Risk factors for SARS-CoV-2 infection in hospital workers: results from a screening study in New Jersey, U.S. in Spring 2020

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40-word summary: In a screening of 3904 New Jersey hospital employees and clinicians, 9.8% tested SARS-CoV-2 virus or IgG antibody positive. In multivariable models, direct patient contact, job role, and Black and Latinx race/ethnicity were all associated with positive test results.

Abstract:

Background: SARS-CoV-2 infection is a critical concern among health care workers (HCW). Other studies have assessed SARS-CoV-2 virus and antibodies in HCW, with disparate findings regarding risk based on role and demographics.

Methods: We screened 3,904 employees and clinicians for SARS-CoV-2 virus positivity and serum IgG at a major New Jersey hospital from April 28-June 30, 2020. We assessed positive tests in relation to demographic and occupational characteristics and prior COVID-19 symptoms using multivariable logistic regression models.

Results: Thirteen participants (0.3%) tested positive for virus and 374 (9.6%) tested positive for IgG (total positive: 381 [9.8%]). Compared to participants with no patient care duties, the odds of positive testing (virus or antibodies) were higher for those with direct patient contact: below-median patient contact, adjusted OR (aOR): 1.71, 95% CI: 1.18, 2.48); above-median patient contact aOR: 1.98, 95% CI: 1.35, 2.91. The proportion of participants testing positive was highest for phlebotomists (23.9%), maintenance/housekeeping (17.3%), dining/food services (16.9%), and interpersonal/support roles (13.7%) despite lower levels of direct patient care duties. Positivity rates were lower among doctors (7.2%) and nurses (9.1%), roles with fewer under-represented minorities. After adjusting for job role and patient care responsibilities and other factors, Black and Latinx workers had two-fold increased odds of a positive test compared to White workers. Loss of smell, taste, and fever were associated with positive testing.

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Conclusions: The HCW categories at highest risk for SARS-CoV-2 infection include support staff and underrepresented minorities with and without patient care responsibilities. Future work is needed to examine potential sources of community and nosocomial exposure among these under-studied HCW.

Keywords: SARS-CoV-2; COVID-19; hospital epidemiology; disparities; health care workers

Introduction:

As the global community continues to confront the COVID-19 pandemic, the potential for occupational exposure among health care workers (HCW) remains a critical concern. Multiple studies comparing SARS-CoV-2 infection among HCW and non-health care workers have found higher rates of infection among HCW, a disparity persisting after adjustment for the likelihood of being tested [1-3]. Nevertheless, uncertainty remains as to what extent SARS-CoV-2 transmission is heightened within hospitals and what factors put hospital employees at greater risk for infection. For example, several studies have observed that HCW with greater exposure to patients with COVID-19 were more likely to be SARS-CoV-2-infected [2-5] and inadequate personal protective equipment (PPE) was identified as a risk factor for infection [2]. However other studies have observed no associations [6, 7]. For example, at a large Belgian hospital with strong, early infection control measures, no occupational risk factors were associated with SARS-CoV-2 antibody positivity in HCW; positivity was only associated with having household contacts with suspected or confirmed COVID-19 [7]. This finding suggests that little occupational transmission occurred, but whether household contacts were infected *before or after* HCW was not defined. In other contrasting reports,

Importantly, despite the higher number of confirmed U.S. COVID-19 cases (>6 million of >26 million worldwide) and deaths (>180,000 of >860,000 worldwide) as of September 4, 2020 [8], relatively few studies have directly measured infections among U.S. HCW [6, 9-12]. HCW in highly impacted areas may be at particular risk, due both to community transmission and the surge in COVID-19 patients; this may have been particularly true especially during the early phase of the pandemic when PPE and other protections were limited [9-12].

With proximity, strong economic and social ties to New York City (NYC), a large commuter population, and the densest population of any U.S. state, New Jersey (NJ) was particularly hard hit by COVID-19 in

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March-April 2020 [13]. As of August 2020, the NJ per capita death rate was the second highest in the U.S. [14]. To assess occupational safety, we conducted a voluntary SARS-CoV-2 virus and antibody screening of all personnel of a university-affiliated NJ teaching hospital. We aimed to: (1) characterize SARS-CoV-2 virus and antibody status; (2) examine demographic and occupational risk factors for infection; and (3) assess positivity in relation to self-reported symptoms.

Methods:

Setting and data collection. Robert Wood Johnson University Hospital (RWJUH) is an academic medical center located in central New Jersey. Affiliated with Rutgers University and the RWJBarnabas Health network, RWJUH has 614 licensed beds and approximately 5,200 employees and 2,300 affiliated attending and trainee physicians. The first patients with COVID-19 were admitted to RWJUH in early March 2020. To date, the hospital has treated >1,270 inpatients and 520 outpatients with test-positive COVID-19, with cases peaking in mid-April **(Figure 1).**

RWJUH employees and affiliated Rutgers Robert Wood Johnson Medical School (RWJMS) clinicians were invited via email and posters to participate in on-site, voluntary, no-cost screening for SARS-CoV-2 virus and antibodies. Additional in-person recruitment and testing occurred from April 28-June 30, 2020, at a central hospital location. Employees ill with suspected COVID-19 were directed to employee health and not permitted to participate in screening. Thus, the study population represented personnel at work with no major symptoms of active infection. After consent, interested employees ≥18 years old completed a questionnaire providing information about demographics, job role and duties, medical history and co-morbidities, symptoms since the pandemic began locally (fever, cough, shortness of breath, vomiting, diarrhea, loss of smell or taste, muscle aches, or headache), and potential recent sources of exposure. Obesity was classified as BMI≥30kg/m^2, calculated based on self-reported height and weight.

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After completing the questionnaire, each employee provided a blood sample and self-collected nasal swab for antibody and viral testing, respectively. Study data were collected and managed using REDCap electronic data capture tools hosted at RWJMS [15].

Patient consent statement. All study activities were approved by the Rutgers University Institutional Review Board (Pro2020000902) and all participants provided electronic informed consent prior to engaging in study activities.

Laboratory assays. Detection of SARS-CoV-2 viral RNA was performed using real-time reverse transcription polymerase chain reaction (RT-PCR) on the cobas® 6800 system (Roche Diagnostics, Indianapolis, IN) within the RWJUH Clinical Virology laboratory. The assay, which received Emergency Use Authorization from the Food and Drug Administration for clinical detection of SARS-CoV-2 RNA in upper respiratory samples including nasal swab [16], targets two viral genes: ORF1a/b, a non-structural region unique to SARS-CoV-2 (limit of detection 25 copies/ml); and E-gene encoding a structural protein envelope gene specific for pan-Sarbecovirus, including SARS-CoV-2 (limit of detection 32 copies/ml).

SARS-CoV-2 antibody screening of human serum was performed using the Abbott Architect SARS-CoV-2 assay (Abbott Laboratories, Chicago, IL) [16]. The assay detects immunoglobulin class G (IgG) antibodies to the nucleocapsid protein of the SARS-CoV-2 virus. Prior testing showed sensitivity of 96.9% in serum from SARS-CoV-2 PCR-positive patients 14 days after COVID-19 symptom onset and specificity of ≥99.6% in serum from patients collected pre-pandemic and in patients without COVID-19 but who exhibited respiratory symptoms [16, 17].

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Statistical analysis. We first calculated descriptive statistics for all variables of interest. Given the low prevalence of viral PCR positivity, we aggregated positive tests results by PCR and antibody screening. We examined the relationship between job roles, proportion reporting direct patient care duties, and positive testing prevalence for SARS-CoV-2.

We evaluated the association between variables of interest and SARS-CoV-2 positivity using multivariable logistic regression. We first fit minimally adjusted models examining demographic and lifestyle factors only (gender, age, race/ethnicity, BMI, tobacco use, and comorbidities) in relation to virus/antibody positivity, calculating odds ratios and 95% confidence intervals (CIs). We initially considered co-morbidities individually and then aggregated them to a binary "any comorbidity" variable, given the similar point estimates observed across individual comorbidities. Fully adjusted models were then fit including those demographic and lifestyle covariates, as well as level of direct patient care and hospital job roles. For this analysis, we consolidated job titles as follows: physicians (including trainees); nurses (including nurse practitioners and trainees); technicians, technologists, transport staff, and phlebotomists (roles with generally brief but numerous patient interactions); interpersonal and support roles (including clerks, counselors, security, monitors, social workers, dieticians, and chaplains); other patient care roles; other non-patient care roles; and unclassified workers. Physicians were selected as the reference group because they represented one of the larger groups of participants and were considered lower risk than others. We imputed missing data (<5% for most variables) with multiple imputation using chained equations and conducted multivariable models based on 20 imputed datasets [18].

We additionally fit logistic regression models to examine odds of SARS-CoV-2 virus or antibody positivity in relation to self-report symptoms since the pandemic began. The first model included all participants; the second model included only participants who reported ≥1 symptom. A final linear regression model

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limited to participants with positive testing examined antibody concentrations in relation to self-reported symptoms, history of hospital-based care, and time since first symptom. All statistical analyses were performed using SAS 9.4.

Results:

Of an estimated 7,500 employees, 4,482 (59.8%) consented to participate in the screening. Of these, 3,907 (87.2%) ultimately provided blood and nasal swab samples for testing. In total, 13 (0.3%) participants were positive for the virus and 374 (9.6%) were positive for IgG antibodies, corresponding to an overall positive result (virus or IgG antibodies) in 381 (9.8%) of those screened.

The majority of participants (74.0%) were female, and the sample was relatively diverse, including 22.5% non-Hispanic Asian, 13.8% non-Hispanic Black, 14.5% Hispanic/Latinx, and 7.9% identifying as belonging to another racial/ethnic group **(Table 1).** Nearly one-fifth (19.2%) reported at least one symptom consistent with COVID-19 in the prior two weeks, and nearly one-quarter (24.1%) reported at least one symptom with a prior illness consistent with COVID-19. Over two-thirds of participants (68.8%) reported having direct patient care responsibilities, with a wide variety of roles included. The proportion of participants testing positive was highest for phlebotomists (23.9%), followed by maintenance/housekeeping (17.3%), dining/food services (16.9%), and interpersonal/support (13.7%). By comparison, positivity rates were lower among doctors (7.2%) and nurses (9.1%) **(Figure 2).** Of note, participants in higher-risk roles had greater proportions of under-represented minorities than doctors and nurses (**Supplementary Table 1**).

In minimally adjusted models, compared to non-Hispanic White participants, the odds of positive testing were over 2-fold higher among non-Hispanic Black (OR: 2.17, 95% CI: 1.60, 2.94) and Hispanic/Latinx participants (OR: 2.13, 95% CI: 1.58, 2.87), and 56% higher among participants self-identifying as "other"

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races (OR: 1.56, 95% CI: 1.05, 2.33) **(Table 2).** The odds of positive testing were also lower among older participants compared to those under 40. Neither gender nor comorbidities (considered individually or collectively) were associated with positive testing, but current smokers were less likely to be positive.

In fully adjusted models, we examined odds of positive testing in relation to demographic factors (age, sex, race/ethnicity), tobacco use, comorbidities, patient care duties, and job role (**Table 2**). Adjusting for those covariates, compared to participants with no patient care duties, the odds of testing positive were higher for those with direct patient contact, either below the median (OR: 1.71, 95% CI: 1.18, 2.48) or above the median (OR: 1.98, 95% CI: 1.35, 2.91). In addition, relative to physicians, workers in several groups had higher odds of positive testing, including interpersonal/support roles (OR: 2.07, 95% CI: 1.25, 3.44), technicians/technologists (OR: 1.71, 95% CI: 1.08, 2.71), and other non-patient care (OR: 1.75, 95% CI: 1.01, 3.03). Associations between positive testing and age, race, and smoking were consistent with those observed in minimally adjusted models.

In models examining self-reported symptoms, the strongest predictors of positive testing were loss of smell (OR: 5.13, 95% CI: 2.85, 9.24) and loss of taste (OR: 4.01, 95% CI: 2.30, 7.01) (**Table 3**). Odds of a positive test were also higher among those reporting recorded fever >100°F (OR: 2.58, 95% CI: 1.75, 3.81). In models limited to participants who reported at least one symptom consistent with COVID-19 (36.8%), results were largely unchanged. In analyses examining self-reported symptoms in relation to IgG antibody levels, body aches were associated with higher IgG levels (β=0.75, 95% CI: -0.01, 1.51), with no strong associations observed for other symptoms **(Table 4).** Antibody concentrations were non-significantly higher among participants reporting symptoms ≤84 days earlier compared to those who tested positive but reported no symptoms, with the highest antibody levels observed among individuals whose symptoms began 14-28 days earlier **(Table 4).**

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Discussion:

In this screening of nearly four thousand hospital employees in NJ, an early epicenter of the US COVID-19 pandemic, approximately 10% of staff tested positive for SARS-CoV-2 virus and/or antibodies. Both demographic and occupational factors were associated with odds of testing positive. In multivariable models, non-white hospital staff (particularly those identifying as Black, Hispanic/Latinx, or other) were most likely to test positive, consistent with findings reported in the general population [19-21]. After accounting for demographic differences, the odds of infection were higher among employees with patient care duties as well as several groups besides physicians and nurses, including interpersonal/support staff (e.g., security staff, clerks), and technicians/technologists (including phlebotomists).

Prevalence of antibody positivity in HCW has been highly variable across studies, hospitals, and geographic settings. Our results are similar to the 12% IgG positivity reported in a small (n=91) study of NYC anesthesiologists and intensive care providers as well as the 13.7% seropositivity reported in a large (n=46,117) NYC hospital system [10, 12]. However another NYC study reported much higher (36%) IgG positivity among high risk HCW with direct patient contact (e.g., emergency medicine, critical care, and anesthesiology staff) [9]. Even within individual medical systems, HCW seroprevalence can vary considerably across hospitals or geographic areas. In another large NYC study, seroprevalence in HCW varied more than two-fold (10.9-22.7%) by county [12] while in seven affiliated Houston, Texas hospitals, antibody positivity ranged from 0-12.5% [11]. Seroprevalence studies of European HCW have mostly shown lower rates of antibody positivity, ranging from 1.6-6.5% [7, 22, 23]. Overall, the considerable geographic variability likely reflects differences in local trends in community transmission but may also reflect variation in test characteristics and hospital infection control practices, particularly during the early stage of the pandemic when best practices for protecting HCW were emerging and

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resources for testing and PPE were limited. In our study, IgG antibody positivity (9.6%) was far more

common than SARS-CoV-2 virus positivity (0.03%), suggesting greater prior SARS-CoV-2 exposure among

hospital staff. These results are consistent with the timeline of the screening study, which began as the

local NJ pandemic was waning after April 2020 (**Figure 1**).

Studies focusing on infection among "high-risk" HCW groups reflect the implicit premise that within

hospitals, risks of workplace SARS-CoV-2 acquisition likely vary by work unit and role [9, 10, 24]. After

adjustment for covariates including race/ethnicity and job role, we observed that participants with

patient care responsibilities were more likely to have been infected than those who provided no patient

care, which is consistent with some [e.g.,3, 25], but not all [e.g.,6, 7] prior studies. However, we also

observed that those with "interpersonal/support" roles (including clerks, counselors, security staff,

monitors, social workers, dieticians, and chaplains) and high-throughput patient care roles (technicians,

technologists, phlebotomists, and transport staff) had significantly increased likelihood of infection

compared with physicians. More granular analyses of infection rates by specific job titles showed

highest rates of infections among phlebotomists, dining and food services, maintenance, housekeeping,

security, and other support workers (**Figure 2**). By contrast, physicians, nurses, and emergency medical

technicians, who have attracted more attention as "health care heroes," showed much lower infection

rates. A recent large study of NYC-area HCW also observed increased risks of virus positivity among

service/maintenance workers vis-a-vis physicians, although differences across roles were less marked

than in our study and largely explained by other factors [12]. A smaller study reported that nearly 35%

of English housekeeping staff tested positive for antibodies [26]. These results contrast with those of an

Italian hospital during the early phase of the pandemic, in which physicians were most likely to be

infected, and clerical and administrative workers, least infected [27]. Variation in infection rates among

frontline workers with direct patient care responsibilities may reflect differences in hospitals' abilities to

provide adequate PPE and enact precautionary policies during COVID-19 surges. With the safety of

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frontline HCW prioritized in many hospital settings, hospital employees without direct patient care roles likely had less access to PPE and enforcement of social distancing and safety protocols.

The higher infection rates we observed may reflect community infection as workers in these support roles were disproportionately black and Hispanic/Latinx, whose communities have been most impacted by the pandemic. After adjusting for job role and other risk factors, the odds of infection were twice as great among Black and Latinx workers compared to white workers, consistent with other evidence of social determinants of COVID-19 vulnerability [19, 20]. Similar patterns were observed in a screening of nearly 10,000 United Kingdom university hospital workers, in which Black and Asian race as well as hospital porter and cleaning job roles were strong predictors of infection [25]. Lacking additional information on potential sources of community exposure or additional measures of socioeconomic status in these vulnerable HCW, we are unable to test hypotheses regarding community versus hospital infection, but suggest that this is an important future direction. Ultimately, differences in infectivity rates by race/ethnicity and job role warrant additional consideration of individual hospital practices as well as the larger community context. Regardless of whether infections occurred through nosocomial or community transmission, these results suggest a need to enact safety protocols (including marking and social distancing) for all hospital employees to preserve and protect the health care workforce through future waves of infection. Importantly, workers in support roles in health care settings (with little or no patient contact) have attracted relatively little attention to date; nevertheless, our results suggest potentially high infection rates in this group. Indeed the 40% of infected HCW who reported no prior symptoms of infection in our study could indicate an important contribution to nosocomial SARS-CoV-2 spread, even if their infections were initially acquired in the community.

Consistent with prior research in other populations [reviewed in 28], loss of smell and taste were the symptoms most strongly associated with positive testing. We also observed approximately 2.5-fold

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increased odds of positive testing among participants reporting a measured fever >100F during the pandemic. Our results suggest that other symptoms may be less specific and informative for diagnosing SARS-CoV-2 infection. Interestingly, fever and symptoms other than body aches were not strongly associated with IgG levels among test-positive participants. Associations between SARS-CoV-2 disease severity and IgG response in patient populations have been reported elsewhere [29-31]. Our data only captured symptom presence, not severity; hospital-based medical care was positively but not significantly associated with antibody level. In a small study of German HCW, most participants with SARS-CoV-2 infections had detectable IgG antibodies over 12-week follow-up; as in our study, no strong associations with symptoms were observed [32].

Strengths of our study include recruitment from a large hospital with diverse staff and use of a unified testing protocol. Few studies to date have reported on infections among diverse HCW populations or simultaneously tested for both virus and antibodies, signifying current and prior infection, respectively. At the time of recruitment, the hospital and surrounding communities had already experienced the "surge," making us well-positioned to assess infections through antibody testing. Our antibody tests targeted IgG, and unlike most previous studies of HCW, we analyzed quantitative antibody results among those testing positive (**Table 4**).

Limitations of our study included participation of only half of all employees and affiliated clinicians. Those who suspected current or prior infection may have been more likely to enroll, whereas ill employees with active infection could not attend work and were excluded; thus, the true prevalence of SARS-CoV-2 infections among all employees and clinicians may have been lower or higher than observed. Despite the higher infection rates in those providing patient care, we cannot determine whether infections were contracted in the hospital or community setting. Our measures of socioeconomic status were limited to race/ethnicity and job role; the possibility of residual confounding

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by additional socioeconomic factors remains. Moreover, since most of the positive cases were identified through antibody testing, which reflects a broader past exposure window than viral testing, our assessment of recent exposures and behaviors (e.g., work locations, recent PPE use, and outside infectious contacts in the prior two weeks) was not considered informative and thus excluded from analyses. Analyses of factors associated with antibody levels may have been limited by small sample sizes. Other limitations were the accuracy of self-reported data and self-collected nasal swabs.

In conclusion, in this large hospital-based screening in a U.S. SARS-CoV-2 early U.S. epicenter, we observed that ~10% of HCW had evidence of active or prior SARS-CoV-2 infection. As expected, those with patient care roles had greater likelihood of infection, but absolute infection rates were highest in Black and Latinx HCW and in those with lower-income support roles. These findings highlight potential opportunities for educational interventions to better protect workers across all job roles as well as foster safe practices outside the hospital.

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References:

1. Barrett ES, Horton DB, Roy J, et al. Prevalence of SARS-CoV-2 infection in previously undiagnosed health care workers at the onset of the U.S. COVID-19 epidemic. medRxiv **2020**.

2. Nguyen LH, Drew DA, Graham MS, et al. Risk of COVID-19 among front-line health-care workers and the general community: a prospective cohort study. Lancet Public Health **2020**.

3. Iversen K, Bundgaard H, Hasselbalch RB, et al. Risk of COVID-19 in health-care workers in Denmark: an observational cohort study. Lancet Infect Dis **2020**.

4. Rivett L, Sridhar S, Sparkes D, et al. Screening of healthcare workers for SARS-CoV-2 highlights the role of asymptomatic carriage in COVID-19 transmission. Elife **2020**; 9.

5. Ran L, Chen X, Wang Y, Wu W, Zhang L, Tan X. Risk Factors of Healthcare Workers with Corona Virus Disease 2019: A Retrospective Cohort Study in a Designated Hospital of Wuhan in China. Clin Infect Dis **2020**.

6. Mani NS, Budak JZ, Lan KF, et al. Prevalence of COVID-19 Infection and Outcomes Among Symptomatic Healthcare Workers in Seattle, Washington. Clin Infect Dis **2020**.

7. Steensels D, Oris E, Coninx L, et al. Hospital-Wide SARS-CoV-2 Antibody Screening in 3056 Staff in a Tertiary Center in Belgium. Jama **2020**; 324(2): 195-7.

8. NYT. Coronavirus Map: Tracking the Global Outbreak. Available at: https://www.nytimes.com/interactive/2020/world/coronavirus-maps.html. Accessed August 27.

9. Mansour M, Leven E, Muellers K, Stone K, Mendu DR, Wajnberg A. Prevalence of SARS-CoV-2 Antibodies Among Healthcare Workers at a Tertiary Academic Hospital in New York City. J Gen Intern Med **2020**; 35(8): 2485-6.

10. Morcuende M, Guglielminotti J, Landau R. Anesthesiologists' and intensive care providers' exposure to COVID-19 infection in a New York City academic center: a prospective cohort study assessing symptoms and COVID-19 antibody testing. Anesth Analg **2020**.

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11.   Vahidy FS, Bernard DW, Boom ML, et al. Prevalence of SARS-CoV-2 Infection Among

        Asymptomatic Health Care Workers in the Greater Houston, Texas, Area. JAMA Netw Open

        2020; 3(7): e2016451.

12.   Moscola J, Sembajwe G, Jarrett M, et al. Prevalence of SARS-CoV-2 Antibodies in Health Care

        Personnel in the New York City Area. Jama **2020**.

13.   NYT. New Jersey Coronavirus Map and Case Count. Available at:

        https://www.nytimes.com/interactive/2020/us/new-jersey-coronavirus-cases.html. Accessed

        August 27.

14.   KFF. Confirmed COVID-19 Cases and Deaths. Available at: https://www.kff.org/other/state-

        indicator/confirmed-covid-19-cases-and-deaths. Accessed August 27.

15.   Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture

        (REDCap)--a metadata-driven methodology and workflow process for providing translational

        research informatics support. J Biomed Inform **2009**; 42(2): 377-81.

16.   FDA. Emergency Use Authorization: Emergency Use Authorization (EUA) information and list of

        all current EUAs. Available at: https://www.fda.gov/emergency-preparedness-and-

        response/mcm-legal-regulatory-and-policy-framework/emergency-use-authorization#LDTs.

        Accessed August 27.

17.   Bryan A, Pepper G, Wener MH, et al. Performance Characteristics of the Abbott Architect SARS-

        CoV-2 IgG Assay and Seroprevalence in Boise, Idaho. J Clin Microbiol **2020**; 58(8).

18.   White IR, Royston P, Wood AM. Multiple imputation using chained equations: Issues and

        guidance for practice. Stat Med **2011**; 30(4): 377-99.

19.   Poulson M, Geary A, Annesi C, et al. National Disparities in COVID-19 Outcomes between Black

        and White Americans. J Natl Med Assoc **2020**.

20. Rosenberg ES, Tesoriero JM, Rosenthal EM, et al. Cumulative incidence and diagnosis of SARS-CoV-2 infection in New York. Ann Epidemiol **2020**; 48: 23-9.e4.

21. Vahidy FS, Nicolas JC, Meeks JR, et al. Racial and ethnic disparities in SARS-CoV-2 pandemic: analysis of a COVID-19 observational registry for a diverse US metropolitan population. BMJ Open **2020**; 10(8): e039849.

22. Korth J, Wilde B, Dolff S, et al. SARS-CoV-2-specific antibody detection in healthcare workers in Germany with direct contact to COVID-19 patients. J Clin Virol **2020**; 128: 104437.

23. Schmidt SB, Gruter L, Boltzmann M, Rollnik JD. Prevalence of serum IgG antibodies against SARS-CoV-2 among clinic staff. PLoS One **2020**; 15(6): e0235417.

24. El-Boghdadly K, Wong DJN, Owen R, et al. Risks to healthcare workers following tracheal intubation of patients with COVID-19: a prospective international multicentre cohort study. Anaesthesia **2020**.

25. Eyre DW, Lumley SF, O'Donnell D, et al. Differential occupational risks to healthcare workers from SARS-CoV-2 observed during a prospective observational study. Elife **2020**; 9.

26. Shields AM, Faustini SE, Perez-Toledo M, et al. SARS-CoV-2 seroconversion in health care workers. medRxiv **2020**: 2020.05.18.20105197.

27. Lombardi A, Consonni D, Carugno M, et al. Characteristics of 1573 healthcare workers who underwent nasopharyngeal swab testing for SARS-CoV-2 in Milan, Lombardy, Italy. Clin Microbiol Infect **2020**.

28. Agyeman AA, Chin KL, Landersdorfer CB, Liew D, Ofori-Asenso R. Smell and Taste Dysfunction in Patients With COVID-19: A Systematic Review and Meta-analysis. Mayo Clin Proc **2020**; 95(8): 1621-31.

29. Reifer J, Hayum N, Heszkel B, Klagsbald I, Streva VA. SARS-CoV-2 IgG antibody responses in New York City. Diagn Microbiol Infect Dis **2020**; 98(3): 115128.

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30.   Lynch KL, Whitman JD, Lacanienta NP, et al. Magnitude and kinetics of anti-SARS-CoV-2 antibody

        responses and their relationship to disease severity. Clin Infect Dis **2020**.

31.   Robbiani DF, Gaebler C, Muecksch F, et al. Convergent antibody responses to SARS-CoV-2 in

        convalescent individuals. Nature **2020**; 584(7821): 437-42.

32.   Fill Malfertheiner S, Brandstetter S, Roth S, et al. Immune response to SARS-CoV-2 in health care

        workers following a COVID-19 outbreak: A prospective longitudinal study. J Clin Virol **2020**; 130:

        104575.

Table 1. Characteristics of Robert Wood Johnson Screening Study participants.

	Total cohort (n= 3904)[a]	Negative on both SARS-CoV-2 virus and antibody test (n=3523; 90.2%)	Positive on SARS-CoV-2 virus or antibody test (n=381; 9.8%)	p-value[b]
	N (Column %)	N (Row %)	N (Row %)	
Demographics				
Gender				
Female	2874 (74.0)	2593 (90.2)	281 (9.8)	0.93
Male	1030 (26.0)	930 (90.3)	100 (9.7)	
Age (years)				**<0.001**
20-39	1703 (44.1)	1502 (88.2)	201 (11.8)	
40-59	1690 (43.7)	1548 (91.6)	142 (8.4)	
≥60	472 (12.2)	439 (93.0)	33 (7.0)	
Race ethnicity				**<0.001**
Non-Hispanic white	1612 (41.3)	1492 (92.6)	120 (7.4)	
Non-Hispanic Black	540 (13.8)	460 (85.2)	80 (14.8)	
Non-Hispanic Asian	878 (22.5)	819 (93.3)	59 (6.7)	
Hispanic	565 (14.5)	478 (84.6)	87 (15.4)	
Other/missing	309 (7.9)	1492 (92.6)	120 (7.4)	
Clinical variables				
BMI				
<18.5	94 (2.5)	85 (90.4)	9 (9.6)	0.19
18.5≤BMI<25	1438 (38.2)	1309 (91.0)	129 (9.0)	
25≤BMI<30	1271 (33.7)	1154 (90.8)	117 (9.2)	
30≤BMI<40	827 (21.9)	729 (88.1)	98 (11.9)	
≥40	139 (3.7)	128 (92.1)	11 (7.9)	
Tobacco use				0.25
Never	3175 (82.0)	2855 (89.9)	320 (10.1)	
Former	459 (11.9)	419 (91.3)	40 (8.7)	
Current	238 (6.1)	221 (92.9)	17 (7.1)	
Comorbidities				
No comorbidities	1810 (48.2)	1646 (90.9)	164 (9.1)	0.33
Diabetes	257 (6.7)	234 (91.1)	23 (8.9)	0.73
High Blood Pressure	729 (18.9)	666 (91.4)	63 (8.6)	0.28
Asthma	548 (14.3)	495 (90.3)	53 (9.7)	0.99
Obesity	966 (25.6)	857 (88.7)	109 (11.3)	0.055
Other[c]	173 (4.5)	158 (91.3)	15 (8.7)	0.74
Recent COVID-19 symptoms (any)	738 (19.2)	640 (86.7)	98 (13.3)	**<0.001**
Prior or recent COVID-19 symptoms (any)	1404 (36.6)	1175 (83.7)	229 (16.3)	**<0.001**
Health exposures				
Direct patient care				**0.02**
No	1171 (31.2)	1076 (91.9)	95 (8.1)	
Yes, close contact (≤40% of total worktime)	1358 (36.2)	1227 (90.4)	131 (9.6)	
Yes, close contact (>40% of total worktime)	1226 (32.6)	1085 (88.5)	141 (11.5)	
Household member with COVID-19 diagnosis or	208 (5.3)	161 (77.4)	47 (22.6)	**<0.001**

symptoms				
Co-worker with COVID-19 diagnosis or symptoms	1108 (28.5)	988 (89.2)	120 (10.8)	0.15
Other contact with COVID-19 diagnosis or symptoms	296 (7.6)	258 (87.2)	38 (12.8)	0.08
Hospital Role				**<0.001**
Dentist / Dental	22 (0.6)	22 (100.0)	0 (0.0)	
Dining / Food	89 (2.3)	74 (83.1)	15 (16.9)	
Interpersonal / Support	351 (9.0)	303 (86.3)	48 (13.7)	
Maintenance / Housekeeping	150 (3.8)	124 (82.7)	26 (17.3)	
Non-Physician Emergency Workers	13 (0.3)	12 (92.3)	1 (7.7)	
NP/PA	159 (4.1)	137 (86.2)	22 (13.8)	
Nurse / Trainee	1239 (31.7)	1122 (90.6)	117 (9.4)	
OR / Surgical Staff	54 (1.4)	52 (96.3)	2 (3.7)	
Other Non-Patient Care	433 (11.1)	411 (94.9)	22 (5.1)	
Other Patient Care	136 (3.5)	117 (86.0)	19 (14.0)	
Pharmacist	115 (2.9)	113 (98.3)	2 (1.7)	
Phlebotomist	46 (1.2)	35 (76.1)	11 (23.9)	
Physician / Trainee	502 (12.9)	466 (92.8)	36 (7.2)	
PT/OT/ST	98 (2.5)	91 (92.9)	7 (7.1)	
Respiratory	56 (1.4)	53 (94.6)	3 (5.4)	
Technicians / Technologists	399 (10.2)	353 (88.5)	46 (11.5)	
Unclassified	42 (1.1)	38 (90.5)	4 (9.5)	

BMI: body mass index; COVID-19: coronavirus disease-2019; NP: nurse practitioner; OR: operating room; OT:

occupational therapist; PA: physician's assistant; PT: physical therapist; ST: speech therapist

[a] n's for individual variables vary with some missing data from up to 4% of respondents.

[b] Bold font indicates p<0.05.

[c] Other comorbidities include: cancer, cardiovascular or cerebrovascular disease, chronic autoimmune disease,

chronic kidney disease, chronic obstructive pulmonary disease, or other chronic lung disease.

Table 2. Logistic regression models examining risk factors for positive SARS-CoV-2 test (virus and/or antibody; n=3904).[a]

Risk factor	Minimally adjusted model	Fully adjusted model
	Odds Ratio (95% CI)	Odds Ratio (95% CI)
Age		
18-39	Ref	Ref
40-59	**0.71 (0.56, 0.90)**	**0.74 (0.59, 0.95)**
60 and above	**0.62 (0.42, 0.91)**	0.72 (0.49, 1.07)
Male[b]	1.03 (0.80, 1.32)	1.12 (0.86, 1.45)
Race/ethnicity		
Non-Hispanic white	Ref	Ref
Non-Hispanic Black	**2.13 (1.58, 2.87)**	**2.06 (1.51, 2.80)**
Non-Hispanic Asian	0.89 (0.64, 1.24)	0.90 (0.65, 1.24)
Hispanic/Latinx	**2.17 (1.60, 2.94)**	**2.10 (1.53, 2.89)**
Other	**1.56 (1.05, 2.33)**	1.48 (0.99, 2.23)
Tobacco use		
Never	Ref	Ref
Current	0.61 (0.37, 1.02)	**0.59 (0.35, 1.00)**
Former	0.95 (0.67, 1.35)	0.92 (0.64, 1.32)
Any comorbidity[c]	1.11 (0.89, 1.40)	1.09 (0.87, 1.38)
Direct patient care		
None		Ref
Below Median		**1.71 (1.18, 2.48)**
Above Median		**1.98 (1.35, 2.91)**
Hospital role		
Physician (including trainee)		Ref
Nurse (including trainee)		1.33 (0.88, 2.01)
Technician/technologist		**1.71 (1.08, 2.71)**
Interpersonal/support		**2.07 (1.25, 3.44)**
Other patient care		0.72 (0.42, 1.23)
Other non-patient care		**1.75 (1.01, 3.03)**
Unclassified		1.08 (0.35, 3.32)

[a] Results significant at p<0.05 are indicated in bold font.

[b] Reference group: female

[c] Any comorbidity includes: diabetes, hypertension, asthma, obesity, cancer, cardiovascular or cerebrovascular disease, chronic autoimmune disease, chronic kidney disease, chronic obstructive pulmonary disease, or other chronic lung disease.

Table 3. SARS-CoV-2 test positivity (virus and/or antibody) in relation to self-reported recent or prior symptoms of COVID-19 (n=3904).[a]

Reported symptom	All participants (n=3904)	Participants with at least one symptom (n=1435)
	Odds Ratio (95% CI)	
Fever[b]		
Felt feverish but did not take temperature	0.97 (0.64, 1.46)	0.95 (0.64, 1.42)
Recorded temperature over 100F	**2.58 (1.75, 3.81)**	**2.47 (1.68, 3.64)**
Cough	1.03 (0.70, 1.50)	0.96 (0.65, 1.41)
Shortness of breath or difficulty breathing	0.86 (0.55, 1.33)	0.86 (0.56, 1.31)
Vomiting	0.82 (0.40, 1.68)	0.81 (0.40, 1.66)
Diarrhea/multiple watery stools	1.23 (0.81, 1.85)	1.19 (0.79, 1.78)
Loss of smell	**5.13 (2.85, 9.24)**	**4.97 (2.78, 8.90)**
Loss of taste	**4.01 (2.30, 7.01)**	**4.00 (2.30, 6.94)**
Body ache	1.39 (0.95, 2.04)	1.30 (0.88, 1.90)
Headaches	1.19 (0.86, 1.66)	1.06 (0.74, 1.52)
Other symptoms[c]	**0.52 (0.35, 0.78)**	**0.52 (0.35, 0.76)**

[a] Results significant at p<0.05 are indicated in bold font.

[b] Reference group: no fever

[c] Includes: fatigue, nausea, loss of appetite, conjunctivitis, nasal and sinus congestion, runny nose, sneezing, chest

tightness, abdominal pain, rash

Table 4. Antibody levels in relation to clinical features and timing of illness among antibody-positive participants (n=374).

Variables	Point estimates (95% Confidence Interval)
Fever[a]	
Felt feverish but did not take temperature	0.15 (-0.58, 0.88)
Recorded temperature over 100F	0.26 (-0.44, 0.96)
Cough	-0.09 (-0.80, 0.61)
Shortness of breath or difficulty breathing	0.01 (-0.75, 0.76)
Vomiting	0.49 (-0.77, 1.75)
Diarrhea /multiple watery stools	0.32 (-0.47, 1.11)
Loss of smell	-0.21 (-1.43, 1.02)
Loss of taste	-0.64 (-1.87, 0.60)
Body aches	0.75 (-0.01, 1.51)
Headaches	-0.03 (-0.70, 0.64)
Other Symptoms[b]	0.10 (-0.63, 0.83)
Any treatment in hospital for COVID-19	0.58 (-0.27, 1.43)
Time since beginning of illness[c]	
0 - 14 days	0.40 (-2.92, 3.73)
15 - 28 days	1.37 (-0.46, 3.20)
29 - 56 days	0.77 (-0.25, 1.79)
57 – 84 days	0.50 (-0.48, 1.48)
> 84 days	-0.41 (-1.52, 0.69)

[a] Reference group: no fever

[b] Includes: fatigue, nausea, loss of appetite, conjunctivitis, nasal and sinus congestion, runny nose, sneezing, chest

tightness, abdominal pain, rash

[c] Reference group: no suspected COVID-19 illness

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Figure 1. COVID-19 cases at Robert Wood Johnson University Hospital and New Jersey COVID-19 deaths in Spring 2020.

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Figure 2. SARS-CoV-2 virus and antibody positivity by job role and in relation to patient contact in the RWJSS.
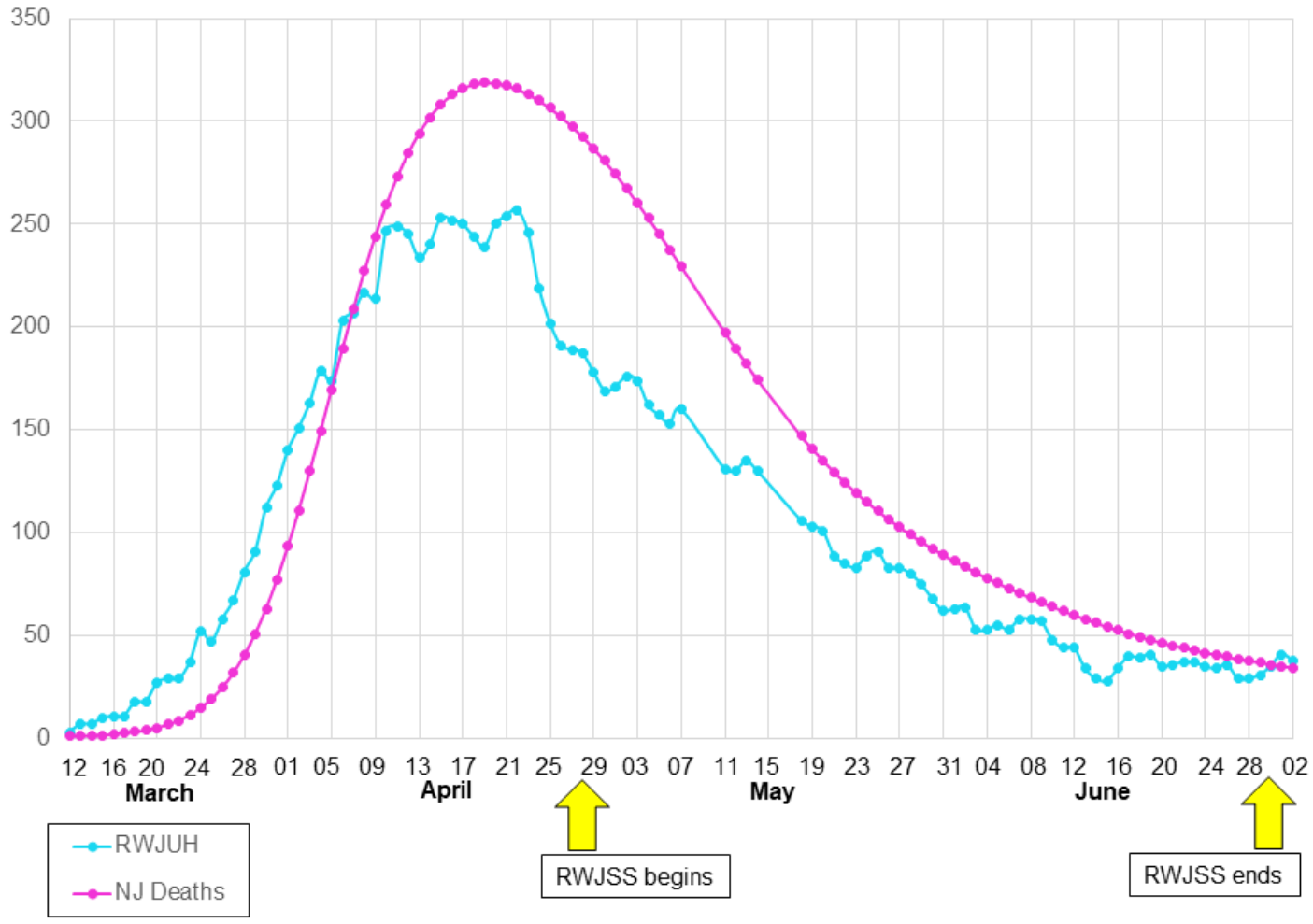
Figure 1

Figure 2

Figure 2