, Peckham, and Seixas 2020), further studies of COVID-19 burden by occupation would help validate national risk estimation frameworks established early in the pandemic, for future prevention of respiratory infectious diseases.

Finally, OSHA's role in CDPH's workplace surveillance was not explored. Discrepancies between current data collection and occupational health conventions speak to the need for collaboration between OSHA and public health agencies, including as surveillance systems are developed. Given OSHA's expertise in worksite organization and risk reduction, cooperation could increase potential for limiting disease spread and marshalling resources during an outbreak or a pandemic.

10.4.2 **Aim 1 Conclusions**

Analyses of COVID-19 clusters and outbreaks among NHNCW in Chicago suggest that prioritization of frontline and essential workers for vaccination has helped reduce burden of disease among high-risk workplaces over time (Bui et al. 2020; Cummings et al. 2021; Chen et al. 2021). Use of both direct reporting and case investigation improved identification of clusters and outbreaks among NHNCW. However, changes in reporting, testing, and case interviewing decreased the representativeness of surveillance data. As new epidemics or pandemics with high transmission or high severity may occur, multi-pronged methods including broad surveillance testing will be necessary to improve detection of outbreaks in workplaces. Businesses should be required to self-report work-related outbreaks, with clear guidance from health departments. Finally, health departments should place greater emphasis on collection of industry and occupation data during laboratory reporting, case investigation and vaccination. These data are needed to define populations at greatest risk of workplace-acquired infection, and to measure the impact of public health interventions in reducing disease among workers.

11. AIM 2 FINDINGS: USE OF A JOB EXPOSURE MATRIX TO INFORM OCCUPATION-BASED COVID-19 VACCINE PROMOTION AMONG NON-HEALTHCARE, NON-CONGREGATE WORKERS IN CHICAGO

11.1 Introduction

In early phases of the COVID-19 pandemic, large outbreaks occurred among workplaces with poor ventilation and prolonged proximity between workers, and informed national vaccination prioritization by industry. Initial allocations included health care personnel in Phase 1a, followed by frontline (non-health care) essential workers (first responders, corrections officers, U.S. Postal Service, and workers in food and agriculture, manufacturing, grocery, public transit, education and childcare) in Phase 1b. Other essential workers (transportation and logistics, water and wastewater, food service, shelter and housing, finance, information technology and communications, energy, legal, media, public safety and public health) were prioritized in Phase 1c over the general working-age population (Phase 2) (Dooling et al. 2021; McClung 2020). However, work-related data are not generally collected during vaccination, precluding broader descriptions of vaccination rates or identification of coverage disparities among workers by industry or occupation.

To address a lack of industry and occupation data among workers testing positive for COVID-19, the Council for State and Territorial Epidemiologists (CSTE) devised a disease-specific job exposure matrix, the SOEM (SARS-CoV-2 Occupational Exposure Matrix) (CSTE Occupational Health Subcommittee 2021). This framework estimates the risk of workplace-acquired infection for 696 non-health care occupations described in the U.S. Department of Labor's Occupational Information Network (O*NET) survey. The O*NET survey utilizes workers' self-reported job characteristics, manually reviewed by occupational health experts to produce standardized estimates of factors associated with occupational health outcomes (U.S. Department of Labor. n.d.). In the SOEM, occupational risk is defined as a three-level variable

(Low, Medium, High) based on 32 combinations of risk related to indoor, public-facing work and proximity to others.

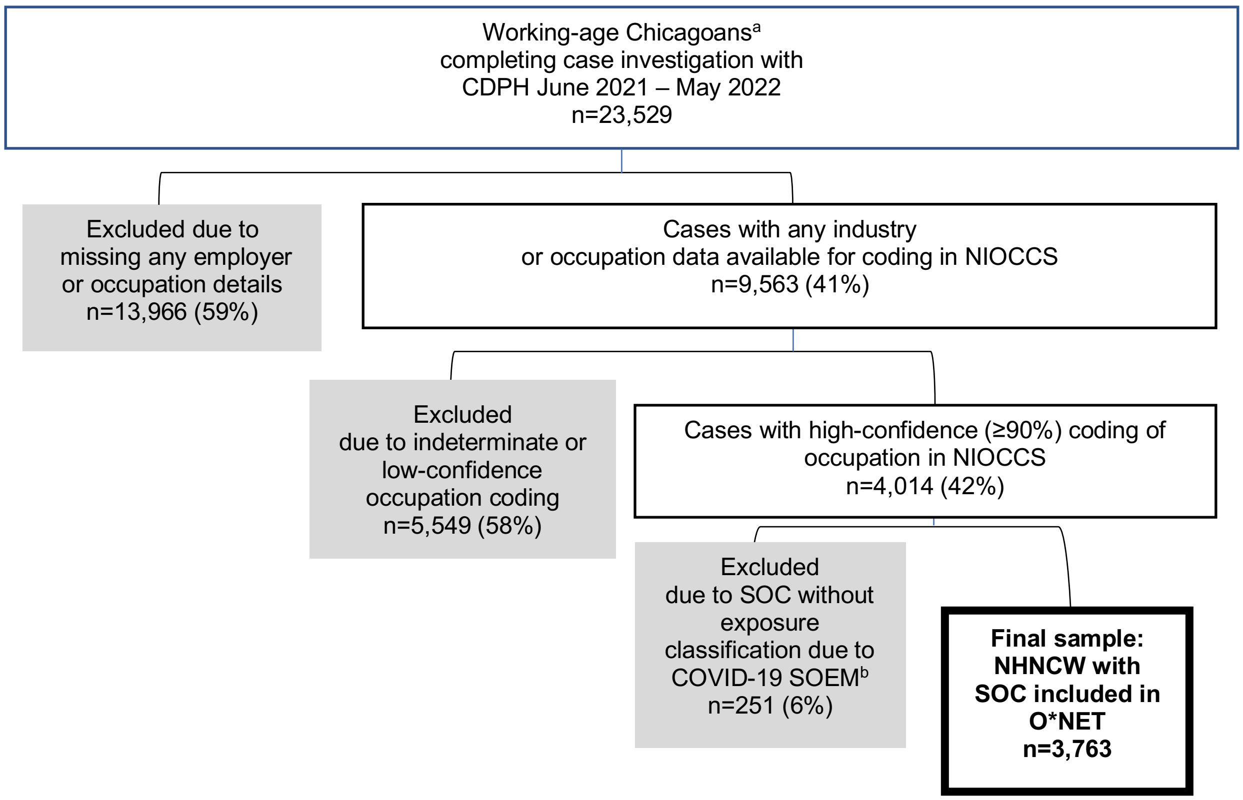
The SOEM and its component risk factors (being indoors, public-facing work, proximity to others) have been validated in studies of COVID-19 incidence by occupation and used to compare risk among workers by demographic groups. For example, in their analyses of Wisconsin's COVID-19 cases from September 2020 through May 2021, Pray et al. found that occupational groups ranking high in the SOEM (e.g., personal care and service, food and beverage, personal appearance, and law enforcement workers) had the highest incidence of all non-health care occupational groups (Pray et al. 2022). Hawkins et al. used O*NET data to describe workers at high risk of contracting SARS-CoV-2, and found that workers more likely to have prolonged proximity to others were also more likely to identify as Black, non-Latinx or Latinx (Hawkins 2020). Persisting COVID-19 vaccination coverage disparities among racial and ethnic minorities in the United States have been well-described (Barry et al. 2021; Kriss 2022; Centers for Disease Control and Prevention 2020d); data showing that occupational risk is associated with both COVID-19 incidence and race/ethnicity suggest that outreach to high-risk workplaces could help reduce coverage disparities among working-age Americans.

Laboratory and vaccination data for COVID-19 in Illinois have not routinely collected occupation. However, case interviews conducted by the Chicago Department of Public Health (CDPH) through May 2022 assessed occupation; matching these with vaccination records enables description of Chicagoans who have contracted COVID-19 by both occupational risk and vaccination status. The objectives of this analysis were to describe Chicagoans working in non-health care occupations by level of work-related COVID-19 risk, and to explore associations between occupational risk and vaccination status in both Pre-Omicron and Post-Omicron periods.

11.2 **Methods**

11.2.1 **Data Sources and Inclusion Criteria**

All analyses were conducted using SAS v9.4. Aim 2 included data from all Chicagoans aged 18-64 who completed routine case investigation with CDPH after laboratory-confirmed COVID-19 infection between June 1, 2021, and May 31, 2022, inclusive (N=25,047). Interview data were matched by State Case Number [for COVID-19 infection] to case and vaccination data from the Illinois National Electronic Disease Surveillance System (I-NEDSS) and State immunization record (I-CARE), respectively. Free-text occupation data were coded to 6-digit 2010 Standard Occupation Codes (SOC) using NIOCCS (NIOSH's Industry and Occupation Computerized Coding System) (Centers for Disease Control and Prevention n.d.). The CSTE constructed the SOEM to estimate risk among non-health care workers, given the increased infection control precautions including availability of PPE and vaccination in health care environments. This analysis focuses further on workers outside of education and congregate settings (corrections, homeless shelters) given surveillance and vaccination initiatives dedicated to these workers during Chicago's COVID-19 response. As such, 1,518 records assigned SOC codes excluded for health care (n=929), congregate settings (n=10, all in corrections) and education (n=579) were excluded. Other exclusions due to missing or indeterminate occupation or SOEM classification data are summarized in Figure 28. Records were excluded due to (a) missing occupation (n=13,966), (b) indeterminate SOC coding (i.e., <0.9 probability match, a threshold used in other applications of the SOEM (Pray et al. 2022), n=5,549), and (c) non-healthcare occupations not described in O*NET, thus also missing from the SOEM (n=251, Table XXIII, Appendix D). A total of 3,763 Chicagoans reporting working in non-health care, non-congregate occupations were included in the final sample.



[a]Cases age 18-64 at time of laboratory-confirmed COVID-19 were included; ages 16-17 were excluded for comparability with existing data sources describing case burden and vaccination coverage.

[b]Excluded due to missing exposure classification: “All Other” occupations and military (n=217), unpaid (n=34). These are detailed in Table XXIII, Appendix D.

Figure 28. Cases included in Aim 2 analyses of vaccination status by occupational risk (n=3,763)

11.2.2 **Exposure Definition: SARS-CoV-2 Occupational Exposure**

Case data were matched by SOC to level of risk of workplace-acquired infection (low, medium, high) from the 2021 SOEM. Risk was dichotomized in modeling (high vs. low or medium risk): higher risk environments may be more easily distinguished from medium or low risk environments, for implementation of any recommendations based on model findings. Occupations can meet some SOEM criteria for ‘high risk’ by having one of 8 combinations of environmental parameters, whereas ‘medium risk’ describes a broader spectrum (18 possible combinations).

11.2.3 **Outcome Definition: Vaccination Status**

In primary analyses, “vaccination status at infection” referred to the CDC’s definitions of full vaccination and a breakthrough case (Centers for Disease Control and Prevention 2023): a second dose of mRNA vaccine (Pfizer or Moderna) or first dose of Johnson & Johnson/Janssen vaccine) at least 14 days prior to positive SARS-CoV-2 test date in a probable or confirmed COVID-19 case record in I-NEDSS.

11.2.4 **Demographic Variables**

Demographic variables (age group, sex, race-ethnicity) were defined categorically to be consistent with the existing CDPH COVID-19 surveillance data. These were derived primarily from I-NEDSS and supplemented with race-ethnicity data from case interviews to decrease missingness. Age groups were defined in more granular groups for descriptive analyses (18-29, 30-39, 40-49, 50-59, 60-64), and collapsed to three (18-29, 30-49, 50-64) for bivariate analyses and subsequent modeling. Zip codes were used to classify cases into the six Healthy Chicago Equity Zones, defined to assist in localized public health initiatives (City of Chicago n.d.). To reduce unmeasured confounding, CCVI was approximated by residential zip code (City of Chicago n.d.). This index adapts those from Surgo Ventures and the CDC (Surgo Ventures n.d.;

Centers for Disease Control and Prevention 2022d) to rank Chicago's community areas by COVID-19 burden, sociodemographic, epidemiological, and occupational factors that make them uniquely vulnerable to vaccination barriers. CCVI was categorized consistently with how CDPH has prioritized areas for outreach (15 very high, 11 other high), distinctly from others (51 not high). In modeling, CCVI was dichotomized (26 high vulnerability vs. 51 not high) to balance cell size, for a comparison of "high vulnerability" versus "other" areas.

11.2.5 Definitions of Time Periods

To explore differences in association between occupational risk and vaccination status before and after Omicron predominance, cases were classified by specimen collection date as either Pre-Omicron (through December 14, 2021) or Post-Omicron (December 15, 2021 – May 31, 2022) (City of Chicago n.d.). Distributions of cases by season were compared within periods, as seasonality has been observed among COVID-19 incidence data (City of Chicago n.d.). Two Pre-Omicron periods were defined (June - August and September - December 14, 2021), allowing comparison of cases during relaxed masking restrictions and lower community transmission to those during reinstated restrictions and Chicago's Fall surge. Two Post-Omicron periods were defined (December 15, 2021 - January 2, 2022, and January 3 - May 31, 2022), allowing comparison of greater mobility through the holiday Omicron surge, to when vaccine requirements for some indoor settings were first mandated.

11.2.6 Analytic and Statistical Methods

Demographics, major occupational group, occupational risk and vaccination status at infection were described in univariate analyses, overall, by period, and season within Pre- and Post-Omicron periods. Correlations between demographic variables and occupational risk were evaluated using Cramér's V tests [of association between categorical variables]. Distributions of characteristics by vaccination status, and demographics by occupational risk level were compared in bivariate analyses with Pearson's chi-squared tests. Logistic regression analyses were conducted by period. Associations between occupational risk and vaccination status by age, sex, race-ethnicity, and city region were described in single-factor stratified analyses. All of these were included as *a priori* defined confounders in multivariable modeling. First, neighborhood-level associations between these demographics, occupational risk and vaccination status were explored in multilevel models generated using PROC GLIMMIX: the efficiency of specifying city region as a random versus fixed effect was evaluated using the Chi-squared values from likelihood ratio testing. The intra-class correlation coefficient (ICC) was also calculated, assuming an error variance of 3.29 ($\pi^2/3$) for logistic regression with a dichotomous outcome. Covariates with differing stratum-specific odds ratios (OR) for associations between occupational risk and vaccination status were then evaluated as effect modifiers. Models were limited to one interaction term at a time to avoid issues with small cell size: one model was created for each potential effect modifier, including all main effects and an interaction term (e.g., a model assessing interaction by age included all demographic confounders, occupational risk and one additional term for age and occupational risk). All models with single interaction terms were compared to each other and the fully adjusted model of only main effects. The final model was selected based on lowest Akaike Information Criterion (AIC). Post hoc power analyses were conducted using PROC POWER and sample sizes achieved by period.

Two types of sensitivity analyses were conducted. Potential selection bias related to exclusion of cases with <0.9 probability match was evaluated: demographic and occupational risk distributions of cases coded with 0.80-0.89 probability were compared to the final sample (≥0.9 probability). Associations between occupational risk and being up-to-date with COVID-19 vaccination (i.e., including receipt of booster doses, if eligible) were also explored, in an analysis restricted to the Post-Omicron period (December 15, 2021 and later): boosters were recommended for non-immunocompromised working-age Chicagoans effective November 29, 2021 (City of Chicago n.d.). Cases were described as (1) unvaccinated, (2) vaccinated and not yet eligible for boosting, (3) vaccinated, eligible for boosting but not yet boosted, or (4) vaccinated and boosted at time of COVID-19 infection. These categories were collapsed to a dichotomous outcome variable (up-to-date, versus not up-to-date) in logistic regression models.

11.3 **Results**

11.3.1 **Univariate Analyses: Characteristics of Cases by Period**

Demographics of the final sample are shown by period in Table XI (next page). From Pre- to Post-Omicron periods, the proportion of cases who were fully vaccinated at infection increased substantially, from 44% to 75%. Cases with low occupational risk comprised a greater proportion of infections Post-Omicron than Pre-Omicron (32% vs 27%). Among the diverse occupational subgroups represented (Table XII), cases in office settings increased slightly while those in transportation occupations deceased slightly.

11.3.2 **Bivariate Analyses: Vaccination by Occupational Risk and Demographics**

Comparisons of vaccination status by occupational risk and demographic groups are shown in Table XIII. Being unvaccinated was more common among high vs. lower-risk workers in the pre-Omicron period only ($p < 0.0001$). In comparisons by major occupational group (Table XXIV, Appendix D), pre-Omicron coverage rates were lowest among protective service (28%), installation, maintenance and repair (30%) and transportation and construction (31% each). Post-Omicron coverage rates were lowest among construction (49%), transportation (57%) and production (66%).In both periods, vaccination rates were lower among 18-29-year-olds and among Latinx, Black, non-Latinx or Other, non-Latinx race/ethnicity groups than among older and White, non-Latinx groups. Coverage varied widely across regions, from 24% in the Far South to 62% in North Central regions Pre-Omicron, and 63% in the South to 81% in the North Central region Post-Omicron.

TABLE XII. DEMOGRAPHICS OF NON-HEALTHCARE, NON-CONGREGATE WORKER COVID-19 CASES IN CHICAGO (N=3,763), BY PERIOD

	All n=3,763	**Pre-Omicron n=2,455**	**Post-Omicron n=1,308**
	n (%)	n (%)	n (%)
Age group (years)			
18-29	1,063 (28.2)	763 (31.0)	300 (22.9)
30-39	1,214 (32.2)	779 (31.7)	435 (33.2)
40-49	787 (20.9)	498 (20.2)	289 (22.0)
50-59	528 (14.0)	315 (12.8)	213 (16.2)
60-64	171 (4.5)	100 (4.0)	71 (5.4)
Sex			
Male	1,910 (50.7)	1,292 (52.6)	618 (47.2)
Female	1,844 (49.0)	1,159 (47.2)	685 (52.3)
Unknown	9 (0.2)	4 (0.1)	5 (0.3)
Race-ethnicity group			
Latinx	848 (22.5)	546 (22.2)	302 (23.0)
Black, non-Latinx	950 (25.2)	726 (29.5)	224 (17.1)
White, non-Latinx	1,493 (39.6)	911 (37.1)	582 (44.4)
Asian, non-Latinx	162 (4.3)	78 (3.1)	84 (6.4)
Other, non-Latinx	200 (5.3)	126 (5.1)	74 (5.6)
Unknown	110 (2.9)	68 (2.7)	42 (3.2)
City region			
North Central	1,054 (28.0)	596 (24.2)	458 (35.0)
Northwest	849 (22.5)	559 (22.7)	290 (22.1)
West	607 (16.1)	405 (16.4)	202 (15.4)
Southwest	506 (13.4)	361 (14.7)	145 (11.0)
Far South	399 (10.6)	299 (12.1)	100 (7.6)
South	335 (8.9)	228 (9.2)	107 (8.1)
Unknown	13 (0.3)	7 (0.2)	6 (0.4)
CCVI			
Very high CCVI	646 (17.1)	482 (19.6)	164 (12.5)
High CCVI	309 (8.2)	217 (8.8)	92 (7.0)
Not High CCVI	2,808 (74.6)	1,756 (71.5)	1,052 (80.4)
Hospitalized			
Yes	108 (2.8)	89 (3.6)	19 (1.4)
No	526 (13.9)	277 (11.2)	249 (19.0)
Unknown	3,129 (83.1)	2,089 (85.0)	(79.5)
Deceased			
Yes	2 (-)	1 (-)	1 (-)
No	3,761 (99.9)	2,454 (99.9)	1,307 (99.9)
Fully Vaccinated			
Yes	2,089 (55.5)	1,104 (44.9)	985 (75.3)
No	1,674 (44.4)	1,351 (55.0)	323 (24.6)

TABLE XIII.OCCUPATIONAL CHARACTERISTICS OF NON-HEALTHCARE, NON-CONGREGATE WORKERS WITH COVID-19 (N=3,763), BY PERIOD

	All n=3,763	**Pre-Omicron n=2,455**	**Post-Omicron n=1,308**
	n (%)	n (%)	n (%)
Occupational risk			
High Risk	1,991 (52.9)	1,318 (53.6)	673 (51.4)
Medium Risk	684 (18.1)	466 (18.9)	218 (16.6)
Low Risk	1,088 (28.9)	671 (27.3)	417 (31.8)
Major occupation group			
Office and Administrative Support	480 (12.7)	307 (12.5)	173 (13.2)
Management	446 (11.8)	278 (11.3)	168 (12.8)
Transportation and Material Moving	418 (11.1)	327 (13.3)	91 (6.9)
Business and Financial Operations	348 (9.2)	192 (7.8)	156 (11.9)
Sales and Related	295 (7.8)	211 (8.5)	84 (6.4)
Food Preparation and Serving	288 (7.6)	198 (8.0)	90 (6.8)
Protective Service	257 (6.8)	174 (7.0)	83 (6.3)
Personal Care and Service	167 (4.4)	118 (4.8)	49 (3.7)
Building and Grounds Cleaning and Maintenance	166 (4.4)	115 (4.6)	51 (3.8)
Computer and Mathematical	150 (3.9)	84 (3.4)	66 (5.0)
Construction and Extraction	146 (3.8)	105 (4.2)	41 (3.1)
Arts, Design, Entertainment, Sports, and Media	131 (3.4)	87 (3.5)	44 (3.3)
Legal Occupations	120 (3.1)	59 (2.4)	61 (4.6)
Production	111 (2.9)	76 (3.0)	35 (2.6)
Life, Physical, and Social Science	82 (2.1)	29 (1.1)	53 (4.0)
Architecture and Engineering	76 (2.0)	42 (1.7)	34 (2.5)
Installation, Maintenance, and Repair	70 (1.8)	47 (1.9)	23 (1.7)
Educational Instruction and Library	7 (0.1)	2 (-)	5 (0.3)
Farming, Fishing, and Forestry	5 (0.1)	4 (0.1)	1 (-)

11.3.3 **Demographics of Cases by Season in Pre- and Post-Omicron Periods**

Demographics by season (Early vs. Late) by period are shown in Table XXV, Appendix D. The sample size in the early Post-Omicron season was notably smaller (n=247) than in both Pre-Omicron seasons and the later Post-Omicron season (n > 1,000 each). Since trends by season within periods were similar to those by period over time, no bivariate analyses or logistic modeling were conducted by season.

11.3.4 **Bivariate Analyses: Occupational Risk by Demographics**

Demographic comparisons by level of occupational risk are shown in Table XIV. Cases differed significantly by age, sex, race-ethnicity, city region and CCVI. The youngest and oldest age groups were more likely to work in high-risk occupations: 57% of 18-29-year-olds and 57% of 50-64-year-olds. Black, non-Latinx NHNCW were the most likely to work in high-risk occupations (66%), as were residents of South, Far South and Southwest regions (65%, 62%, 58% of cases in these regions, respectively), and communities with high CCVI (61%).

11.3.5 **Bivariate Analyses: Occupational Risk by Major Occupational Groups**

The major occupational groups represented over both periods are shown in Figure 29, by proportion of occupations classified as high risk. Five occupational groups included over 90% of occupations classified as high-risk, and corresponded to 1b/1c workplaces. In contrast some occupational groups corresponding to essential workplaces (transportation, production, construction) included a majority of occupations defined as lower risk.

11.3.6 **Single-Factor Analyses of Vaccination Status by Occupational Risk**

As shown in Table XXVI, Appendix D, unadjusted models found an association between occupational risk and vaccination among Pre-Omicron cases only (odds ratio (OR) 1.40, 95% CI 1.19-1.64). Single-factor adjusted Pre-Omicron models suggested confounding by region and race/ethnicity, and single-factor-stratified analyses indicated effect modification by age, sex, region and CCVI. Among 18-29-year-olds, females, and those living in Southwest regions or communities with high CCVI, NHNCW in higher-risk occupations had greater odds of being unvaccinated at time of COVID-19 infection, compared to those in lower-risk occupations.

11.3.7 **Multivariable Models of Occupational Risk and Vaccination Status**

In fully-adjusted mixed-effect models specifying region as a random effect, cluster variances were very small (0.075 Pre-Omicron, 0.007 Post-Omicron), resulting in very small ICC by period (0.022, 0.002, respectively). These suggest that clustering within regions accounted for about 2% of variance Pre-Omicron and <1 % Post-Omicron. Likelihood ratio testing of nested models was attempted but specifying region as both a random and fixed effect resulted in too few clusters and not enough variance to estimate within-cluster correlation. The final logistic regression model for the Pre-Omicron period included all *a priori* confounders, CCVI, and interaction term for age (Table XV). Among 18-29-year-olds, those working in higher-risk environments were found to have greater odds of being unvaccinated at infection (adjusted OR 1.53, 95% CI 1.10 - 2.14). No association was found between occupational risk and vaccination status at infection among Post-Omicron cases (adjusted OR 0.92, 95% CI 0.70-1.21). CCVI was excluded from models in both periods due to collinearity with region (Table XXVII, Appendix D). Power calculations including Pre-Omicron cases by vaccination status and occupational risk indicated that n= 2,455 cases had 60% power to observe an OR of 1.4 (the result from unadjusted analyses). These analyses were not conducted for Post-Omicron cases, given no observed associations between risk and vaccination status in unadjusted or adjusted models.

TABLE XIII. DEMOGRAPHICS OF CASES BY VACCINATION STATUS AND PERIOD

	Pre-Omicron			Post-Omicron		
	Vaccinated	Unvaccinated		Vaccinated	Unvaccinated	
	n (%)	n (%)	*p*	n (%)	n (%)	*p*
	1,104 (45.0)	1,351 (55.0)		985 (75.3)	323 (24.7)	
Occupational Risk			*<0.001*			*1.000*
High	542 (41.1)	776 (58.8)		507 (75.3)	166 (24.6)	
Not High	562 (49.4)	575 (50.5)		478 (75.2)	157 (24.7)	
Age			*<0.001*			*<0.001*
18-29	274 (35.9)	489 (64.0)		197(65.6)	103 (34.3)	
30-49	592 (46.3)	685 (53.6)		561 (77.4)	163 (22.5)	
50-64	238 (57.3)	177 (42.6)		227 (79.9)	57 (20.0)	
Sex						
Male	573 (44.3)	719 (54.1)	*0.150*	463 (74.9)	155 (25.0)	*0.930*
Female	531 (45.8)	628 (55.6)		518 (75.6)	167 (24.3)	
Unknown	0 (-)	4 (100)		4 (80.0)	1 (20.0)	
Race-ethnicity group						
Latinx	231 (42.3)	315 (57.6)	*<0.001*	212 (70.1)	90 (29.8)	*<0.001*
Black, non-Latinx	170 (23.4)	556 (76.5)		153 (68.3)	71 (31.6)	
White, non-Latinx	594 (65.2)	317 (34.7)		474 (81.4)	108 (18.5)	
Asian, non-Latinx	52 (66.6)	26 (33.3)		70 (83.3)	14 (16.6)	
Other, non-Latinx	40 (31.7)	86 (68.2)		46 (62.1)	28 (37.8)	
Unknown	17 (25.0)	51 (75.0)		30 (71.4)	12 (28.5)	
City region						
North Central	370 (62.0)	226 (37.9)	*<0.001*	369 (80.5)	89 (19.4)	*<0.001*
Northwest	304 (54.3)	255 (45.6)		223 (76.8)	67 (23.1)	
West	174 (42.9)	231 (57.0)		149 (73.7)	53 (26.2)	
Southwest	121(33.5)	240 (66.4)		100 (68.9)	45 (31.0)	
Far South	73 (24.4)	226 (75.5)		79 (73.8)	28 (26.1)	
South	62 (27.1)	166 (72.8)		63 (63.0)	37 (37.0)	
Unknown	0 (-)	7 (100)		2 (33.3)	4 (66.6)	
City region			*<0.001*			*0.004*
High CCVI	195 (27.9)	504 (74.2)		174 (65.2)	82 (34.7)	
Not High CCVI	909 (51.7)	84.0 (48.2)		811 (77.0)	241 (22.9)	
Season			*<0.001*			*0.002*
Early	400 (37.4)	669 (62.5)		167 (67.6)	80 (32.3)	
Late	704 (50.7)	682 (49.2)		818 (77.0)	243 (22.9)	

TABLE XIV. DEMOGRAPHICS OF HIGH VS. LOW-RISK OCCUPATION GROUPS (N=3,763)

	High-Risk Occupation		**Lower-Risk Occupation**		
	n	%	n	%	
	1,991	(52.9)	1,772	(47.1)	*p*
Age					*<0.0001*
18-29	606	(57.0)	457	(42.9)	
30-49	987	(49.3)	1014	(50.6)	
50-64	398	(56.9)	301	(43.0)	
Sex					*<0.0001*
Female	1,139	(61.7)	705	(38.2)	
Male	845	(44.2)	1,065	(55.7)	
Unknown	7	(77.7)	2	(22.2)	
Race-ethnicity group					*<0.0001*
Latinx	448	(52.8)	400	(47.1)	
Black, non-Latinx	631	(66.4)	319	(33.5)	
White, non-Latinx	654	(43.8)	839	(56.1)	
Asian, non-Latinx	78	(48.1)	84	(51.8)	
Other, non-Latinx	116	(58.0)	84	(42.0)	
Unknown	64	(58.1)	46	(41.8)	
City region					*<0.0001*
North Central	480	(45.6)	574	(54.4)	
Northwest	424	(49.9)	425	(50.0)	
West	320	(52.7)	287	(47.2)	
Southwest	295	(58.3)	211	(41.6)	
Far South	246	(61.6)	153	(38.3)	
South	219	(65.3)	116	(34.6)	
Unknown	7	(53.8)	6	(46.1)	
CCVI					*<0.0001*
High CCVI	578	(60.5)	377	(39.4)	
Not High CCVI	1413	(50.3)	1395	(49.6)	
Season					*0.0355*
Early	727	(55.2)	589	(44.7)	
Late	1264	(51.6)	1183	(48.3)	

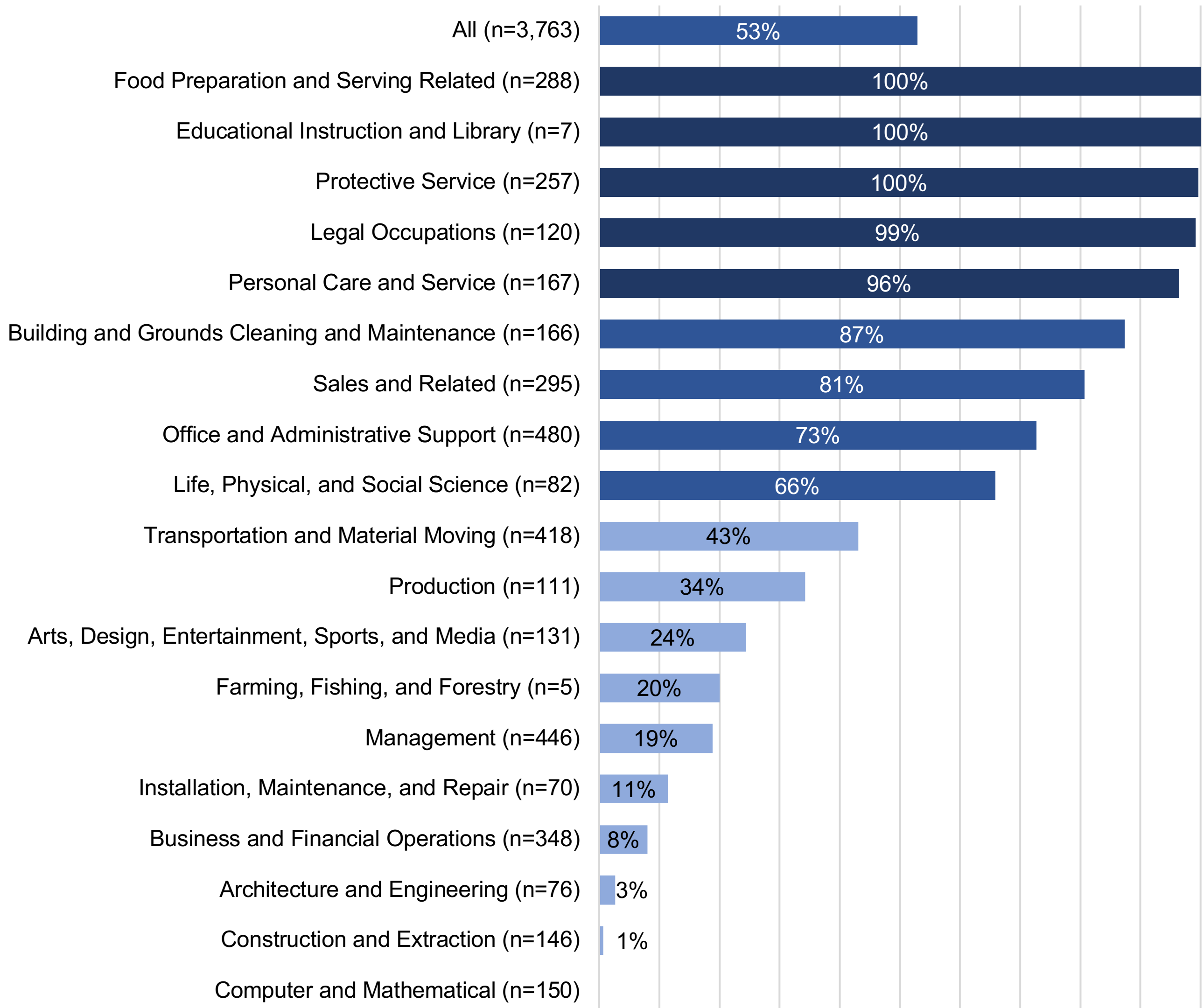


Figure 29. COVID-19 cases among non-healthcare, non-congregate workers (June 2021-May 2022): High-risk occupations by major occupational groups (N=3,763)

TABLE XV. MULTIVARIABLE-ADJUSTED MODELS BY PERIOD: ODDS OF BEING UNVACCINATED AT INFECTION BY OCCUPATIONAL RISK

	Pre-Omicron [a] OR	(95% CI)	*p*	Post-Omicron [b] OR	(95% CI)	*p*
Age group			0.0009			*<0.0001*
18-29	**3.16**	**(2.40 – 4.17)**		**2.52**	**(1.69 - 3.75)**	
30-49	**1.80**	**(1.40 – 2.30)**		1.31	(0.91 - 1.87)	
50-64	(ref)			(ref)		
Sex at birth			0.01			*0.3869*
Female	0.79	(0.65 - 0.94)		0.89	(0.68 - 1.17)	
Male	(ref)			(ref)		
Race-ethnicity group			<.0001			*0.0005*
Latinx	**2.12**	**(1.66 - 2.70)**		**1.67**	**(1.16 - 2.39)**	
Black, non-Latinx	**4.71**	**(3.59 - 6.18)**		**1.73**	**(1.11 - 2.71)**	
Asian, non-Latinx	0.94	(0.57 - 1.55)		0.85	(0.46 - 1.58)	
Other, non-Latinx	**3.59**	**(2.37 - 5.43)**		**2.71**	**(1.59 - 4.60)**	
White, non-Latinx	(ref)			(ref)		
City region			<.0001			*0.1031*
Far South	**2.54**	**(1.76 - 3.65)**		**2.22**	**(1.28 - 3.84)**	
Northwest	**1.38**	**(1.07 - 1.79)**		1.27	(0.87 - 1.86)	
South	**1.93**	**(1.29 - 2.87)**		1.18	(0.65 - 2.13)	
Southwest	**2.03**	**(1.48 - 2.80)**		1.46	(0.90 - 2.35)	
West	**1.43**	**(1.07 - 1.92)**		1.28	(0.84 - 1.96)	
North Central	(ref)			(ref)		
Occupational Risk						
High				0.92	(0.70 - 1.21)	*0.5456*
High, by Age Group:			*0.0291*			
18-29	**1.53**	**(1.10 -2.14)**				
30-49	1.08	(0.84 - 1.39)				
50-64	0.74	(0.48 – 1.14)				

[a] *Pre-Omicron model adjusted for demographics listed, and interaction of occupational risk by age group.*
[b] *Post-Omicron model adjusted for all demographic variables listed, no interaction terms.*

11.3.8 **Sensitivity Analyses: Broader Exclusion Criteria by Occupation Coding**

Broadening the inclusion criteria to include cases with a 0.8 probability SOC match from NIOCCS (compared to ≥ 0.9) increased the final sample size by 6% (3,763 to 3,996) with no appreciable difference in proportions excluded for SOC in health care, educational or residential settings, or for missing corresponding risk levels in the SOEM. Distributions of cases by probability score are shown in Figure 35, Appendix D. Cases with a 0.8-0.89 match versus those in the primary sample were similar by demographics, occupational risk and vaccination status as shown in Table XXVIII, Appendix D**;** this suggests that narrower inclusion criteria used in the main analysis did not differentially exclude cases based on these characteristics.

11.3.9 **Sensitivity Analyses: Boosters, Being "Up-to-Date" with Vaccination**

Distributions of cases after incorporating booster status as "up-to-date" or not up-to-date with vaccinations are shown in Figure 30 (and Table XXIX, Appendix D). Lower-risk workers were most likely to be up-to-date with vaccinations. No associations were found between occupational risk and being up-to-date at time of infection before or after adjusting for demographics. Analyses resulted in the same final model as in primary analyses (age, sex, race-ethnicity, and city region), with adjusted OR of 1.10 (95% CI 0.86-1.40).

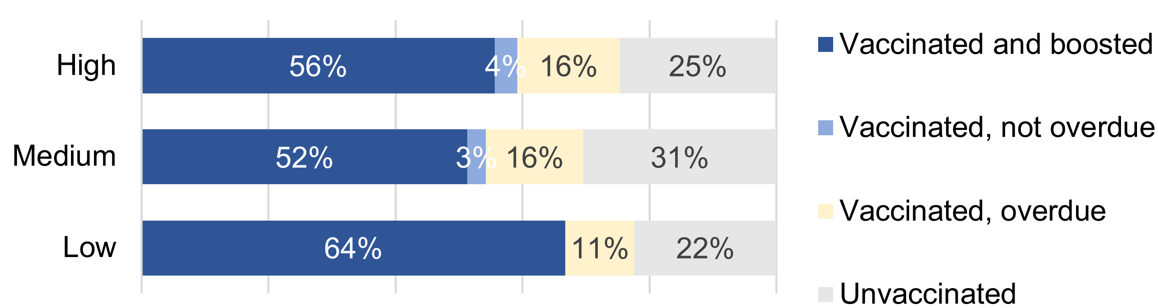


Figure 30. COVID-19 cases among non-healthcare, non-congregate workers in Post-Omicron period (n=1,308): vaccination status by occupational risk

11.4 **Discussion**

This analysis included novel descriptions of COVID-19 cases by occupational risk, and associations between demographics and occupational risk, to help assess the potential utility of workplace-based vaccine outreach. The lack of association between occupational risk and vaccination status among NHNCW who have acquired COVID-19 suggest that outreach targeting under-vaccinated demographic groups would decrease coverage disparities between occupational groups, but that outreach specific to workers in high-risk environments may aid these efforts.

Vaccination rates by age group in this study sample were lower than citywide rates in the Pre-Omicron period, but similar to vaccination rates during the Post-Omicron period. These findings are unsurprising: the study sample only includes cases. Since vaccination was more protective against pre-Omicron SARS-CoV-2 variants, vaccinated Chicagoans were more under-represented earlier in this study.

The occupation groups with lowest Pre-Omicron vaccination rates in this study were also among the most likely to be vaccine hesitant, in a large online survey of working-age Americans conducted Pre-Omicron (April 20, 2021 through May 19, 2021, N=338,226) (King et al. 2021). King et al. found that respondents working in construction and extraction (35%), installation, maintenance and repair (29%), protective service (26%), and transportation and material moving (22%) were most likely to say they would “definitely not” be vaccinated against COVID-19. Mistrust of the COVID-19 vaccines and fear of side effects were the most cited reasons across these groups, followed by perceptions of reduced COVID-19 risk (complacency), which could be due to frequent work outdoors among these groups. This speaks to the critical distinction between classifications of occupational risk and conventional occupational groupings: risk can vary within major occupational groups, and not all groups defined as critical infrastructure during the COVID-19 pandemic (Cybersecurity & Infrastructure Security Agency n.d.) consist of occupations that are considered high-risk by the SOEM.

Goldman et al analyzed American Communities Survey and O*NET data to examine demographic distributions of high versus lower-risk occupations (N. Goldman et al. 2021); their analyses of these nationally representative datasets incorporated occupational standing as a proxy for educational attainment, and access to and compliance with risk mitigation measures. (Occupational standing, determined from the ACS as the percentage of all workers within an occupation who have completed at least one year of college education, has been shown to be highly correlated with and more complete than income as an indicator of socioeconomic status (N. Goldman et al. 2021).) Their study found that racial and ethnic minorities were more likely to work in jobs characterized as high risk for workplace exposure to COVID-19, and more likely to be in occupations with lower occupational standing. These findings emphasize the value of workplace-based vaccine promotion initiatives as a mechanism for helping protect workers in higher risk occupations. As illustrated in Figure 36, Appendix D, of five major occupational groups with the most workers at high *occupational* risk for COVID-19 among our sample, four also had high proportions of workers in racial and ethnic minority groups. For example: 83% of NHNCW in building, grounds cleaning and maintenance reported a race-ethnicity other than White, non-Latinx, and 87% of the NHNCW in this occupational group were also classified as high risk following the SOEM.

Due to collinearity with city region, CCVI, which incorporates both income and education level, was excluded from our modeling analyses. Including disaggregated neighborhood-level cofounders (such as education) or using other social vulnerability indices such as those devised by the CDC (Centers for Disease Control and Prevention 2022c) and University of Illinois at Chicago (Kim, Sage n.d.), being less correlated with *a priori* specified covariates included in these indices, might have more appropriately controlled for socioeconomic status. Region was chosen over CCVI for inclusion in modeling because it is more conducive to operationalizing findings about geographic disparities: Chicago has designated public health partners to address needs defined by Healthy Chicago Equity Zone. Mixed-effect models describing associations within six (large) city regions may not have been not sufficiently granular to capture geographic clustering among cases (compared to modeling by community level or census tract, for example), resulting in fixed effect models showing superior fit.

11.4.1 **Strengths and Limitations**

A lack of occupation data included in broader COVID-19 laboratory and vaccination datasets is a major limitation these analyses. While case investigations provide a rich data source for describing Chicagoans who have contracted COVID-19, restriction to a case-based sample introduces several biases. Chicagoans with natural or vaccine-induced immunity were less likely to contract COVID-19 and thus less likely to be represented in the sample, especially pre-Omicron, when vaccines offered greater protection against predominantly circulating variants. Only laboratory-confirmed cases were contacted for interview by CDPH, and only those who completed interviews and disclosed occupation could be included in our analyses. These criteria over-represented subgroups who were more likely to practice health-seeking behavior. NHNCW in this study may also have been more likely than other NHNCW to comply with vaccine recommendations, resulting in non-differential overestimation of vaccination coverage, biasing results toward the null. Similarly, they also may have been more likely to access testing, or undergo routine testing (e.g., if required by employers, though the frequency of workplace-required testing among Chicago businesses is not known). This might explain the increasing proportions of cases among women, residents of more affluent regions (e.g., North and Central Chicago), those in lower-vulnerability areas and lower-risk occupations. The observed increases in cases working in office settings in the Post-Omicron period are consistent with over-representation of offices among the workplaces reporting clusters and outbreaks to CDPH in the Post-Omicron period (Lendacki et al. 2023), similarly attributable to changes in testing and reporting behavior. Table XXX, Appendix D compares the demographics of interviewed cases with complete, missing or indeterminate occupation data, by period. In both periods, cases with complete occupation data were more likely to be vaccinated. Cases with complete occupation data were also more likely to be in the 30-49-year age groups, and cases with incomplete or missing occupation data were more likely to be younger (18-29), both differences that became more prominent in the Post-Omicron period. In the Pre-Omicron period, cases with missing or incomplete data were more likely to be female. Differences by sex were not observed in the Post-Omicron period, but differences by race/ethnicity and city region increased: White, Non-Latinx, and cases from West and low-vulnerability areas were over-represented among cases with complete data; Black, non-Latinx and Latinx, cases from the Southwest and South regions and areas with very high CCV were under-represented.

As cited in SOEM documentation, the occupational risk defined in the SOEM is specific to risk of *on-site* work in 2020. While this is more germane to a discussion of the validity of the SOEM in prediction of workplace-related SARS-CoV-2 infection, it also implies that occupational risk may be over-estimated in the study sample for those working remotely, or in workplaces that have implemented other infection prevention strategies (e.g., masking, physical distancing, increased work outdoors) during this study period. Nonetheless, this SOEM enables more precise classification of workplace-related risk for COVID-19 than general methodologies less specific to SARS-CoV-2 transmission mechanisms (Zhang 2021).

The proportion of cases who have been vaccinated may have been under-estimated through reliance on I-CARE alone: I-CARE is not a comprehensive vaccination record and does not receive data from federal vaccine registries or capture vaccinations administered out of state. This might have differentially under-estimated coverage among groups such as protective service who have been vaccinated largely through federal efforts. Recommendations regarding time to first booster eligibility changed during the Post-Omicron study period, including by vaccine manufacturer (Pfizer or Moderna). To increase precision of vaccination definitions for sensitivity analyses, cases were classified as up-to-date according to recommendations on the date of positive test and by manufacturer of initial vaccine series received. However, analyses could not account for earlier eligibility or additional recommendations based on individual comorbidities and may have under-estimated proportions of cases who were not up-to-date with booster doses. Despite these caveats, identification of workers who were not up-to-date with boosters supplemented analyses of completed initial vaccination alone, given the increased protection of boosters against COVID-19-related hospitalization and death.

11.4.2 **Aim 2 Conclusions**

To our knowledge, this is the first application of the CSTE SOEM to descriptions of COVID-19 cases among workers in the Post-Omicron period, and the first to use this framework to examine associations between occupational risk and vaccination status. Our findings suggest that disparities in vaccination among NHNCW working in high-risk environments are attributable to coverage gaps among demographic groups that comprise these occupations. Workplace-based outreach may offer another mechanism for increasing coverage among younger workers, those from racial and ethnic minority groups and under-vaccinated regions in Chicago. Immunization records should include collection of industry and occupation data, to help identify industries and occupations with low coverage rates and enable evaluation of workplace-based interventions to reduce these disparities.

12. AIM 3 FINDINGS: WEVAX SURVEY OF COVID-19 VACCINATION REQUIREMENTS, ENCOURAGEMENT AND HESITANCY AMONG NON-HEALTHCARE, NON-CONGREGATE WORKPLACES IN CHICAGO

12.1 Introduction

As the COVID-19 pandemic has continued, vaccinations have proven critical to prevention of severe illness, hospitalization, and death. Recognizing the associations between workplace exposure and likelihood of contracting COVID-19, the Advisory Committee on Immunization Practices (ACIP) recommended that employees in critical infrastructure and highest-risk industries be prioritized for vaccination (McClung 2020). In March 2021, the U.S. Cybersecurity & Infrastructure Security Agency (CISA) cited vaccine hesitancy among these workers as detrimental to both the nationwide vaccine rollout and the continued functioning of the U.S. critical infrastructure (Cybersecurity & Infrastructure Security Agency 2021).

The World Health Organization has defined vaccine hesitancy as “a delay or refusal to accept vaccines” despite their availability (World Health Organization 2014), with a “3’C’s” framework characterizing reasons as related to (1) a lack of confidence in vaccines (2) inconvenience of being vaccinated, and (3) complacency about needing vaccination. While most studies of COVID-19 vaccine hesitancy by occupation have focused on healthcare workers, nationally-representative surveys conducted during early vaccine availability (March through June 2021) measured vaccine coverage and intent specifically among frontline essential and other non-healthcare workers (Nguyen et al. 2021; Evelyn Bellew et al. 2021)Overall, these studies identified a lack of vaccine confidence (concerns of side effects, safety, and vaccine ineffectiveness) as an overarching reason for vaccine hesitancy; they cited that strategies to increase convenience of vaccination (providing on-site vaccination, or paid time off for vaccination and recovery) have potential to increase vaccination. At the time of this report, coverage rates remain sub-optimal among working-age Americans, despite broad availability of three FDA-approved COVID-19 vaccines, and updated evaluations of strategies to increase coverage are needed.

Given the continuing need to inform vaccine promotion initiatives, the Chicago Department of Public Health (CDPH) conducted a study of workplace encouragement for COVID-19 vaccination (“WEVax Chicago”) from July - September of 2022. The survey aimed to describe frequency of vaccination requirements, encouragement strategies and persisting challenges to uptake among non-healthcare workplaces of varying sizes and industries throughout Chicago. This report summarizes the survey’s findings and implications for future research to improve vaccination coverage among non-healthcare workers.

12.2 **Methods**

12.2.1 **Study Design, Inclusion and Exclusion Criteria, Recruitment**

The Workplace Encouragement for COVID-19 Vaccination in Chicago (WEVax Chicago) survey was a cross-sectional survey administered through REDCap (Harris et al. 2019) from July 11 through September 12, 2022, among businesses with at least one location in Chicago. The study excluded businesses classified as healthcare-related, government, or based in congregate settings (e.g., long-term care facilities, educational and childcare settings, shelters, and correctional facilities), given vaccination requirements and rollout strategies specific to these (Illinois Department of Public Health n.d.; Centers for Disease Control and Prevention n.d.; Illinois Department of Public Health 2021; Centers for Disease Control and Prevention 2020b). Survey respondents are thus described as non-healthcare, non-congregate workplaces (NHNCW) for the remainder of this report. NHNCW were categorized into thirteen industry sectors for sampling, consistent with those used to summarize Chicago’s workplace COVID-19 surveillance data. These included four early eligibility (“1b”) (Food Production and Processing, Factory and Manufacturing, Warehousing and Distribution, Grocery) and nine others (Bars and Restaurants, Construction, Retail, Hotel, Office Settings, Personal Care and Service, Janitorial, Transportation and Other) (City of Chicago n.d.). The sample included 537 businesses that had been previously contacted by CDPH for COVID-19 surveillance and vaccine-related outreach (e.g., follow-up on reported cases or potential workplace-related transmission among employees, or mobile vaccination efforts during early-phase vaccine rollout in Chicago in 2021).

To improve response rate, two CDPH interviewers conducted active recruitment by calling just over one-third (35%, 186/537) of businesses from the initial contact list, chosen through random sampling stratified by industry group for representativeness. Businesses in zip codes with first-dose coverage rates below the citywide average according to CDPH's vaccine dashboards (City of Chicago n.d.) were oversampled for phone outreach. These comprised 38% of all businesses called, and at least two per industry strata except for janitorial and hotel (each with one contact in a low-coverage zip code). Within factory/manufacturing, bars and restaurants, food production/processing, and transportation/warehousing strata, at least half (≥50%) of workplaces called were in low-coverage zip codes. The survey was sent to five businesses during a pilot period the week before deployment for feedback on length, clarity, feasibility, and ease of answering questions. This study was determined to be exempt from review by the Institutional Review Board (IRB) at CDPH (Protocol #22-03).

12.2.1 **Workplace (Business) and Workforce (Employee) Characteristics**

Questions assessing business characteristics mirrored those included in routine COVID-19 workplace assessments administered by CDPH, for comparability. Industry was collected as free-text, per NIOSH recommendations (Centers for Disease Control and Prevention 2020e) ("How would you describe your primary type of business or industry?"). With closed-ended response categories, respondents were asked to indicate whether describing employees of multi-location businesses, or a single-location business (in which case zip code was also collected). Total full-time and part-time staff, proportion working off-site at time of survey, primary languages spoken, and availability of employer-sponsored health insurance were collected. (In this report, part-time or other temporary/contract staff are referred to collectively as “part-time staff’.) Workforce race and ethnicity data are not included, due to concerns around inaccuracies and missingness in reported data, potentially stemming from reluctance of businesses to disclose in relation to COVID.

12.2.2 **Estimation of COVID-19 Vaccine Coverage among Employees**

A definition of terms preceded the vaccination requirements section of the survey. “Primary series” of COVID-19 vaccination was defined as “the doses recommended for individuals to be considered "fully vaccinated" against COVID-19”. During the survey period, this included: (1) 2 doses of Pfizer-BioNTech given 3–8 weeks apart, (2) 2 doses of Moderna given 4–8 weeks apart, or (3) 1 dose of Johnson & Johnson’s Janssen vaccine. This survey was conducted before the availability of updated (“bivalent”) boosters, so did not distinguish between original and newer-formulation booster doses when assessing proportions of boosted employees. Businesses were asked to report employee vaccination and booster rates or the number of employees who had received their primary series and any booster doses. Among businesses that specified numbers instead of proportions of employees who were fully vaccinated and boosted, vaccination rates were calculated from reported total numbers of employees. Due to the small sample and degrees of missingness, rates were maintained as a categorical variable (lower vaccination coverage (≤75%), higher vaccination coverage (>75%), missing).

12.2.3 **Vaccine Requirement, Encouragement Strategies and Barriers**

Businesses were asked if they required employees to be (1) fully vaccinated and/or (2) boosted as eligible, and if vaccination status was verified. The survey also assessed any use of eight other strategies derived from CISA guidance for vaccine encouragement among essential workers (offering on-site vaccination, paid time off for vaccination or side effects, monetary or other incentive for vaccination, use of workplace signage or other communication tools to promote vaccination, training for staff to serve as vaccine ambassadors, and townhalls or information sessions to promote vaccination among workers) (Cybersecurity & Infrastructure Security Agency 2021). Free-text sections allowed respondents to describe other strategies and challenges to vaccine encouragement among employees.

12.2.4 **Analytic and Statistical Methods**

All analyses were conducted using SAS v9.4.Vaccine eligibility was defined dichotomously by City-designated industry group, as frontline essential/early eligibility for vaccine (“1b”, beginning January 25, 2021) (City of Chicago n.d.) or other. While essential workers not included in 1b may have been vaccinated in the 1c phase preceding broad (“Phase 2”) eligibility in Chicago, most 1c and Phase 2 workers were vaccinated in the same period (April through June 2021), compared to 1b workers (February and March 2021). To aid comparison with findings from other jurisdictions, NIOSH’s Industry and Occupation Computerized Coding System (NIOCCS) was also used to categorize free-text industry descriptions into one of 27 major groupings per the North American Industry Classification System (NAICS) (Centers for Disease Control and Prevention n.d.). Business size was defined categorically from total number of staff. Zip codes were used to classify single-location businesses by city region, consistent with the conventions used by other City departments for planning purposes and resource allocation.

Use of each encouragement strategy was dichotomized (any or never) for primary series and/or boosters, and among full-time and part-time employees separately. Mean (with standard deviation, SD) and median (with interquartile range, IQR) numbers of strategies reported per workplace were calculated. Bivariate analyses with Fisher’s exact test compared coverage rates (higher versus lower) among workplaces reporting and not reporting use of each strategy. The Kruskal-Wallis test compared distributions of the *number* of strategies reported by workplaces in each coverage group. The hypotheses for these comparisons were (1) that businesses reporting use of encouragement strategies would also report higher coverage, and (2) that high-coverage workplaces would report using a greater number of vaccine encouragement strategies.

Thematic analyses of barriers to vaccine encouragement reported in free text responses utilized a deductive approach: encouragement practices and barriers were classified using the "3C's" model of factors of vaccine hesitancy (complacency, confidence, and convenience) (World Health Organization 2014). Factors related to confidence included safety (side effects), medical conditions or provider advice, other mistrust or anxiety (e.g., related to efficacy, government mistrust, philosophical or religious objections). Factors related to convenience included being too busy or lacking access (perceived cost, transportation, difficulty finding providers). Factors of complacency included workers not feeling the vaccine was necessary, or perceiving that prior infection would be sufficiently protective against future COVID-19 infection.

12.3 **Results**

12.3.1 **Characteristics of WEVax Survey Respondents and Workforce**

From July 11 through September 12, 2022, survey response rates were 9% (49/537) among e-mailed contacts, and 11% (21/186) among those called directly by CDPH; 1 additional respondent was recruited through social media. Among 50 respondents, 1 out-of-jurisdiction business was excluded. The final sample (n=49) is described by workplace type and coverage rate in Figure 31, and by other characteristics in Table XVI (NAICS classifications are in Table XXXI, Appendix E). About one-third (n=17, 35%) were in 1b industries. Most businesses were in Central Chicago (n=15, 31%) or West Chicago (n=14, 29%). Half had < 100 employees (n=25, 51%). Three quarters (n=36, 73%) said most staff were on-site. Spanish was the second most frequently reported primary language among employees (n=24, 49%) after English (n=46, 94%). Almost all (n=46, 94%) reported sponsoring health insurance for full-time employees).

12.3.2 **Employee Vaccination Requirements and Coverage**

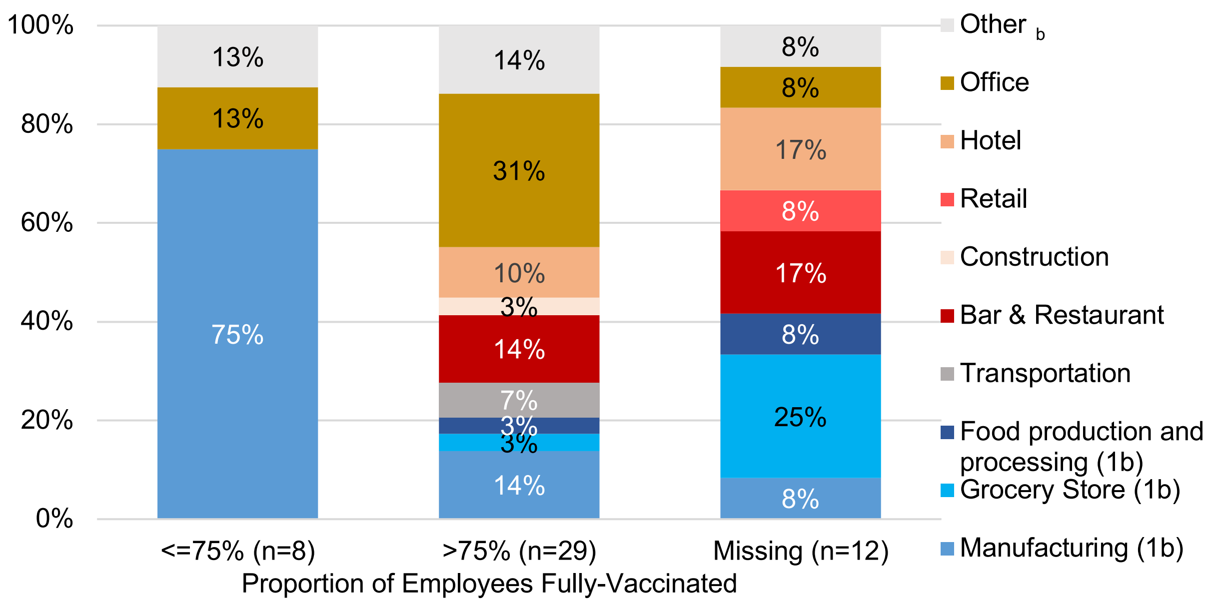
Distributions of COVID-19 vaccine coverage estimates are shown in Table XVII. Most businesses (n=29/49, 59%) reported high rates of full vaccination among full-time staff. The 8 workplaces reporting that 75% or fewer full-time staff were fully vaccinated were geographically diverse (Table 1); most were (non-food) manufacturing facilities (n=6, 75%) and had fewer than 100 full-time employees (n=5, 63%). Due to high levels of missing data, subsequent sections of this report focus on full vaccination and encouragement among full-time employees only; data on part-time employees are described in supplemental content (Table XXXII, Appendix E).

12.3.3 **Vaccination Requirement and Encouragement Strategies**

Frequencies of vaccine encouragement strategies are summarized in Figure 32. Less than one third (n=14, 28%) of businesses reported ever requiring employees to be vaccinated against COVID-19. Verifying vaccination was more common (n=25, 51%). All 14 businesses requiring vaccination and 11 others ever verified vaccination. Of those, 5 (20%) reported still doing so at the time of the survey. Providing time off to recover from side effects (n=35, 71%), or to get vaccinated (n=34, 69%) were the most frequently reported strategies, followed by use of promotional signage and communication (n=31, 63%). Fifteen businesses (30%) reported offering vaccine on-site; 12 (24%) reported organizing informational townhalls, 7 (14%) offered monetary incentives, 5 (10%) reported training staff as vaccine ambassadors. Eleven (22%) described other strategies aimed at convenience (sign-up or transportation, vaccine events with neighboring companies and at city-run sites). Non-monetary incentives included access to work-related social events and prioritization for job openings. Some respondents said employees got vaccinated to comply with requirements at client sites, or to protect coworkers. Bivariate analyses of strategies reported among high versus lower-coverage workplaces are shown in Table XVIII. Thirteen of 14 (93%) businesses requiring full vaccination also reported high coverage, compared to 16 of 33 (49%) without this requirement (p=0.03).

TABLE XVI. DEMOGRAPHICS OF WEVAX CHICAGO SURVEY RESPONDENTS (N=49), OVERALL AND BY ESTIMATED COVERAGE RATE AMONG FULL-TIME EMPLOYEES

		% Full-time employees fully vaccinated		
	All (N=49)	**<=75% (n=8)**	**>75% (n=29)**	**Missing (n=12)**
	n (%)	n (%)	n (%)	n (%)
Eligibility phase				
1b (early)	17 (34.6)	6 (75.0)	6 (20.6)	5 (41.6)
Other	32 (65.3)	2 (25.0)	23 (79.3)	7 (58.3)
City region				
Central	15 (30.6)	2 (25.0)	10 (34.4)	3 (25.0)
West	14 (28.5)	2 (25.0)	10 (34.4)	2 (16.6)
Northwest	7 (14.2)	2 (25.0)	4 (13.7)	1 (8.3)
North	5 (10.2)	1 (12.5)	3 (10.3)	1 (8.3)
Southwest	4 (8.1)	0 (–)	1 (3.4)	3 (25.0)
Far South	2 (4.0)	1 (12.5)	1 (3.4)	0 (–)
Multiple	1 (2.0)	0 (–)	0 (–)	1 (8.3)
Unknown	1 (2.0)	0 (–)	0 (–)	1 (8.3)
Workplace size				
Fewer than 100	25 (51.0)	5 (62.5)	15 (51.7)	5 (41.6)
100-500	17 (34.6)	2 (25.0)	12 (41.3)	3 (25.0)
Over 500 employees	5 (10.2)	1 (12.5)	2 (6.8)	2 (16.6)
Unknown	2 (4.0)	0 (–)	0 (–)	2 (16.6)
Proportion teleworking				
0	21 (42.8)	5 (62.5)	10 (34.4)	6 (50.0)
1-25%	15 (30.6)	1 (12.5)	10 (34.4)	4 (33.3)
26-50%	1 (2.0)	0 (–)	1 (3.4)	0 (–)
51-75%	2 (4.0)	0 (–)	2 (6.8)	0 (–)
76-99%	4 (8.1)	1 (12.5)	3 (10.3)	0 (–)
100% (all employees)	4 (8.1)	1 (12.5)	3 (10.3)	0 (–)
NA or do not know	2 (4.0)	0 (–)	0 0.0	2 (16.6)
Primary languages spoken in workplace				
English	46 (93.8)	8 (100.0)	29 (100.0)	9 (75.0)
Spanish	24 (48.9)	3 (37.5)	13 (44.8)	8 (66.6)
Polish	4 (8.1)	1 (12.5)	3 (10.3)	0 (–)
Arabic	3 (6.1)	1 (12.5)	1 (3.4)	1 (8.3)
Chinese (including Mandarin and Cantonese)	4 (8.1)	0 (–)	3 (10.3)	1 (8.3)
Tagalog	1 (2.0)	0 (–)	1 (3.4)	0 (–)
Employer-sponsored health insurance				
For full-time employees	42 (85.7)	8 (90)	26 (89.6)	10 (83.3)
For both full-time and part-time employees	2 (4.0)	0 (–)	2 (6.8)	0 (–)
No	1 (2.0)	0 (–)	1 (3.4)	0 (–)
Unknown	2 (4.0)	1 (12.5)	1 (3.4)	2 (16.6)
Location types				
Single (only) location	27 (55.1)	5 (62.5)	16 (55.1)	6 (50.0)
Multiple locations, combined	13 (26.5)	1 (12.5)	6 (20.6)	6 (50.0)
One of multiple	9 (18.3)	2 (25.0)	7 (24.1)	0 (–)



[a] *"Vaccination rate": reported rates of full vaccination (initial series) among full-time employees only.*

[b] *"Other" workplaces (n=6) included: 3 performing arts and 1 veterinary in high coverage group, 2 utilities (1 low coverage, 1 missing coverage data)*

Figure 31. WEVax Chicago survey respondents (n=49), workplace type by vaccination rate[a]

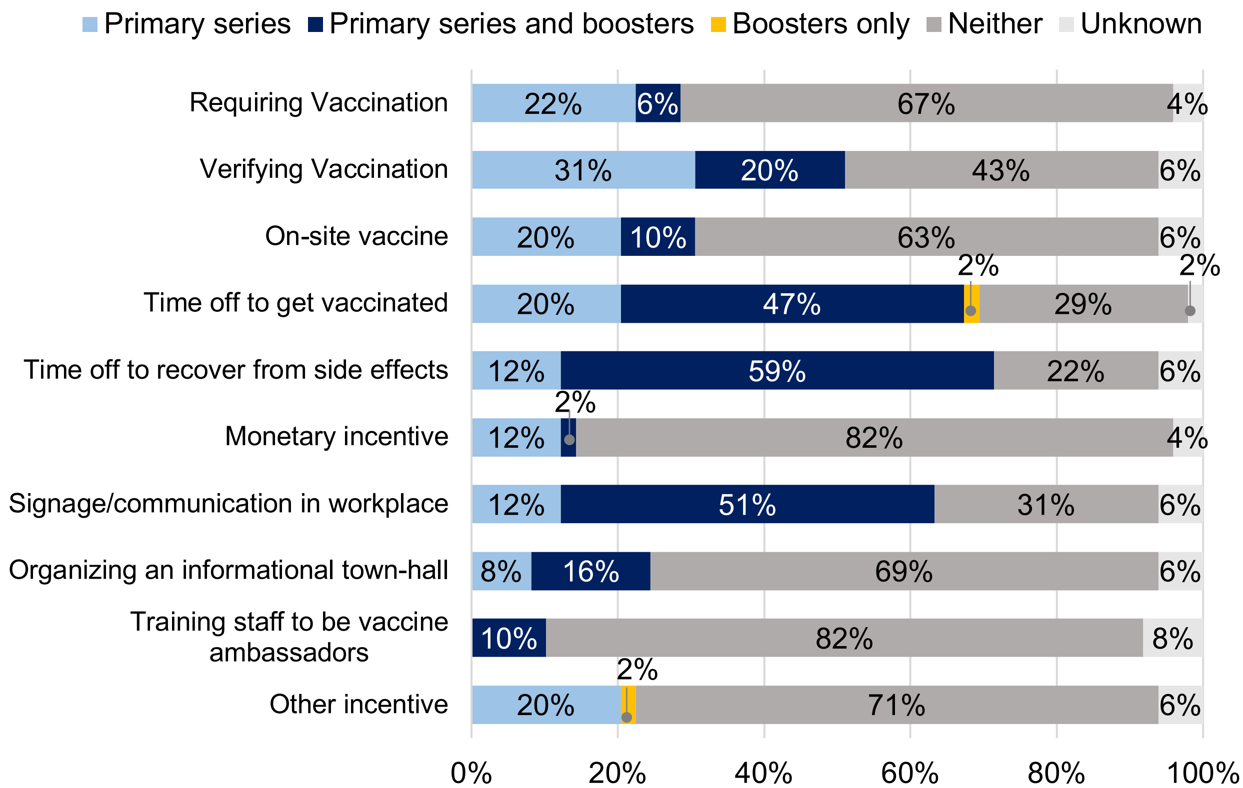
TABLE XVII. ESTIMATED COVID-19 VACCINATION COVERAGE AMONG FULL-TIME AND PART-TIME WORKERS AMONG WEVAX CHICAGO SURVEY RESPONDENTS (N=49)

		Full-time (n=49)[a] n (% of non-missing)	Part-time or other (n=37)[b] n (% of non-missing)
Primary series	0%	0 (-)	1 (4.2)
	1-25%	0 (-)	0 (-)
	26-50%	6 (16.2)	2 (8.3)
	51-75%	2 (5.4)	1 (4.2)
	76-99%	21 (56.8)	10 (41.7)
	100%	8 (21.6)	10 (41.7)
Any boosters	0%	1 (3.4)	1 (5.9)
	1-25%	3 (10.3)	0 (-)
	26-50%	8 (27.6)	5 (29.4)
	51-75%	7 (24.1)	1 (5.9)
	76-99%	5 (17.2)	3 (17.6)
	100%	5 (17.2)	7 (41.2)

[a]*Number of businesses missing COVID-19 vaccination rate estimates for full-time employees: n=12 for primary series (24.5%), n=20 for boosters (40.8%)*

[b]*Number of businesses missing COVID-19 vaccination rate estimates for part-time or other employees: n=13 for primary series (35.1%), n=20 for boosters (54.1%)*

Among businesses that reported verifying vaccination, almost all had high coverage rates (n=21/25, 84%), compared to 8/21 (38%) among businesses that never verified vaccination (p=0.07). Most businesses missing coverage data (8/12 missing rates of vaccination among full-time employees) reported not verifying vaccination. Lower-coverage workplaces reported a slightly higher median number of encouragement strategies compared to higher-coverage and those missing data (p=0.12).



Other incentives reported (n=10) included hiring preference for vaccinated candidates (among a highly vaccinated business), appointment assistance at city vaccination sites (among a low-vaccinated business), details were missing for one respondent.

Figure 32.Strategies to encourage employee COVID-19 vaccination among WEVax Chicago survey respondents (n=49).

TABLE XVIII. STRATEGIES TO ENCOURAGE EMPLOYEE COVID-19 VACCINATION AMONG WEVAX CHICAGO SURVEY RESPONDENTS, OVERALL AND BY COVERAGE RATE (N=49)

	% Full-time staff fully vaccinated			
	<=75% (n=8) n, (%)	**>75% (n=29)** n, (%)	**Missing (n=12)** n, (%)	*p* value[a]
Require vaccination				
Yes	0 (-)	13 (92.9)	1 (7.1)	0.03
No	8 (24.2)	16 (48.5)	9 (27.3)	
Unknown	0 (-)	0 (-)	2 (100)	
Verify vaccination status				
Yes	2 (8.0)	21 (84)	2 (8.0)	0.07
No	5 (23.8)	8 (38.1)	8 (38.1)	
Unknown	1 (33.3)	0 (-)	2 (66.7)	
On-site vaccine [b]				
Yes	4 (26.7)	7 (46.7)	4 (26.7)	0.23
No	4 (12.9)	20 (64.5)	7 (22.6)	
Paid time off to vaccinate				
Yes	6 (18.2)	19 (57.6)	8 (24.2)	1.0
No	2 (13.3)	10 (66.7)	3 (20)	
Paid time off to recover				
Yes	8 (22.9)	21 (60)	6 (17.1)	0.31
No	0 (-)	7 (63.6)	4 (36.3)	
Monetary				
Yes	1 (14.3)	5 (71.4)	1 (14.3)	1.0
No	7 (17.5)	24 (60)	9 (22.5)	
Workplace signage				
Yes	6 (19.4)	19 (61.3)	6 (19.4)	1.0
No	2(13.3)	9 (60)	4 (26.7)	
Vaccine ambassadors				
Yes	1 (20)	3 (60)	1 (20)	1.0
No	7 (17.5)	25 (62.5)	8 (20)	
Townhalls				
Yes	4 (33.3)	7 (58.3)	1 (8.3)	0.20
No	4 (11.8)	22 (64.7)	8 (23.5)	
Other incentives[c]				
Yes	0 (10.0)	7 (70.0)	2 (20.0)	0.31
No	8 (21.6)	21 (56.8)	8 (21.6)	
Unknown	0 (-)	1 (33.3)	2 (66.7)	
Number strategies				
Mean (SD)	3.75 (1.7)	3.0 (1.5)	2.4 (0.9)	0.12
Median (IQR)	4 (2-5)	3 (2-4)	2 (2-3)	

[a]*p-values from Fisher's exact test except comparing number of strategies reported (Kruskal-Wallis)*

[b]*Data missing on use of on-site vaccine, signage, townhalls (n=3, 6% each), time off to be vaccinated (n=1, 2%) or recover (n=3, 6%), monetary incentive (n=2, 4%), vaccine ambassadors (n=4, 8%)*

[c]*Other incentives (among highly-vaccinated business): conversations, access to work-sponsored social events, (missing coverage levels): hiring preference for vaccinated candidates*

12.3.4 **Vaccination Barriers, Challenges and Hesitancy**

From free text responses, multiple businesses reported that requiring vaccination was a challenge given already-existing difficulties with employee retention and unwillingness to end teleworking. Among descriptions of other barriers to encouragement of employee vaccination (Table XIX), the primary theme was a lack of confidence in vaccines. One company cited complacency among employees who had already recovered from COVID-19 infection.

TABLE XIX. REASONS FOR COVID-19 VACCINE HESISTANCY AMONG EMPLOYEES, AS REPORTED BY BUSINESSES RESPONDING TO WEVAX CHICAGO SURVEY (N=49)

Theme	**Subcategories**	Examples

Confidence	**Safety**	• Fear of side effects
		  ◦ Perceptions of mRNA vaccines as unsafe compared to older vaccines
		  ◦ Claims that family members died soon after receiving vaccine

	Other mistrust, skepticism, or anxiety	• Feeling that vaccination is too politicized (government mistrust) • Hesitancy to work at a company that requires vaccination • Misinformation about life insurance policy cancellation • Conspiracies of vaccines containing implanted devices • Religious objections • Disbelief that COVID-19 is real • Skepticism of frequently-changing CDC guidance
Complacency	**Already had COVID-19**	• Belief that natural immunity obviates need to vaccinate

12.4 **Discussion**

The WEVax survey had three major findings regarding (1) vaccine requirements, 2) encouragement strategies, and 3) persisting barriers to workforce vaccination. Having a requirement for employee vaccination appeared to be associated with greater likelihood of achieving high vaccination coverage rates. Almost all respondents indicated use of multiple strategies for encouragement of vaccination, usually to increase the convenience of vaccination (offering time off to be vaccinated or recover, providing transportation, facilitating appointments). While themes of reported vaccine hesitancy centered around low vaccine confidence (personal concerns of vaccine safety, misinformation, and other skepticism among workers), initiatives to improve confidence and reduce complacency (vaccine ambassador training, informational town halls) were the least-frequently reported by WEVax survey respondents. Respondents did not indicate reasons for not employing these strategies, and barriers to their use have not been widely reported. In their summary of six virtual town halls encouraging COVID-19 vaccination among racial and ethnic minority groups in South Florida, Wagner et al noted that these efforts were resource intensive and may have resulted in only small increases in likelihood to vaccinate among a highly-vaccinated population (Wagner et al. 2022).

Though not collected concomitantly with the WEVax survey, individual-level CICT data collected by CDPH from June 2021 -May 2022 (Figure 37, Appendix E) echo our findings. Vaccine confidence and misinformation about vaccine safety were identified as primary reasons for hesitancy, while inconvenience was reported far less frequently and decreasingly over time. This is important because it suggests that the encouragement strategies reported by workplaces may not directly address prevailing reasons for hesitancy as described by both workplaces and working-age Chicagoans. Furthermore, 41% of unvaccinated working-age Chicagoans refused to specify reasons for *not* vaccinating, suggesting that assessment of potential *motivators* (e.g. – “what would it take for you to change your mind about being vaccinated for COVID-19”?) instead of barriers alone may generate more actionable data for increasing coverage rates among NHNCW. For example, the longitudinal HEROES RECOVER study conducted in 2020 found that increases in COVID-19 vaccine knowledge, safety and effectiveness were positively associated with intent to vaccinate among essential workers (Lutrick et al. 2022). In their 2021 report, Nguyen et al. also described top motivators for COVID-19 vaccination by worker group (Nguyen et al. 2021). Among non-healthcare frontline workers, the most frequently specified motivators were more data on vaccine effectiveness (29%) and safety (37%), workplace vaccination requirements (27%), and prevention of transmission to family and friends (31%) or in the community (21%), with similar findings among other non-healthcare workers. COVID-19 vaccines have received FDA approval since these studies have been conducted, and hospitalization and mortality rates have decreased substantially. Updated assessments could elucidate whether vaccine effectiveness, safety, and desire to protect others should still be considered key motivators for vaccination, or whether other messaging may be more effective at this phase of the pandemic.

12.4.1 **Strengths and Limitations**

The WEVax study was limited by low response rate, though direct outreach by phone increased responsiveness. Low-coverage regions were underrepresented despite oversampling. The regional coverage data used to inform this sampling, representative of residents, may not have been representative of workplaces in those regions. It is also possible that workplaces that are less promotive of workplace vaccination (whether by requirement or incentivization) or with poor coverage rates were less likely to participate. In addition, selection bias may have resulted in overestimates of high vaccine coverage and encouragement strategies used, since contact lists were comprised of businesses already willing to engage with CDPH for COVID-19 vaccination and prevention efforts. Survey data were subject to recall limitation, in that respondents may not have remembered (or been present for) encouragement strategies practiced by their workplaces previously. Differential misclassification may have occurred among businesses that reported never verifying vaccination status; these had greater missingness of coverage data (n=8 or 38% compared to n=2 or 8% among those who checked vaccination status). Incomplete data on workforce demographics prevented identification of demographic groups that would benefit from targeted workplace-based messaging and outreach to improve vaccination.

Though limited, results from the WEVax survey may be useful in informing larger studies, and among small business outreach organizations like BACP in Chicago: 85% of respondents were small businesses (500 or fewer employees). The finding that higher-coverage workplaces reported a lower median number of encouragement strategies suggests that specific types of strategies, such as vaccine requirement and verification, are more strongly associated with increased coverage than others; use of more strategies is not necessarily associated with higher coverage. However, the temporality of encouragement strategies and vaccine coverage cannot be established given the cross-sectional nature of the survey. Larger prospective studies including a greater proportion of under-vaccinated workplaces could provide insights into approaches that have been differentially successful in highly vaccinated settings. These and future efforts to describe vaccine hesitancy at the individual level should include standardized collection of industry and occupation information, to facilitate classification (e.g., using NIOCCS) and stratification to describe NHNCW specifically.

Frequent allotment of time off to be vaccinated or recover from vaccination is unsurprising, given Chicago's Vaccine Anti-Retaliation Ordinance passed in March 2021 (City of Chicago n.d.): businesses must allow workers to use allotted sick time or paid time off to be vaccinated against COVID-19, and those requiring employee vaccination must provide paid time off for employees to be vaccinated. Infrequent vaccination requirement is consistent with updated data from the KFF Vaccine Monitor Survey (April 13-26, 2022), indicating that only 40% of respondents said their workplaces required vaccines after withdrawal of federal vaccine mandates in January 2022. The WEVax survey did not ask respondents to specify the amount of any monetary incentives offered. A 2021 study conducted at a large manufacturing company in Minnesota found that from August through September 2021, a substantial ($1000) financial incentive increased employee vaccination rates from 76% to 86%, citing the limitations of no control group, and FDA-approval of the Pfizer vaccine during the study period (Georgiou, Chang, and Karaca-Mandic 2022). Such incentives are not likely to be sustainable among smaller workplaces, or to outweigh all skepticism about safety and intention of vaccination efforts to combat COVID-19. A lack of other available data evaluating encouragement among non-healthcare workplaces in the U.S. highlights the need for future studies in these areas.

While the Center for Medicare and Medicaid Services vaccine mandate for healthcare workers was upheld by court challenges, the U.S. Supreme Court overturned OSHA's emergency temporary standard for healthcare which required not only vaccines, but also masking and regular testing; the Supreme Court also disallowed these requirements for nonhealthcare workers. This study demonstrates the practices of, likely, the most compliant companies in Chicago, and is instructive of what to expect without a national mandate for employers.

12.4.2 **Conclusions**

Most workplaces that responded to the WEVax survey reported high vaccination coverage against COVID-19, use of workplace communication to promote vaccination, and multiple strategies to increase convenience of getting vaccinated. Persisting vaccine mistrust and safety concerns were found to be greater barriers to vaccination than convenience among working-age Chicagoans in both workplace and individual-level analyses. Requirement and verification of vaccination were more common among high-coverage workplaces. Future studies to identify mechanisms for increasing vaccination among workers should include, at minimum, increased recruitment of low-coverage workplaces and assessment of potential motivators (in addition to barriers) among unvaccinated workers.

13. CONCLUSIONS

13.1 Introduction

The goals of this dissertation were to generate information related to workplace-based COVID-19 surveillance, controls, and vaccination promotion among workers outside of healthcare and congregate settings in Chicago. The COVID-19 pandemic has demonstrated the association between work and disease risk among workers and their communities, as well as opportunities to mitigate such risk through workplace-level public health intervention. However, as this dissertation has described, the pandemic has also illuminated the discrepancies between the occupation-related data that are collected in public health practice, and the data that are necessary to quantify and help control disease burden among workers (Armenti et al. 2023). This chapter summarizes findings across aims, before detailing limitations and failed components. Finally, additional epidemiological considerations and implications for future studies are described.

13.2 Summary of Findings

Aim 1's workplace-level characterizations of cluster and outbreak investigations among NHNCW in Chicago suggested that industry-based vaccination strategies did reduce COVID-19 burden among workplaces prioritized as 'higher risk'. The hypotheses for this aim, that (1) investigations among non-essential, lower-risk workplaces would increase, and that (2) median numbers of associated cases, hospitalization and mortality rates would decrease were supported. However, study findings were heavily influenced by changes in workplace and individual-level COVID-19 surveillance as the pandemic progressed, in addition to the re-opening of businesses and the introduction of vaccination.

Aim 2 found that after adjusting for demographics, younger NHNCW in higher-risk work environments did have greater odds of being unvaccinated at COVID-19 infection, only during the Pre-Omicron period; during the Post-Omicron period, no association was found between workplace risk and vaccination status. Characterizations of NHNCW by occupational risk and demographics indicated that disparities in vaccination among higher-risk workers, as observed in the Pre-Omicron period, were attributable to coverage gaps among younger, Latinx and Black-non Latinx workers who tended to comprise higher-risk occupations. This is an example of how identification of a confounded relationship can still be useful for informing public health practice: workplace-based outreach may be an effective complement to initiatives more directly targeting younger age groups, those from racial and ethnic minority groups and under-vaccinated regions in Chicago. Selection bias in these case-level analyses increased over time, and over-represented Chicagoans with more resources to seek testing and report to CDPH: those in lower-risk work environments, lower-vulnerability areas and city regions.

Finally, the WEVax survey conducted in Aim 3 identified types of content that should be prioritized in development of workplace-based COVID-19 vaccine outreach: messaging to address vaccine misinformation, and skepticism about the safety and importance of vaccination. These were the most frequently cited barriers to uptake from perspectives of both employers and working-age Chicagoans. Most workplaces who responded to the WEVax survey, however, reported strategies to increase convenience of being vaccinated, and few reported strategies to address these other reasons for hesitancy. A greater number of encouragement strategies did not correlate with higher workplace vaccination rates among survey respondents; rather, workplaces reporting vaccine verification and/or requirement were more likely to have high employee vaccination rates.

13.3 **Data Limitations and Failed Components**

Additional analyses were proposed as part of this dissertation, but not completed in part due to data limitations, iterated in this section. Case-level descriptive analyses proposed in Aims 1 and 2 included classification of NHNCW by major industry sector and vaccine eligibility phase. Aim 2 analyses of associations between occupational risk and vaccination status at infection were also proposed to model associations between vaccine eligibility phase (as determined by workplace industry) and vaccination status. However, the CICT data available for case-level analyses only included employer name, not industry. As described in Chapter 10, this information directly informs workplace outreach; however, employer name cannot be used to impute industry without further descriptions of industry, or a great deal of manual recoding.

To determine how accurately employer name predicted NAICS codes for major industry sector, 2020 CICT data were submitted to NIOCCS with employer name in place of an industry description (e.g., “McDonald’s”, in place of “Fast Food Service”), and outputs were reviewed manually. Of 1,369 records, 444 required manual recoding, indicating 68% agreement (925/1,369) between manual and computerized coding of industry based on employer name. Restricting this assessment to records with >0.90 probability match (for industry) yielded similar findings, of 71% (674/956) agreement when excluding and 72% (365/1304) when including records coded as unknown/missing industry. This suggests that probability thresholds alone may not help prioritize records for manual review of coding by employer. Such effort-intensive review, including searching online for business descriptions, would not have been feasible for the remainder of 2021 and 2022 case data. Furthermore, some employer names apply to multiple industry sectors (e.g., “United” could correctly correspond to an insurance, transportation, or security-related business in Chicago, without further information describing industry or occupation). As a result, CICT data were not classified by industry or corresponding vaccine eligibility phase in any individual-level analyses.

A second modeling aim proposed exploring the odds of *outbreak association* among NHNCW cases by level of occupational risk. This required supplementing CICT data with additional cases reported to CDPH by employers. However, regardless of how clusters or outbreaks were first identified by CDPH (direct report from businesses, CICT data, public concern), the full lists of investigation-associated cases were usually reported to CDPH directly by employers, who did not specify the occupations of cases. It is expected that most cases reported to CDPH by employers did not subsequently self-report occupation data to CDPH through separate CICT processes. Given the high proportion of CICT records missing occupation data as described in Chapter 11, most outbreak-associated cases (identified by employers and not CICT) would thus have incomplete exposure information (level of occupational risk) to preclude modeling.

To supplement our analyses of COVID-19 outbreaks and clusters by workplace type, Aim 1 also proposed a descriptive analysis of COVID-19 safety assessment data from workplaces investigated by CDPH over time, in part to compare frequencies of preventive strategies (physical distancing, barriers, masking, vaccine verification or requirement) reported by workplaces with vs. without outbreaks. For these and other outbreaks identified through the beginning of October 2020 (29/54 or 54% of all outbreaks), assessments were completed on paper by CDPH outreach personnel when calling businesses. Most of these assessments did not have legible or complete data that could be transcribed accurately to the REDCap database, so could not be compared with later investigations. By excluding them from our analyses, we are unable to describe the work environments of facilities reporting large outbreaks early in the pandemic, or to compare work environments by industry sector in periods before and after guidance was widely issued. Furthermore, workplace-level safety assessments were completed among facilities after outbreaks had been identified (facilities may have closed during outbreaks or otherwise delayed responding to the health department), potentially after facilities had increased their compliance with public health recommendations and preventing accurate characterizations of practices that led to outbreaks.

Table XX describes findings from the REDCap-based facility assessments, completed by workplace representatives directly, or by CDPH during phone discussions with businesses. Facilities rarely indicated non-compliance with OSHA's recommended hierarchy of controls or t public health guidance, especially before vaccines became available. For example, 90% of all assessments (95% before vaccines were available) indicated configuration of work environments for physical distancing, and 96% of all assessments indicated universal masking among workers. It is unsurprising that rates of non-pharmaceutical intervention (physical distancing, barriers) decreased after vaccine availability. However, many workplaces were missing data on vaccine requirement (60%) and verification (77%), preventing assessment of whether vaccination lessened the risk of relaxing other preventive measures. Between-worker exposures (including in carpooling, at mealtimes, when preventive measures are less likely to be practiced) were generally discerned from conversations between workplaces and CDPH, separately from the OSHA assessment. This suggests that reviewing hierarchy of controls with facilities is not always sufficient to explain workplace COVID-19 transmission. In future assessments, standardized collection of data about other employee interactions (shared break areas, carpooling, known exposures outside of work) might be more useful for a) advising businesses on ways to reduce disease transmission and b) developing data-driven guidance for workplace practices.

Finally, the proposal included a descriptive analysis of vaccine hesitancy among NHNCW as part of Aim 3, by vaccine eligibility phase. This was contingent on categorization of cases by industry sector, which was not feasible as discussed previously. Data about vaccine hesitancy among all working-age Chicagoans (i.e., not subset to NHNCW alone) were included in the proposal and supplemental material to aid interpretation of WEVax findings in Chapter 11. As described, 42% of all interviewees refused to specify reasons for not vaccinating. Among those who did specify, safety concerns were the most frequently reported reason overall (26%) and each month since data collection began (21% in June 2021 to 27% in June 2022) (Figure 37, Appendix E). Restriction of the CICT data sample to the small proportion who reported any NHNCW occupation was not expected to yield meaningfully different results than these broader descriptions of all working-age Chicagoans. Moreover, the WEVax survey data were collected more recently than the CICT data, and continued to indicate that vaccine safety concerns, mistrust and skepticism are predominant barriers to vaccination among NHNCW.

TABLE XX. WORKPLACE-LEVEL COVID-19 REDUCTION STRATEGIES REPORTED BY NON-HEALTH CARE, NON-CONGREGATE WORKPLACES IN CHICAGO (N=358)

	All Periods (n=358)	**Partial re-opening, pre-vaccine (n=104)** 6/4/20 – 1/23/21	**Partial re-opening, vaccine rollout (n=135)** 1/24/21 – 6/10/21	**Full re-opening, pre-Omicron (n=60)** 6/11/21 – 12/14/21	**Omicron phase (n=59)** 12/15/21 – 1/31/22
Vaccine requirement[a]					
Yes	11 (9.2%)	–	–	5 (8.3%)	6 (10.2%)
No	37 (31.1%)	–	–	30 (50%)	7 (11.9%)
Unknown	71 (59.7%)	–	–	25 (41.7%)	46 (78%)
Vaccine verification[b]					
Yes	33 (13.0%)	–	1 (0.7%)	23 (38.3%)	9 (15.3%)
No	25 (9.8%)	–	3 (2.2%)	18 (30%)	4 (6.8%)
Unknown	196 (77.2%)	–	131 (97%)	19 (31.7%)	46 (78%)
Sick leave policy					
Yes	322 (89.9%)	102 (98.1%)	109 (80.7%)	53 (88.3%)	58 (98.3%)
No	24 (6.7%)	2 (1.9%)	18 (13.3%)	4 (6.7%)	0 (0%)
Unknown	12 (3.4%)	0 (0%)	8 (5.9%)	3 (5%)	1 (1.7%)
Physical distancing					
Yes	322 (89.9%)	99 (95.2%)	130 (96.3%)	51 (85%)	42 (71.2%)
No	20 (5.6%)	2 (1.9%)	0 (0%)	7 (11.7%)	11 (18.6%)
Unknown	16 (4.5%)	3 (2.9%)	5 (3.7%)	2 (3.3%)	6 (10.2%)
Universal masking					
Yes	344 (96.1%)	100 (96.2%)	131 (97%)	57 (95%)	56 (94.9%)
No	9 (2.5%)	4 (3.8%)	1 (0.7%)	2 (3.3%)	2 (3.4%)
Unknown	5 (1.4%)	0 (0%)	3 (2.2%)	1 (1.7%)	1 (1.7%)
Physical barriers					
Yes	208 (58.1%)	69 (66.3%)	82 (60.7%)	36 (60%)	21 (35.6%)
No	95 (26.5%)	26 (25%)	18 (13.3%)	19 (31.7%)	32 (54.2%)
Unknown	55 (15.4%)	9 (8.7%)	35 (25.9%)	5 (8.3%)	6 (10.2%)

[a] Frequency of vaccine requirement is reported for June 2021 and later, when vaccines were available to all working-age Chicagoans, total n=119 assessments. This under-represents workplaces who may have required vaccination among workers who had early eligibility for vaccination.

[b] Frequency of vaccine verification is reported for January 2021 and later (vaccine availability for 1b, non-healthcare essential workplaces in Chicago), total n=254 assessments.

13.4 **Additional Epidemiologic Considerations**

In Chapter 11, models of the associations between occupational risk and vaccination status had better fit when region was specified as a fixed versus random effect, despite known associations between neighborhood-level factors (such as education level and income) and vaccination against COVID-19. As described briefly in Chapter 11, this could be because the variables for region, informed by Healthy Chicago Equity Zone boundaries, encompass areas with too much overlap of neighborhood-level confounders *within* each. In contrast, alternative sociodemographic indices have described factors such as income and educational attainment by the more granular unit of census tracts, which are defined to represent an average 4,000 residents per population (Proximity One n.d.). Census-tract level data could be crosswalked to approximate respective zip codes (e.g., using tools by the U.S. Department of Housing and Urban Development) for use in datasets such as ours, not already defined at the census tract level) (U.S. Department of Housing and Urban Development n.d.). Because our models were designed to aid region-specific public health agencies, we were interested in findings at each level of the region variable, which could only be generated by specifying region as a fixed effect. While incorporation of a geographic variable as a random effect might have better represented the structure of the data, specification region as a fixed effect may have been more useful for public health planning.

13.5 **Suggestions for Future Studies**

At this phase of the COVID-19 pandemic, outbreak reporting and other surveillance guidelines have been refined to focus on highest-risk settings. Nonetheless, learnings from this dissertation can be applied to future public health responses, when there is a heightened need for broader disease surveillance among workers. For example, recruitment efforts for workplace-based outreach could mirror those used by CDPH to plan industry-specific mobile vaccination events in 2021: contact lists were established based on lists of all city-licensed food and agriculture workplaces, for example. Health departments could issue periodic surveys to workplaces, requesting information about outbreaks that have occurred among on-site workers by occupation, with recurring checklists of mitigations in place. Compared to among the results described in this dissertation, selection bias due to self-reporting would be reduced, and there would be greater potential for timely intervention, compared to when relying on direct reports or complaints of workplace spread that has already occurred. These types of data collection might also enable exploration of associations between workplace practices and contemporaneous occurrence of outbreaks, including by levels of infection control practices implemented.

Analyses of individual-level CICT data as described in Chapter 10 could similarly have been optimized by incorporating lists of workplace names by industry, for more timely metrics of incidence or exposures within specific workplaces, more readily characterized by industry sector. However, representativeness of these data would still be contingent on employees' completion of interview. Two ways to address this limitation are through collecting industry and occupation during patient registration at COVID-19 test sites, or matching reporting employer names to businesses in the State's unemployment insurance database, as other jurisdictions have demonstrated. For example, Pray et al estimated the incidence of COVID-19 among working-age Wisconsin residents by major industry and occupation group (Pray et al. 2022). They reported that, among cases from September 2020 to May 2021, supplementing CICT data with testing and unemployment claims data increased the proportions of records with classifiable occupation data by 16% and classifiable industry data by 23%. Such processes enable more representative comparisons of COVID-19 cases with ACS and other 'denominator' data describing Chicagoans by industry and occupation, for calculation of industry and occupation-specific incidence rates.

While laboratory data have become less representative of the overall case burden over time, they are still relatively representative of hospitalizations, because inpatient testing is captured in I-NEDSS. Incorporation of industry and occupation data into public health surveillance systems would help describe severe COVID cases by occupation and be useful for other communicable disease surveillance. The focus of the COVID-19 pandemic response has shifted away from precise quantification of case burden to identification of unvaccinated populations, emphasizing the value of capturing industry and occupation data in the state immunization record. If this had been done when COVID-19 vaccines were being introduced, “real-time” coverage data by industry or occupation may have been available; this information might have helped identify under-vaccinated groups more quickly, without requiring synthesis of multiple data sources, and without reliance on interviews or survey completion as done in this dissertation.

The WEVax survey might have had a greater response if administered sooner after vaccines were introduced – when workplaces were more actively involved in vaccine promotion and vaccine requirements were in place. As protectiveness of the initial COVID-19 vaccination series decreases and SARS-CoV-2 continues to circulate, there may be a greater need to promote booster doses among on-site workers. However, most WEVax survey respondents did not have complete data on booster doses received among workers. Unless there is emergence of more transmissible or virulent variants, tracking this information may remain a low priority among workplaces. Future studies of vaccination among NHNCW could address this limitation by collecting data from both employers and employees at the same worksites. Employees could complete a survey that collected (1) occupation, (2) demographics and (3) motivation for being vaccinated regardless of vaccination status (i.e. – among unvaccinated, “what would motivate you to be vaccinated”, and among vaccinated, “what motivated you to be vaccinated against COVID-19”), and (4) exposure to promotion strategies offered by their workplace. At the same time, employers would be asked to report (1) industry, and (2) strategies utilized to encourage employee vaccination. This design would enable measurement of motivators among vaccinated vs. unvaccinated populations, and associations between employer-based strategies and coverage rates among employees, including by occupational group and industry.

13.6 **Final Conclusions**

This dissertation highlighted the importance of industry and occupation data in both the identification of workers with high burden of COVID-19, and the evaluation of related interventions. It also helped illustrate the utility of diverse surveillance practices for monitoring work-related infections through multiple phases of a pandemic. Finally, it described how workplace-based vaccine outreach has the potential to help improve vaccination coverage among younger and racial and ethnic minority groups in Chicago, if designed to address the skepticism, complacency and misinformation that persist surrounding COVID-19 vaccines.

Routine collection of work information can dramatically expedite definition of priority groups for outreach (through workplace and case-level surveillance) and development of public health metrics (such as immunization coverage among disproportionately impacted groups). Though lab-confirmed testing has decreased, and most working-age Chicagoans are now vaccinated against COVID-19, incorporation of work-related data into testing and immunization databases would still help identify populations of workers experiencing severe illness and who would most benefit from vaccine promotion. Lessons learned about incorporating these data elements into surveillance systems can and should be applied in planning and improving public health response to emerging communicable disease threats.

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APPENDICES

Appendix A. Code for Power Calculations and Sample Size Estimates

Aim 1B: SAS code and output for estimating sample sizes needed to detect association between single predictor (vaccine eligibility phase) and known relation to an outbreak using PROC POWER, varying the mean probability of outbreak status (associated or not) across groups and desired odds ratios:

```
proc power;
  logistic
   vardist("Vaxphase") = ordinal((1 2 3) : (.25 .25 .5))
   testpredictor = "Vaxphase"
   responseprob = 0.1 .05 0.01 0.001
 /*ranges for average probability of association to a known outbreak.*/
   testoddsratio = 1.2 2.0 5.0 /*hypothetical OR for association by vaccine eligibility phase*/
   units= ("Vaxphase" = 1)
   alpha = 0.05
   power = 0.8
   ntotal = .;

run;
```

Aim 2: Code for single predictor (occupational risk) of being unvaccinated among COVID cases from broad eligibility (June) through May 2022; resulting sample sizes varying the mean probability of being unvaccinated across groups and resulting measure of association:

```
proc power;
  logistic /*code as low medium high and use distribution similar to Aim 1b*/
   vardist("occrisk") = ordinal((1 2 3) : (.25 .25 .5))
   testpredictor = "occrisk"
   responseprob = 0.001 0.1 0.25 .33 .45 .5 .66 .75
          /*ranges for average probability of being unvaccinated. */
   testoddsratio = 1.2 2.0 3.0 4.0 5.0
   units= ("occrisk" = 1)
   alpha = 0.05
   power = 0.8
   ntotal = .;

run;
```

Appendix B. Schematic of Employer-Facing Survey (Aim 3)

Business Characteristics

Name of Business	Point of Contact First Name
Business Address	Point of Contact Last Name
City	Point of Contact Title
Zipcode	Point of Contact Phone Number
	Point of Contact e-mail address

1. Type of Business (choose 1) *(Branching logic: free text, if 99-Other is chosen. These choices are pre-specified in existing workplaces assessments at CDPH and will be collapsed for NAICS coding*

1= Bar	2= Construction	7= Hotel	17= Veterinary Practice / Animal Hospital
11= Restaurant (Fast Food)	3= Factory/Manufacturing	8= Janitorial	18= Warehouse/Distribution Center
12= Restaurant (Sit-down Dining)	4= Food (Non-Meat) Production	9= Meat/Poultry Processing	19= Apartment Complex / Residential Building
13= Restaurant (Other)	5= Grocery Store	10= Office Setting	99= Other
14= Retail	6= Gym/Fitness Center	15= Salon/Spa	

2. Approximately how many employees do you have?	Total # full-time staff			Total # part-time, contract, temporary staff *(Branching logic: if the value is zero, no choices related to these staff for the remainder of questions will be shown)*
3. Approximately what percent of your workforce are off-site or teleworking?	[0] 1-25% [1] 1-25% [2]26-50% [3] 51-75% [4] 76-99% [5] 100%(all)			[0] 1-25% [1] 1-25% [2]26-50% [3] 51-75% [4] 76-99% [5] 100%(all)
4. Primary languages spoken by employees *(check all that apply)*	1 =English	2 =Spanish	3= Other *(Branching logic with free text to capture other languages, if Other chosen)*	
5. Do you offer health insurance for your employees? *(check all that apply)*	1= Yes, for full-time staff	2=Yes, for part-time, temporary or contract staff	0= No	99 = Unknown

Appendix B *(continued)*

COVID-19 Vaccination Requirements Among Workers

	For full-time staff			For part-time, temporary or contract staff			
1. Does your workplace require employees to be fully-vaccinated and/or boosted, if eligible? *(check all that apply)*	2 = Yes, including booster shots	1=Yes, for initial series (full vaccination)	0=No	2 = Yes, including booster shots	1=Yes, for initial series (full vaccination)	0=No	99 = Unknown or Not applicable
2. Does your workplace verify vaccination status of staff? *(If yes: a) branching logic for free-text capture of details of how vaccination status is verified b) when was this last implemented? (Month/Year))*	2 = Yes, including booster shots	1=Yes, for initial series (full vaccination)	0=No	2 = Yes, including booster shots	1=Yes, for initial series (full vaccination)	0=No	99 = Unknown or Not applicable (N/A)
3. How many of your employees are fully-vaccinated? *(This is asked regardless of whether employers indicate they verify vaccination status)*	# boosted (or unknown)	# fully-vaccinated (or unknown)		# boosted (or unknown)	# fully-vaccinated (or unknown)		

Strategies for Employer Encouragement of COVID-19 Vaccination Among Workers

Please indicate if your workplace has ever used any of the following strategies to encourage vaccination among employees.
(Check one or multiple boxes for full-time and any part-time or other staff, as applicable)

	For full-time staff			For part-time, temporary or contract staff			
1. Paid time off for receiving COVID-19 vaccinations	2 = Yes, for booster shots	1=Yes, for initial series (full vaccination)	0=No	2 = Yes, for booster shots	1=Yes, for initial series (full vaccination)	0=No	99 = Unknown or Not applicable (N/A)
2. Paid time off for recovering from any side effects after receipt of COVID-19 vaccinations	2 = Yes, for booster shots	1=Yes, for initial series (full vaccination)	0=No	2 = Yes, for booster shots	1=Yes, for initial series (full vaccination)	0=No	99 = Unknown or Not applicable (N/A)
3. Monetary incentive (bonus) for receipt of COVID-19 vaccination	2 = Yes, for booster shots	1=Yes, for initial series (full vaccination)	0=No	2 = Yes, for booster shots	1=Yes, for initial series (full vaccination)	0=No	99 = Unknown or N/A
4. Other incentive for receipt of COVID-19 vaccination **(check all that apply)** *(Branching logic: details of free text to capture any other incentives, if any are indicated)*	2 = Yes, for booster shots	1=Yes, for initial series (full vaccination)	0=No	2 = Yes, for booster shots	1=Yes, for initial series (full vaccination)	0=No	99 = Unknown or N/A
5. Social media, internal communications, posters or signage around the workplace to encourage vaccination	2 = Yes, for booster shots	1=Yes, for initial series (full vaccination)	0=No	2 = Yes, for booster shots	1=Yes, for initial series (full vaccination)	0=No	99 = Unknown or Not applicable
6. Training for interested staff to become COVID-19 vaccination	2 = Yes, for booster	1=Yes, for initial series	0=No	2 = Yes, for booster shots	1=Yes, for initial series	0=No	99 = Unknown
7. Townhalls or other opportunities for leadership, respected local medical experts, and staff to share their COVID-19 vaccine experience,	2 = Yes, for booster shots	1=Yes, for initial series (full vaccination)	0=No	2 = Yes, for booster shots	1=Yes, for initial series (full vaccination)	0=No	99 = Unknown or N/A

8. If your workplace has used other strategies to encourage vaccination among workers, please describe them here:
(Free text response)

9. CDPH would like to understand potential barriers to encouragement of vaccination or challenges that workplaces have experienced regarding requiring, enforcing or encouraging of vaccine. Please share any details about these topics in the space below. *(Free text response)*

10. CDPH may conduct additional follow-up with businesses about COVID-19 vaccination or related challenges to implementation among workers. May we contact your business for individual and/or group discussions about these topics?

2 = Yes, we would be willing to participate in a short, individual follow-up call with CDPH about this
1 = Yes, we would be willing to participate in a focus group with other businesses about this
0 = We do not wish to participate in follow-up discussions about these topics

Appendix C. Supplemental Materials for Aim 1

Proof of permission for use of final, peer-reviewed articles in the Journal of Occupational and Environmental Medicine was determined from the permissions request process from the publisher website, with results below:

Wolters Kluwer

COVID-19 Clusters and Outbreaks among Non-Healthcare, Non-Congregate Workers in Chicago, Illinois: Surveillance through the First Omicron Wave

Author: Frances R. Lendacki, Linda Forst, Emma Weber, et al

Publication: Journal of Occupational and Environmental Medicine

Publisher: Wolters Kluwer Health, Inc.

Date: Feb 13, 2023

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BACK

CLOSE WINDOW

Appendix C (continued)

TABLE XXI. CHARACTERISTICS OF COVID-19 CLUSTERS AND OUTBREAKS IDENTIFIED AMONG NON-HEALTHCARE, NON-CONGREGATE WORKERS IN CHICAGO, BY IDENTIFICATION SOURCE (N=496)

		Identification Source			
	All sources (N=496)	**CICT data[a] (n=250)**	**Direct report (n=164)**	**Public concern (n=43)**	**Other source (n=39)**
Investigation Type (n, %)					
Outbreak[b]	54 (10.9)	16 (6.4)	18 (11.0)	13 (30.2)	7 (17.9)
Cluster	442 (89.1)	234 (93.6)	146 (89.0)	30 (69.8)	32 (82.1)
Vaccine Eligibility Phase (n, %)					
1b - Frontline Essential	125 (25.2)	71 (28.4)	24 (14.6)	22 (51.2)	8 (20.5)
Workplace Type (n, %)					
Bars & Restaurants	122 (24.6)	64 (25.6)	34 (20.7)	9 (20.9)	15 (38.5)
Office Setting	98 (19.8)	39 (15.6)	49 (29.9)	4 (9.3)	6 (15.4)
Retail	51 (10.3)	25 (10)	19 (11.6)	3 (7.0)	4 (10.3)
Factory/Manufacturing	47 (9.5)	29 (11.6)	8 (4.9)	5 (11.6)	5 (12.8)
Food Production & Processing	41 (8.3)	17 (6.8)	8 (4.9)	13 (30.2)	3 (7.7)
Personal Care and Service	27 (5.4)	17 (6.8)	7 (4.3)	2 (4.7)	1 (2.6)
Hotel	20 (4.0)	4 (1.6)	16 (9.8)	0 (–)	0 (–)
Warehouse/Distribution Center	19 (3.8)	10 (4.0)	6 (3.7)	3 (7.0)	0 (–)
Grocery Store	18 (3.6)	15 (6.0)	2 (1.2)	1 (2.3)	0 (–)
Construction	13 (2.6)	5 (2.0)	5 (3.0)	1 (2.3)	2 (5.1)
Transportation	11 (2.2)	11 (4.4)	0 (–)	0 (–)	0 (–)
Janitorial	8 (1.6)	6 (2.4)	1 (0.6)	0 (–)	1 (2.6)
Other	21 (4.2)	8 (3.2)	9 (5.5)	2 (4.7)	2 (5.1)
Region (n, %)					
North Central	209 (42.1)	85 (34)	96 (58.5)	16 (37.2)	12 (30.8)
West	98 (19.8)	58 (23.2)	19 (11.6)	13 (30.2)	8 (20.5)
Northwest	75 (15.1)	42 (16.8)	18 (11)	5 (11.6)	10 (25.6)
Southwest	65 (13.1)	37 (14.8)	15 (9.1)	7 (16.3)	6 (15.4)
Far South	25 (5.0)	17 (6.8)	5 (3.0)	1 (2.3)	2 (5.1)
Near South	21 (4.2)	10 (4.0)	9 (5.5)	1 (2.3)	1 (2.6)
Unknown	3 (0.6)	1 (0.4)	2 (1.2)	0 (–)	0 (–)
Time Period (n, %)					
1 - Shutdown of non-essential businesses, "Stay at Home" (2020)	32 (6.5)	1 (0.4)	10 (6.1)	13 (30.2)	8 (20.5)
2 - Partial re-opening, pre-vaccine (2020-2021)	213 (42.9)	108 (43.2)	77 (47.0)	18 (41.9)	10 (25.6)
3 - Partial re-opening, vaccine rollout (2021)	118 (23.8)	95 (38)	12 (7.3)	6 (14.0)	5 (12.8)
4 - Full re-opening, pre-Omicron (2021)	74 (14.9)	40 (16.0)	21 (12.8)	5 (11.6)	8 (20.5)
5 - Omicron (2021-2022)	59 (11.9)	6 (2.4)	44 (26.8)	1 (2.3)	8 (20.5)

[a]*CICT: Case investigation and contact tracing.*

[b]*Outbreaks are defined by the Illinois Department of Public Health (IDPH) as "five or more epidemiologically-linked cases within 14 days at a common worksite and no other known close contact outside the workplace". Clusters are defined as "a number of cases that is greater than expected" in one 14-day period within the workplace and no other known close contact outside the workplace; clusters can consist of as few as 2 cases.*

<u>Appendix C</u> (continued)

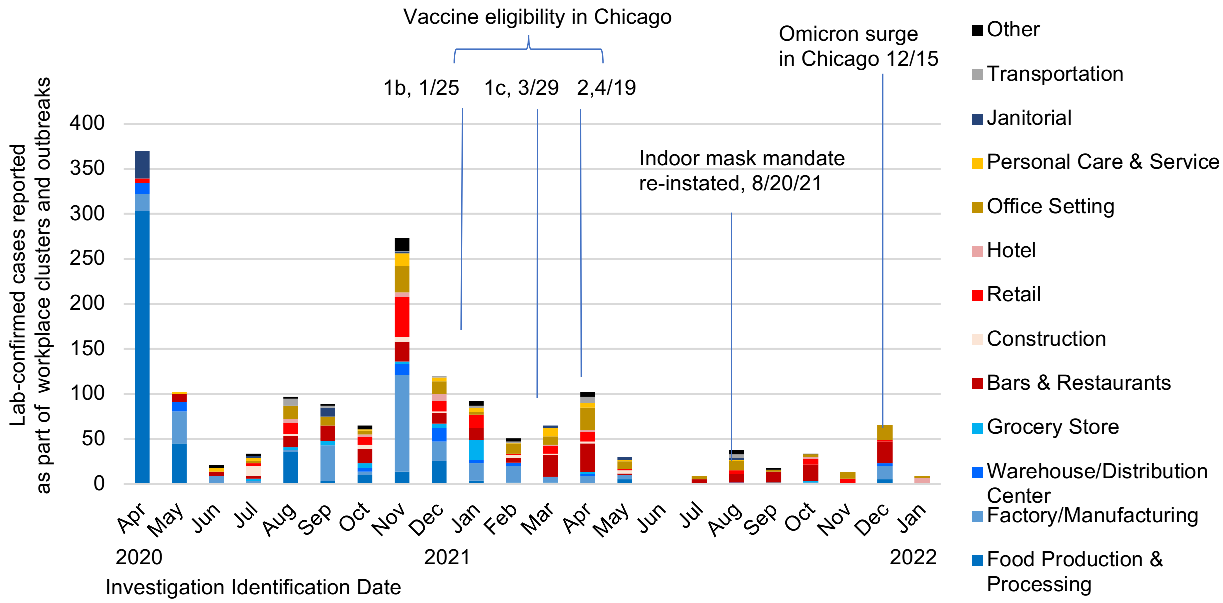


Figure 33. Laboratory-confirmed cases associated with COVID-19 clusters and outbreaks among non-healthcare, non-congregate workers in Chicago, April 2020 – January 2022 by workplace type (n=1,698)

<u>Appendix C</u> (continued)

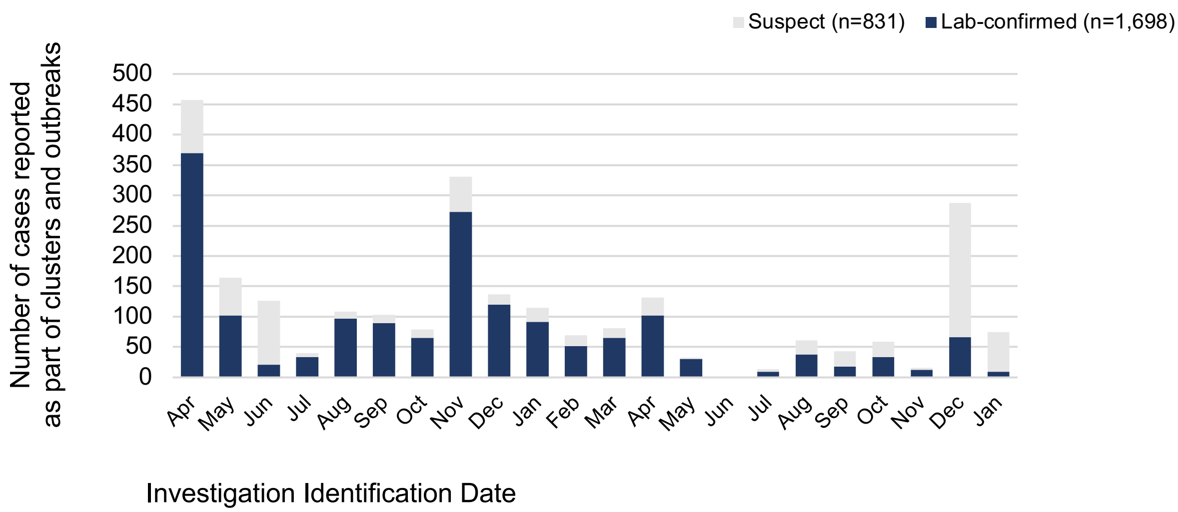


Figure 34. Laboratory-confirmed and suspect cases associated with COVID-19 clusters and outbreaks among non-healthcare, non-congregate in Chicago, April 2020 – January 2022 by case status (N=2,529)

Appendix C (continued)

TABLE XXII. CHARACTERISTICS OF NON-HEALTHCARE, NON-CONGREGATE WORKERS WITH LABORATORY-CONFIRMED COVID-19 FOUND TO BE ASSOCIATED WITH CLUSTER AND OUTBREAKS (N=1,221)

	Full study period (n=1,221) *	**Shutdown of non-essential businesses, (n=360)**	**Partial re-opening, pre-vaccine (n=533)**	**Partial re-opening, vaccine rollout (n=191)**	**Full re-opening, pre-Omicron (n=103)**	**Omicron phase (n=34)**
	3/11/20 – 1/31/22	3/11/20 – 6/3/20	6/4/20 – 1/24/21	1/25/21 – 6/10/21	6/11/21 – 12/14/21	12/15/21 – 1/31/22
Sex (n, %)						
Male	687 (56.3)	194 (53.9)	316 (59.3)	99 (51.8)	58 (56.3)	20 (58.8)
Female	525 (43)	160 (44.4)	214 (40.2)	92 (48.2)	45 (43.7)	14 (41.2)
Unknown	9 (0.7)	6 (1.7)	3 (0.6)	0 (–)	0 (–)	0 (–)
Age Group (n, %)						
16-17	10 (0.8)	0 (–)	6 (1.1)	1 (0.5)	1 (1)	2 (5.9)
18-29	327 (26.8)	54 (15)	161 (30.2)	62 (32.5)	34 (33)	16 (47.1)
30-39	296 (24.2)	76 (21.1)	120 (22.5)	55 (28.8)	36 (35)	9 (26.5)
40-49	257 (21)	108 (30)	103 (19.3)	23 (12)	19 (18.4)	4 (11.8)
50-64	290 (23.8)	111 (30.8)	124 (23.3)	41 (21.5)	11 (10.7)	3 (8.8)
65+	41 (3.4)	11 (3.1)	19 (3.6)	9 (4.7)	2 (1.9)	0 (–)
Race/Ethnicity (n, %)						
Latinx	612 (50.1)	223 (61.9)	296 (55.5)	74 (38.7)	14 (13.6)	5 (14.7)
Black, non-Latinx	206 (16.9)	21 (5.8)	93 (17.4)	51 (26.7)	32 (31.1)	9 (26.5)
White, non-Latinx	182 (14.9)	74 (20.6)	62 (11.6)	22 (11.5)	17 (16.5)	7 (20.6)
Asian, non-Latinx	160 (13.1)	34 (9.4)	54 (10.1)	39 (20.4)	24 (23.3)	9 (26.5)
Other, non-Latinx	32 (2.6)	2 (0.6)	14 (2.6)	5 (2.6)	9 (8.7)	2 (5.9)
Unknown	29 (2.4)	6 (1.7)	14 (2.6)	0 (–)	7 (6.8)	2 (5.9)
City Region (n, %)						
Southwest	387 (31.7)	154 (42.8)	180 (33.8)	33 (17.3)	20 (19.4)	0 (–)
Northwest	262 (21.5)	65 (18.1)	121 (22.7)	53 (27.7)	21 (20.4)	2 (5.9)
West	247 (20.2)	81 (22.5)	95 (17.8)	32 (16.8)	28 (27.2)	11 (32.4)
North Central	180 (14.7)	23 (6.4)	81 (15.2)	42 (22)	17 (16.5)	17 (50)
Far South	71 (5.8)	11 (3.1)	32 (6)	18 (9.4)	8 (7.8)	2 (5.9)
Near South	58 (4.8)	11 (3.1)	23 (4.3)	13 (6.8)	9 (8.7)	2 (5.9)
Unknown	16 (1.3)	15 (4.2)	1 (0.2)	0 (–)	0 (–)	0 (–)
Fully vaccinated (n, %)	81 (6.6)	0 (–)	1 (0.2)	2 (1)	55 (53.4)	23 (67.6)
Hospitalized (n, %)	70 (5.7)	53 (14.7)	17 (3.2)	0 (–)	0 (–)	0 (–)
Deceased (n, %)	10 (0.8)	8 (2.2)	1 (0.2)	1 (0.5)	0 (–)	0 (–

Appendix C (continued)

TABLE XXII. CHARACTERISTICS OF NON-HEALTHCARE, NON-CONGREGATE WORKERS WITH LABORATORY-CONFIRMED COVID-19 FOUND TO BE ASSOCIATED WITH CLUSTER AND OUTBREAKS (N=1,221) (continued)

	Full study period (n=1,221) *	**Shutdown of non-essential businesses, (n=360)**	**Partial re-opening, pre-vaccine (n=533)**	**Partial re-opening, vaccine rollout (n=191)**	**Full re-opening, pre-Omicron (n=103)**	**Omicron phase (n=34)**
	3/11/20 – 1/31/22	3/11/20 – 6/3/20	6/4/20 – 1/24/21	1/25/21 – 6/10/21	6/11/21 – 12/14/21	12/15/21 – 1/31/22
Investigation Type (n, %)						
Cluster	623 (51)	16 (4.4)	351 (65.9)	158 (82.7)	73 (70.9)	25 (73.5)
Outbreak**	598 (49)	344 (95.6)	182 (34.1)	33 (17.3)	30 (29.1)	9 (26.5)
Industry Type (n, %)						
Food Production and Processing	333 (27.3)	243 (67.5)	75 (14.1)	8 (4.2)	7 (6.8)	0 (–)
Manufacturing	237 (19.4)	70 (19.4)	126 (23.6)	29 (15.2)	12 (11.7)	0 (–)
Bars and Restaurants	184 (15.1)	4 (1.1)	79 (14.8)	52 (27.2)	33 (32)	16 (47.1)
Office Setting	111 (9.1)	0 (–)	40 (7.5)	36 (18.8)	25 (24.3)	10 (29.4)
Retail	94 (7.7)	1 (0.3)	65 (12.2)	19 (9.9)	8 (7.8)	1 (2.9)
Other	56 (4.6)	0 (–)	45 (8.4)	5 (2.6)	6 (5.8)	0 (–)
Janitorial	42 (3.4)	23 (6.4)	9 (1.7)	8 (4.2)	2 (1.9)	0 (–)
Grocery Store	42 (3.4)	0 (–)	38 (7.1)	2 (1)	2 (1.9)	0 (–)
Transportation	38 (3.1)	5 (1.4)	18 (3.4)	10 (5.2)	4 (3.9)	1 (2.9)
Personal Care and Service	32 (2.6)	6 (1.7)	17 (3.2)	8 (4.2)	1 (1)	0 (–)
Hotel	22 (1.8)	0 (–)	14 (2.6)	2 (1)	0 (–)	6 (17.6)
Warehouse/ Distribution Center	21 (1.7)	8 (2.2)	5 (0.9)	5 (2.6)	3 (2.9)	0 (–)
Construction	9 (0.7)	0 (–)	2 (0.4)	7 (3.7)	0 (–)	0 (–)
Vaccine Eligibility (n, %)						
Early (Frontline Essential (“1b”))	633 (51.8)	321 (89.2)	244 (45.8)	44 (23)	24 (23.3)	0 (–)

**No investigations were identified from February through May, 2022.*

*** Outbreaks are defined by the Illinois Department of Public Health (IDPH) as “five or more epidemiologically-linked cases within 14 days at a common worksite and no other known close contact outside the workplace”. Clusters are defined as “a number of cases that is greater than expected” in one 14-day period within the workplace and no other known close contact outside the workplace; clusters can consist of as few as 2 cases.*

Appendix D. Supplemental Materials for Aim 2

TABLE XXIII. CASES EXCLUDED FROM O*NET BY OCCUPATION (N=217)

6-digit 2010 SOC Title	n (%)
Office and Administrative Support Workers, All Other	55 (25.3)
Sales and Related Workers, All Other	46 (21.2)
Cooks, All Other	20 (9.2)
Sales Representatives, Wholesale and Manufacturing	20 (9.2)
Building Cleaning Workers, All Other	13 (6.0)
Assemblers and Fabricators, All Other	12 (5.5)
Designers, All Other	8 (3.7)
Military, Rank Not Specified -NIOSH	8 (3.7)
Metal Workers and Plastic Workers, All Other	7 (3.2)
First-Line Supervisors of Protective Service Workers, All Other	4 (1.8)
Personal Care and Service Workers, All Other	4 (1.8)
Entertainers and Performers, Sports and Related Workers, All Other	3 (1.4)
Food Processing Workers, All Other	3 (1.4)
Grounds Maintenance Workers, All Other	3 (1.4)
Information and Record Clerks, All Other	2 (0.9)
Legislators	2 (0.9)
Financial Clerks, All Other	1 (0.5)
Food Preparation and Serving Related Workers, All Other	1 (0.5)
Legal Support Workers, All Other	1 (0.5)
Military, Commissioned Officers and Warrant Officers -NIOSH	1 (0.5)
Military, Non-Commissioned Officer and Other Enlisted Personnel -NIOSH	1 (0.5)
Rail Transportation Workers, All Other	1 (0.5)
Transportation Workers, All Other	1 (0.5)

Appendix D (continued)

TABLE XXIV. OCCUPATIONAL GROUPS OF NON-HEALTHCARE, NON-CONGREGATE WORKER COVID-19 CASES: BY VACCINATION STATUS BY PERIOD

	Pre-Omicron		**Post-Omicron**	
	Vaccinated n (%)	Unvaccinated n (%)	Vaccinated n (%)	Unvaccinated n (%)
	1,104 (45.0)	1,351 (55.0)	985 (75.3)	323 (24.7)
Architecture and Engineering	27 (64.2)	15 (35.7)	25 (73.5)	9 (26.4)
Arts, Design, Entertainment, Sports, and Media	59 (67.8)	28 (32.1)	38 (86.3)	6 (13.6)
Building and Grounds Cleaning and Maintenance	47 (40.8)	68 (59.1)	40 (78.4)	11 (21.5)
Business and Financial Operations	123 (64.0)	69 (35.9)	128 (82.0)	28 (17.9)
Computer and Mathematical	52 (61.9)	32 (38.0)	50 (75.7)	16(24.2)
Construction and Extraction	33 (31.4)	72 (68.5)	20 (48.7)	21 (51.2)
Educational Instruction and Library	2 (100)	0 (-)	5 (100)	0 (-)
Farming, Fishing, and Forestry	2 (50.0)	2 (50.0)	1 (100)	0 (-)
Food Preparation and Serving Related	84 (42.4)	114 (57.5)	65 (72.2)	25 (27.7)
Installation, Maintenance, and Repair	14 (29.7)	33 (70.2)	16 (69.5)	7 (30.4)
Legal Occupations	49 (83.0)	10 (16.9)	56 (91.8)	5 (8.1)
Life, Physical, and Social Science	15 (51.7)	14 (48.2)	43 (81.1)	10 (18.8)
Management	183 (65.8)	95 (34.1)	136 (80.9)	32 (19.0)
Office and Administrative Support	126 (41.0)	181 (58.9)	128 (73.9)	45 (26.0)
Personal Care and Service	39 (33.0)	79 (66.9)	40 (81.6)	9 (18.3)
Production	30 (39.4)	46 (60.5)	23 (65.7)	12 (34.2)
Protective Service	48 (27.5)	126 (72.4)	56 (67.4)	27 (32.5)
Sales and Related	69 (32.7)	142 (67.2)	63 (75.0)	21 (25.0)
Transportation and Material Moving	102 (31.1)	225 (68.8)	52 (57.1)	39 (42.9)

Appendix D (continued)

TABLE XXV. DEMOGRAPHICS OF CASES BY VACCINATION STATUS AND SEASON

PRE-OMICRON

	Early (n=1,069)					Late (n=1,386)				
	Vaccinated		Unvaccinated			Vaccinated		Unvaccinated		
	n	%	n	%	*p*	n	%	n	%	*p*
	400	(37.4)	669	(62.6)		704	(50.8)	682	(49.2)	
Age					*0.0010*					*<.0.0001*
18-29	116	(30.3)	267	(69.7)		158	(41.6)	222	(58.4)	
30-39	140	(40.2)	208	(59.8)		217	(50.3)	214	(49.7)	
40-49	75	(37.9)	123	(62.1)		160	(53.3)	140	(46.7)	
50-59	56	(50.9)	54	(49.1)		117	(57.1)	88	(42.9)	
60-64	13	(43.3)	17	(56.7)		52	(74.3)	18	(25.7)	
Sex					*0.3013*					*0.1257*
Male	207	(36.0)	368	(64.0)		366	(51.0)	351	(49.0)	
Female	193	(39.1)	301	(60.9)		338	(50.8)	327	(49.2)	
Unknown	0	(-)	0	(-)		0	(-)	4	(100)	
Race-ethnicity group					*<0.0001*					*<.0.0001*
Latinx	85	(32.1)	180	(67.9)		146	(52.0)	135	(48.0)	
Black, non-Latinx	58	(16.6)	291	(83.4)		112	(29.7)	265	(70.3)	
White, non-Latinx	228	(63.2)	133	(36.8)		366	(66.5)	184	(33.5)	
Asian, non-Latinx	21	(63.6)	12	(36.4)		31	(68.9)	14	(31.1)	
Other, non-Latinx	5	(15.2)	28	(84.8)		35	(37.6)	58	(62.4)	
Unknown	3	(10.7)	25	(89.3)		14	(35.0)	26	(65.0)	
City region					*<0.0001*					*<.0.0001*
North Central	144	(55.2)	117	(44.8)		226	(67.5)	109	(32.5)	
Northwest	109	(47.8)	119	(52.2)		195	(58.9)	136	(41.1)	
West	66	(38.2)	107	(61.8)		108	(46.6)	124	(53.4)	
Southwest	37	(22.6)	127	(77.4)		84	(42.6)	113	(57.4)	
Far South	20	(14.7)	116	(85.3)		53	(32.5)	110	(67.5)	
South	24	(22.9)	81	(77.1)		38	(30.9)	85	(69.1)	
Unknown	0	(-)	2	(100)		0	(-)	5	(100)	
CCVI					*<.0.0001*					*<.0.0001*
Very high CCVI	40	(17.3)	191	(82.7)		84	(33.5)	167	(66.5)	
High CCVI	20	(22.5)	69	(77.5)		51	(39.8)	77	(60.2)	
Not High CCVI	340	(45.4)	409	(54.6)		569	(56.5)	438	(43.5)	
Hospitalized					*<.0.0001*					*0.5927*
Yes	7	(16.3)	36	(83.7)		20	(43.5)	26	(56.5)	
No	32	(22.5)	110	(77.5)		68	(50.4)	67	(49.6)	
Unknown	361	(40.8)	523	(59.2)		616	(51.1)	589	(48.9)	
Deceased					*<.0.0001*					*0.3095*
Yes	0	(-)	0	(-)		0	(-)	1	(100)	
No	400	(37.4)	669	(62.6)		704	(50.8)	681	(49.2)	
Occupational Risk					*<.0.0001*					*0.1240*
High	186	(31.6)	403	(68.4)		356	(48.8)	373	(51.2)	
Medium	78	(39.6)	119	(60.4)		134	(49.8)	135	(50.2)	
Low	136	(48.1)	147	(51.9)		214	(55.2)	174	(44.8)	

Appendix D (continued)

TABLE XXV: DEMOGRAPHICS OF CASES BY VACCINATION STATUS AND SEASON (*continued)*

POST-OMICRON

	Early (n=1,069)					**Late (n=1,386)**				
	Vaccinated		Unvaccinated			Vaccinated		Unvaccinated		
	n	%	n	%	*p*	n	%	n	%	*p*
	167	(67.6)	80	(32.4)		818	(77.1)	243	(22.9)	
Age					*0.0482*					*0.0015*
18-29	38	(55.1)	31	(44.9)		159	(68.8)	72	(31.2)	
30-39	63	(78.8)	17	(21.3)		267	(75.2)	88	(24.8)	
40-49	32	(68.1)	15	(31.9)		199	(82.2)	43	(17.8)	
50-59	27	(65.9)	14	(34.1)		142	(82.6)	30	(17.4)	
60-64	7	(70.0)	3	(30.0)		51	(83.6)	10	(16.4)	
Sex					*0.4762*					*0.9488*
Male	80	(64.5)	44	(35.5)		383	(61.9)	111	(17.9)	
Female	86	(70.5)	36	(29.5)		432	(76.7)	131	(23.3)	
Unknown	1	(100)	0	(-)		3	(75.0)	1	(25.0)	
Race-ethnicity group					*0.0067*					*0.0006*
Latinx	48	(67.6)	23	(32.4)		164	(71.0)	67	(29.0)	
Black, non-Latinx	42	(59.2)	29	(40.8)		111	(72.5)	42	(27.5)	
White, non-Latinx	55	(80.9)	13	(19.1)		419	(81.5)	95	(18.5)	
Asian, non-Latinx	8	(61.5)	5	(38.5)		62	(87.3)	9	(12.7)	
Other, non-Latinx	4	(33.3)	8	(66.7)		42	(67.7)	20	(32.3)	
Unknown	10	(83.3)	2	(16.7)		20	(66.7)	10	(33.3)	
City region					*0.0439*					*0.0081*
North Central	54	(75.0)	18	(25.0)		315	(81.6)	71	(18.4)	
Northwest	30	(73.2)	11	(26.8)		193	(77.5)	56	(22.5)	
West	30	(73.2)	11	(26.8)		119	(73.9)	42	(26.1)	
Southwest	25	(62.5)	15	(37.5)		75	(71.4)	30	(28.6)	
Far South	10	(45.5)	12	(54.5)		69	(81.2)	16	(18.8)	
South	18	(62.1)	11	(37.9)		45	(63.4)	26	(36.6)	
Unknown	0	(-)	2	(100)		2	(50.0)	2	(50.0)	
CCVI					*0.3764*					*0.0244*
Very high CCVI	35	(62.5)	21	(37.5)		72	(66.7)	36	(33.3)	
High CCVI	15	(60.0)	10	(40.0)		52	(77.6)	15	(22.4)	
Not High CCVI	117	(70.5)	49	(29.5)		694	(78.3)	192	(21.7)	
Hospitalized					*0.4671*					*0.8099*
Yes	5	(83.3)	1	(16.7)		11	(84.6)	2	(15.4)	
No	50	(63.3)	29	(36.7)		131	(77.1)	39	(22.9)	
Unknown	112	(69.1)	50	(30.9)		676	(77.0)	202	(23.0)	
Deceased					*0.4880*					-
Yes	1	(100)	0	(-)		0	(-)	0	(-)	
No	166	(67.5)	80	(32.5)		818	(77.1)	243	(22.9)	
Occupational Risk					*0.1447*					*0.0633*
High	88	(63.8)	50	(36.2)		419	(78.3)	116	(21.7)	
Medium	28	(65.1)	15	(34.9)		123	(70.3)	52	(29.7)	
Low	51	(77.3)	15	(22.7)		276	(78.6)	75	(21.4)	

Appendix D (continued)

TABLE XXVI. SINGLE-FACTOR ANALYSES: ADJUSTED AND STRATUM-SPECIFIC ODDS OF BEING UNVACCINATED AT INFECTION BY OCCUPATIONAL RISK

	Pre-Omicron OR	Pre-Omicron 95% CI			Post-Omicron OR	Post-Omicron 95% CI		
Occupation, Crude	1.399	1.193	1.642		0.997	0.775	1.282	
Stratum Specific				Adjusted OR (95% CI), *p*[a]				Adjusted OR (95% CI), *p*[a]
Age				1.38 (1.18 – 1.63)				1.01 (0.79 – 1.30)
18-29	**2.160**	**1.597**	**2.920**	*0.0013*	1.178	0.730	1.901	*0.6663*
30-49	1.237	0.992	1.541		0.968	0.683	1.372	
50-64	0.930	0.629	1.377		0.843	0.470	1.512	
Sex				1.44 (1.22 – 1.69)				1.01 (0.78 – 1.30)
Male	1.153	0.925	1.438	*0.0043*	0.984	0.681	1.421	*0.8753*
Female	**1.858**	**1.459**	**2.366**		1.025	0.719	1.461	
Race-ethnicity				1.11 (0.94 – 1.33) *0.4725*				0.92 (0.70 – 1.20) *0.3739*
Region				1.25 (1.06 – 1.48)				0.92 (0.72 – 1.20)
Far South	1.015	0.592	1.740	*0.3215*	0.567	0.244	1.318	*0.0013*
South	1.024	0.556	1.885		1.096	0.437	2.749	
Southwest	**1.783**	**1.146**	**2.775**		0.951	0.466	1.940	
West	1.454	0.979	2.160		0.997	0.533	1.867	
Northwest	1.000	0.717	1.395		0.991	0.574	1.712	
North Central	1.312	0.942	1.829		0.882	0.553	1.4	
CCVI				1.31 (1.11 –1.54)				1.00 (0.77 – 1.29)
High	**1.374**	**1.139**	**1.658**	*0.3011*	0.992	0.744	1.323	*0.1446*
Not High	1.121	0.800	1.570		0.882	0.518	1.503	

[a]*p-value for Breslow Day test: heterogeneity of stratum-specific odds ratios, per covariate*

Appendix D (continued)

TABLE XXVII. CORRELATIONS BETWEEN OCCUPATIONAL RISK AND COVARIATES FROM FULLY-ADJUSTED MODELS (CRAMER'S V)

Covariate	Occupational Risk	Age group	Sex	Race-ethnicity	City region	CCVI
Occupational Risk	1.0000					
Age group	0.0777	1.0000				
Sex	0.1770	0.0389	1.0000			
Race-ethnicity	0.1833	0.0416	0.0839	1.0000		
City region	0.1314	0.0903	0.0908	0.3553	1.0000	
High or low CCVI	0.0890	0.0225	0.027	0.4122	**0.6545**	1.0000

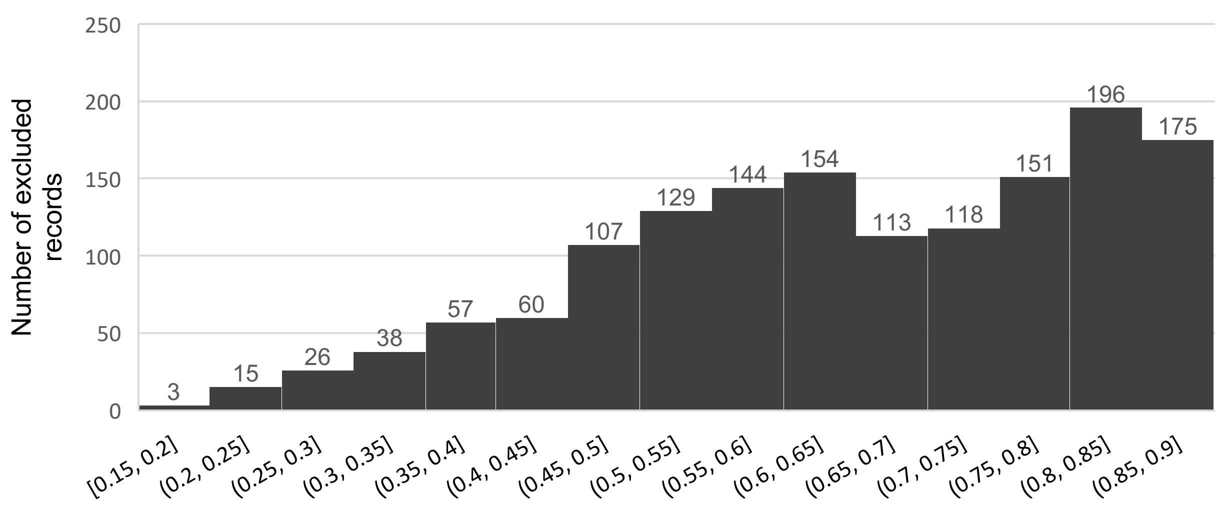


Figure 35. Distribution of excluded records by occupation code match score (n=1,486)

Appendix D (continued)

TABLE XXVIII. DEMOGRAPHICS OF CASES BY HIGH VS. LOWER PROBABILITY OCCUPATION CODING (N=3,996)

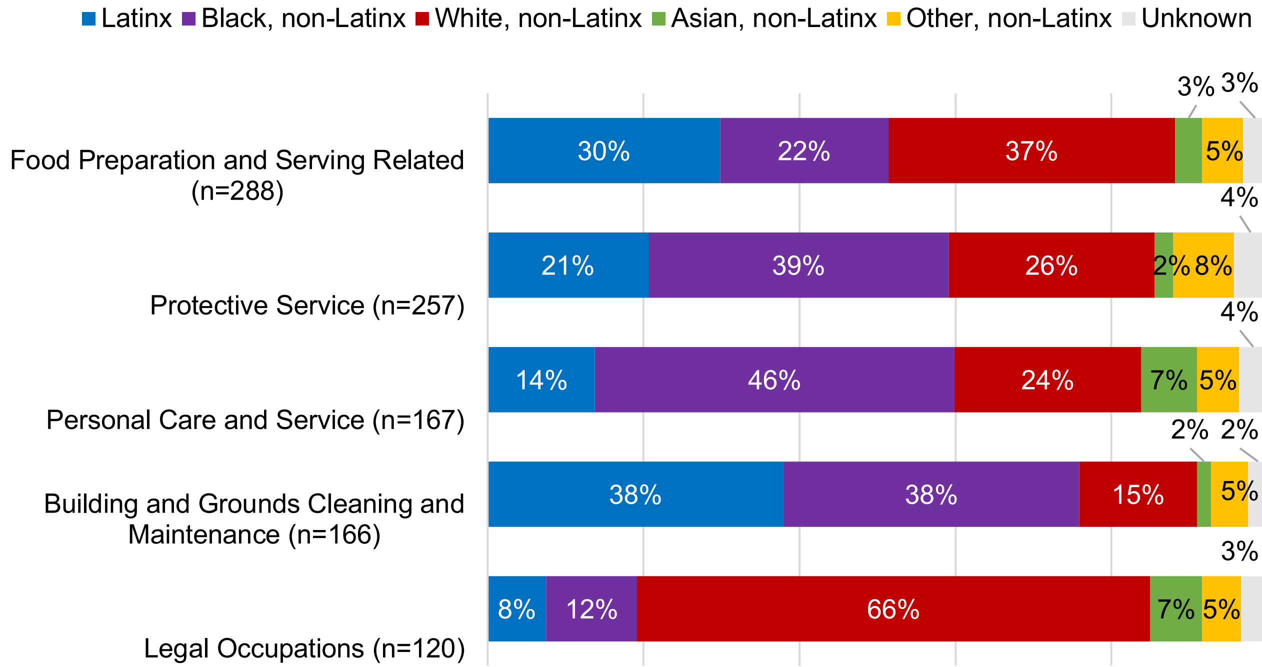
	.8 - 0.89 match n=233		≥0.9 match n=3,763	
Occupational Risk				
High	119	(51.0)	1,991	(52.9)
Medium	37	(15.8)	684	(18.1)
Low	77	(33.0)	1,088	(28.9)
Vaccinated?				
Yes	139	(59.6)	2,089	(55.5)
No	94	(40.3)	1,674	(44.4)
Age				
18-29	68	(29.1)	1,063	(28.2)
30-39	75	(32.1)	1,214	(32.2)
40-49	56	(24.0)	787	(20.9)
50-59	24	(10.3)	528	(14.0)
60-64	10	(4.2)	171	(4.5)
Sex				
Male	115	(49.3)	1,910	(50.7)
Female	118	(50.6)	1,844	(49.0)
Unknown	0	0.0	9	(0.2)
Race-ethnicity				
Latinx	61	(26.1)	848	(22.5)
Black, non-Latinx	49	(21.0)	950	(25.2)
White, non-Latinx	94	(40.3)	1,493	(39.6)
Asian, non-Latinx	9	(3.8)	162	(4.3)
Other, non-Latinx	14	(6.0)	200	(5.3)
Unknown	6	(2.5)	110	(2.9)
City region				
North Central	69	(29.6)	1,054	(28.0)
Northwest	48	(20.6)	849	(22.5)
West	41	(17.5)	607	(16.1)
Southwest	29	(12.4)	506	(13.4)
Far South	24	(10.3)	399	(10.6)
South	22	(9.4)	335	(8.9)
Unknown	0	0.0	13	(0.3)
CCVI				
Very High CCVI	35	(15.0)	646	(17.1)
High CCVI	17	(7.2)	309	(8.2)
Not High CCVI	181	(77.6)	2,808	(74.6)

Appendix D (continued)

TABLE XXIX. DEMOGRAPHICS OF CASES BY VACCINATION STATUS: SENSITIVITY ANALYSES OF POST-OMICRON CASES, INCLUDING BOOSTERS (N=1,308)

	Up-to-date		Not up-to-date		
	n	%	n	%	*Chi-squared p*
	798	(61.0)	510	(39.0)	
Age Group					*<.0001*
18-29	145	(48.3)	155	(51.7)	
30-49	467	(64.5)	257	(35.5)	
50-64	186	(65.5)	98	(34.5)	
Sex					*0.519*
Male	367	(59.3)	251	(40.6)	
Female	428	(62.4)	257	(37.5)	
Unknown	3	(60.0)	2	(40.0)	
Race-ethnicity group					
Latinx	164	(54.3)	138	(45.6)	*<.0001*
Black, non-Latinx	109	(48.6)	115	(51.3)	
White, non-Latinx	408	(70.1)	174	(29.8)	
Asian, non-Latinx	57	(67.8)	27	(32.1)	
Other, non-Latinx	36	(48.6)	38	(51.3)	
Unknown	24	(57.1)	18	(42.8)	
City region					*<.0001*
North Central	319	(69.6)	139	(30.3)	
Northwest	191	(65.8)	99	(34.1)	
West	122	(60.3)	80	(39.6)	
Southwest	68	(46.8)	77	(53.1)	
Far South	62	(57.9)	45	(42.0)	
South	35	(35.0)	65	(65.0)	
Unknown	1	(16.6)	5	(83.3)	
CCVI					*<.0001*
High CCVI	116	(45.3)	140	(54.7)	
Not High CCVI	682	(64.8)	370	(35.2)	
Season					*<.0001*
Early	122	(49.3)	125	(50.6)	
Late	676	(63.7)	385	(36.2)	
Hospitalized					
Yes	10	(52.6)	9	(47.3)	
No	142	(57.0)	107	(42.9)	
Unknown	646	(62.1)	394	(37.8)	
Deceased					
Yes	1	100.0)	0	0.0	
No	797	(60.9)	510	(39.0)	

Appendix D (continued)



[a] Five major occupational groups shown were all identified as having very high frequency (> 85%) of workers in occupations classified as high-risk for workplace-acquired COVID-19.

Figure 36. Non-healthcare workers interviewed with COVID-19 in Chicago: select major occupational groups by race-ethnicity[a]

Appendix D (continued)

TABLE XXX. COMPARISON OF CASES INCLUDED VS. EXCLUDED FOR MISSING OR INDETERMINATE OCCUPATION

	Pre-Omicron			Post-Omicron		
	Non-Missing (0.90 match) n=3,365	**Incomplete n=3,095**	**Missing n=7,299**	**Non-Missing (0.90 match) n=2,167**	**Incomplete n=2,454**	**Missing n=6,667**
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Vaccinated?						
Yes	1,685 (50.0)	1,606 (51.8)	3,419 (46.8)	1,686 (77.8)	1,864 (75.9)	4,644 (69.6)
No	1,680 (49.9)	1,489 (48.1)	3,880 (53.1)	481 (22.1)	590 (24.0)	2,023 (30.3)
Age						
18-29	1,016 (30.1)	1,017 (32.8)	2,488 (34.0)	504 (23.2)	686 (27.9)	2,250 (33.7)
30-39	1,114 (33.1)	1,027 (33.1)	2,053 (28.1)	733 (33.8)	(32.8)	1,821 (27.3)
40-49	671 (19.9)	579 (18.7)	1,300 (17.8)	501 (23.1)	524 (21.3)	1,207 (18.1)
50-59	426 (12.6)	996 (11.6)	996 (13.6)	328 (15.1)	323 (13.1)	969 (14.5)
60-64	138 (4.1)	110 (3.5)	462 (6.3)	101 (4.6)	116 (4.7)	420 (6.2)
Sex						
Female	1,799 (53.4)	1,616 (52.2)	4,323 (59.2)	1,324 (61.0)	1,454 (59.2)	4,022 (60.3)
Male	1,560 (46.3)	1474 (47.6)	2,970 (40.6)	833 (38.4)	989 (40.3)	2,613 (39.1)
Unknown	6 (0.1)	5 (0.1)	6 (-)	10 (0.4)	11(0.4)	32 (0.4)
Race-ethnicity group						
Latinx	711 (21.1)	699 (22.6)	1,619 (22.2)	462 (21.3)	566 (23.1)	1,480 (22.2)
Black, non-Latinx	969 (28.8)	831 (26.8)	2,106 (28.9)	359 (16.6)	473 (19.3)	1,422 (21.3)
White, non-Latinx	1,311 (39.0)	1,204 (38.9)	2,528 (34.6)	966 (44.6)	997 (40.6)	2,430 (36.4)
Asian, non-Latinx	129 (3.8)	131 (4.2)	410 (5.6)	172 (7.9)	166 (6.8)	574 (8.6)
Other, non-Latinx	162 (4.8)	127 (4.1)	339 (4.6)	135 (6.2)	133 (5.4)	354 (5.3)
Unknown	83 (2.5)	103 (3.3)	297 (4.1)	73 (3.4)	119 (4.8)	407 (6.1)
City region						
North Central	879 (26.1)	896 (28.7)	2,098 (28.7)	790 (36.4)	851(34.6)	2,325 (34.8)
West	555 (16.4)	511 (16.5)	1,243 (17.0)	464 (21.4)	468 (19.0)	1,113 (16.6)
Northwest	756 (22.4)	645 (20.8)	1,289 (17.6)	368 (16.9)	442 (18.0)	976 (14.6)
Southwest	451 (13.4)	417 (13.4)	1,056 (14.4)	213 (9.8)	304 (12.3)	840 (12.5)
South	303 (9.0)	293 (9.4)	831 (11.3)	142 (6.5)	223 (9.0)	949 (14.2)
Far South	411 (12.2)	323 (10.4)	760 (10.4)	182 (8.3)	162 (6.6)	438 (6.5)
Unknown	10 (0.2)	10 (0.3)	22 (0.3)	8 (0.3)	4 (0.1)	26 (0.3)
CCVI						
Very High	617 (18.3)	526 (16.9)	1,330 (18.2)	254 (11.7)	336 (13.6)	934(14.0)
High	280 (8.3)	260 (8.4)	656 (8.9)	125 (5.7)	189 (7.7)	539 (8.0)
High	2,468 (73.3)	2,309 (75)	5,313 (72.7)	1,788 (82.5)	1,929 (78.6)	5,194 (77.9)

Appendix E. Supplemental Materials for Aim 3

TABLE XXXI. WEVAX CHICAGO SURVEY RESPONDENTS (N=49), BY MAJOR INDUSTRY SECTOR[a]

Industry Group	n (%)
Manufacturing	14 (28.6)
Accommodation and Food Services	11 (22.5)
Professional, Scientific and Technical Services	6 (12.2)
Wholesale Trade	3 (6.1)
Arts, Entertainment, Recreation	2 (4.1)
Finance and Insurance	2 (4.1)
Retail Trade	2 (4.1)
Utilities	2 (4.1)
Construction	1 (2.0)
Educational Services	1 (2.0)
Health Care and Social Assistance	1 (2.0)
Information	1 (2.0)
Management of Companies and Enterprises	1 (2.0)
Real Estate and Rental and Leasing	1 (2.0)
Transportation and Warehousing	1 (2.0)

[a]coded using NAICS: North American Industry Classification System designations. Free-text descriptions from WEVax survey respondents were classified using NIOCCS (the Industry and Occupation Computerized Coding System) designed by National Institute for Occupational Safety and Health, 2022 version.

When workplaces were classified by major NAICS code, manufacturing (both food and non-food) and accommodation and food services (hospitality) were most frequently represented (n=14, 29% and n=11, 23% of respondents, respectively).

Appendix E (continued)

TABLE XXXII. REASONS FOR COVID-19 VACCINE HESISTANCY AMONG EMPLOYEES, AS REPORTED BY BUSINESSES RESPONDING TO WEVAX CHICAGO SURVEY (N=49), FULL-TIME AND PART-TIME OR OTHER STAFF

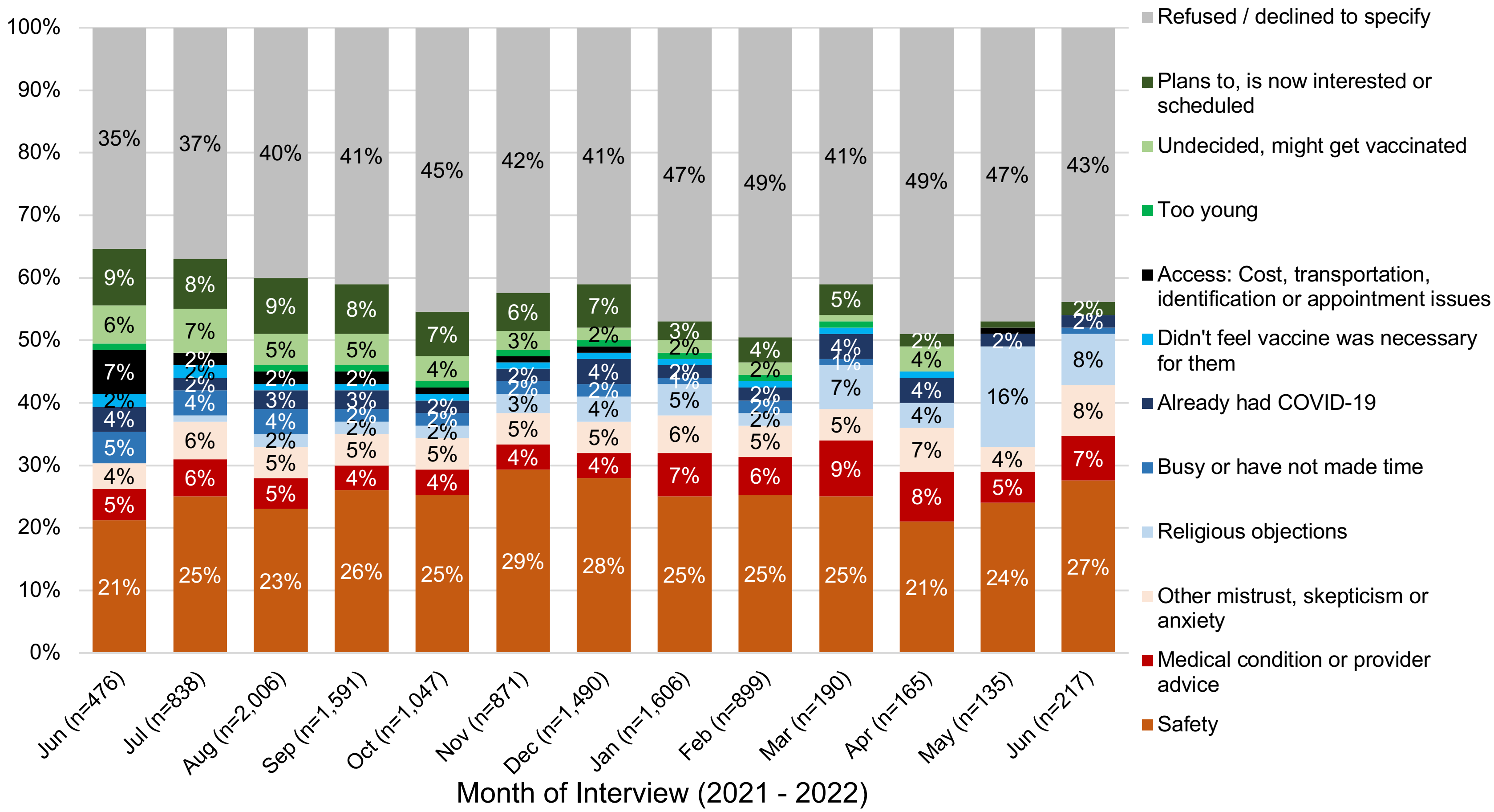
		Full-time n (%)	**Part-time** n (%)
Requiring Vaccination (Assessed once for all types of workers)	Primary series	11 (22.5)	
	Primary and boosters	3 (6.1)	
	No	33 (67.4)	
	Unknown/not sure	2 (4.1)	
Verifying Vaccination (Assessed once for all types of workers)	Primary series	20 (0.4)	-
	Primary and boosters	15 (0.3)	-
	No	10 (0.2)	-
	Unknown/not sure	3 (0.1)	-
On-site vaccine	Primary series	10 (20.4)	6 (16.2)
	Primary and boosters	5 (10.2)	4 (10.8)
	Boosters	0 (0)	0 (-)
	Neither	31 (63.3)	19 (51.4)
	Not applicable	3 (6.1)	7 (18.9)
	Unknown/not sure	- ()	1 (2.7)
Time off to get vaccinated	Primary series	10 (20.4)	9 (24.3)
	Primary and boosters*	23 (46.9)	10 (27)
	Boosters	1 (2)	1 (2.7)
	Neither	14 (28.6)	10 (27)
	Not applicable	1 (2)	6 (16.2)
	Unknown/not sure	0 (-)	1 (2.7)
Time off to recover from side effects	Primary series	6 (12.2)	4 (10.8)
	Primary and boosters	29 (59.2)	15 (40.5)
	Boosters	0 (0)	0 (-)
	Neither	11 (22.4)	11 (29.7)
	Not applicable	1 (2)	5 (13.5)
	Unknown/not sure	2 (4.1)	2 (5.4)

Appendix E (continued)

TABLE XXXII. REASONS FOR COVID-19 VACCINE HESITANCY AMONG EMPLOYEES, AS REPORTED BY BUSINESSES RESPONDING TO WEVAX CHICAGO SURVEY (N=49), FULL-TIME AND PART-TIME OR OTHER STAFF *(continued)*

		Full-time n (%)	**Part-time** n (%)
Monetary incentive	Primary series	6 (12.2)	3 (8.1)
	Primary and boosters	1 (2)	0 (-)
	Boosters	0 (-)	0 (-)
	Neither	40 (81.6)	29 (78.4)
	Not applicable	0 (0)	4 (10.8)
	Unknown/not sure	2 (4.1)	1 (2.7)
Other incentive	Primary series	3 (6.1)	1 (2.7)
	Primary and boosters	0 (-)	2 (5.4)
	Boosters	1 (2)	0 (-)
	Neither	42 (85.7)	28 (75.7)
	Not applicable	1 (2)	5 (13.5)
	Unknown/not sure	2 (4.1)	1 (2.7)
Signage/communication in workplace	Primary series	6 (12.2)	3 (8.1)
	Primary and boosters	25 (51.9)	16 (43.2)
	Boosters	0 (-)	0 (-)
	Neither	15 (30.6)	13 (35.1)
	Not applicable	1 (2)	4 (10.8)
	Unknown/not sure	2 (4.1)	1 (2.7)
Training staff to be vaccine ambassadors	Primary series	0 (-)	0 (-)
	Primary and boosters	5 (10.2)	2 (5.4)
	Boosters	0 (-)	0 (-)
	Neither	40 (81.6)	29 (78.4)
	Not applicable	2 (4.1)	5 (13.5)
	Unknown/not sure	2 (4.1)	1 (2.7)
Organizing an informational town-hall	Primary series	4 (8.2)	3 (8.1)
	Primary and boosters	8 (16.3)	5 (13.5)
	Boosters	0 (-)	0 (-)
	Neither	34 (69.4)	24 (64.9)
	Not applicable	1 (2)	4 (10.8)
	Unknown/not sure	2 (4.1)	1 (2.7)

<u>Appendix E</u> (continued)



[a] *Frequencies <2% not labeled*

Figure 37. Primary reasons for not initiating COVID-19 vaccination
among unvaccinated working-age Chicagoans interviewed June 1, 2021 – May 31, 2022 (n=9,925)[a]

VITA

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