A Model of Disparities: Clinical, Environmental, and Sociodemographic Risk Factors Associated with Likelihood of COVID-19 Contraction

Yelena Rozenfeld (yelena.rozenfeld@providence.org)
Providence Health and Services https://orcid.org/0000-0002-1801-9928
Jennifer Beam
Providence Health and Services
Haley Maier
Providence Health and Services
Whitney Haggerson
Providence Health and Services
Karen Boudreau
Providence Health and Services
Jamie Carlson
Providence Health and Services
Rhonda Medows
Providence Health and Services

Research

Keywords: Social determinants of health, multivariable model, risk of COVID-19 contraction, disparities

Posted Date: June 9th, 2020

DOI: https://doi.org/10.21203/rs.3.rs-31918/v1

Version of Record: A version of this preprint was published on July 29th, 2020. See the published version at https://doi.org/10.1186/s12939-020-01242-z.

Abstract

Background

By mid-May 2020, there were over 1.5 million cases of (SARS-CoV-2) or COVID-19 across the U.S. with new confirmed cases continuing to rise following the re-opening of most states. Prior studies have focused mainly on clinical risk factors associated with serious illness and mortality of COVID-19. Emerging risk factors in the U.S., including clinical, sociodemographic, and environmental variables associated with contraction of COVID-19 have not been widely studied to assess disparities across populations.

Methods

A multivariable statistical model was used to identify predictors associated with COVID-19 contraction in the study population of 34,503 patients, comparing laboratory confirmed positive and negative COVID-19 cases in the Providence Health System (U.S.) between February 28 and April 27, 2020. Publicly available data were utilized as approximations for social determinants of health, and patient-level clinical and sociodemographic factors were extracted from the electronic medical record.

Results

Higher risk of contraction was associated with older age (OR 1.69; 95% CI 1.41–2.02, $p < 0.0001$), male gender (OR 1.32; 95% CI 1.21–1.44, $p < 0.0001$), Asian race (OR 1.43; 95% CI 1.18–1.72, $p = 0.0002$), Black/African American race (OR 1.51; 95% CI 1.25–1.83, $p < 0.0001$), Latino ethnicity (OR 2.07; 95% CI 1.77–2.41, $p < 0.0001$), non-English language (OR 2.09; 95% CI 1.7–2.57, $p < 0.0001$), high school education or less (OR 1.02; 95% CI 1.01–1.14, $p = 0.04$), residing in a neighborhood with financial insecurity (OR 1.10; 95% CI 1.01–1.25, $p = 0.04$), low air quality (OR 1.01; 95% CI 1.0-1.04, $p = 0.05$), housing insecurity (OR 1.32; 95% CI 1.16–1.5, $p < 0.0001$) or transportation insecurity (OR 1.11; 95% CI 1.02–1.23, $p = 0.03$), and living in senior living communities (OR 1.69; 95% CI 1.23–2.32, $p = 0.001$).

Conclusions

Risks associated with COVID-19 contraction reflect disparities across age, race, ethnicity, language, socioeconomic status, and living conditions. Health promotion and disease prevention strategies should prioritize groups most vulnerable to contraction and address structural inequities that contribute to risk through social and economic policy.

Background

As states in the U.S. begin to re-open, reducing COVID-19 cases, especially among populations with a disparate risk for contracting the virus, can mitigate future illness and mortality. While predictive prognostic, diagnostic, and other risk models to assess severe illness and mortality from COVID-19 are surfacing,[1] these models are not focused on risk factors associated with contraction. Even powered studies of risk factors of severe illness and mortality pose limitations to understanding all potential risks associated with contraction. These studies primarily include clinical characteristics such as comorbidities and symptoms, contain limited demographic variables beyond age and gender, are comprised of few study populations outside of China, and include only hospitalized or deceased patients.[2-7]

Because there is little research available on risk factors of contraction, the available evidence is limited to studied risk factors for severe illness and mortality, including older age[3,4] and underlying chronic conditions such as hypertension,[3] cardiovascular disease,[4] and diabetes.[7] As research continues in the U.S., identified risk factors for COVID-19 are evolving. The Centers for Disease Control and Prevention (CDC) recognized other groups at higher risk for severe illness, such as older adults living in long term care facilities, those with a BMI of forty or higher, and people with immunosuppression like HIV/AIDS,[8] among others identified in prior research. However, these new factors have not been incorporated into most risk models. Additionally, most clinical factors have not been examined concurrently with sociodemographic and environmental variables that contribute to the contraction, spread, and mortality across U.S. populations.

Effective disease control strategies should include all significant risk factors, medical, biological, social, cultural and environmental, as well as the underlying determinants of health to address the intersection between the conditions in which we live and our ability to maintain health and prevent disease.[9] Determinants of contraction for COVID-19, including employment, education level, income, and housing conditions, which could influence the ability to practice physical distancing measures and/or shelter in place, remain understudied, especially among communities of lower socioeconomic status.[10] Social determinants can directly impact the rates of infectious disease mortality, as poverty and inadequate housing can influence the burden of disease, including who becomes infected and who responds to treatment.[9] As deaths continue to rise, new data are emerging in the U.S. that show sociodemographic factors and other social determinants of health are critical to understanding the unequal burden of infection and attributed mortality due to COVID-19. Communities of color and/or low socioeconomic status are experiencing disproportionate rates of serious illness if infected, due to pre-existing economic and health inequities.[11,12] Pursuing rigorous models that address the risk of bias found in prior models[1] and incorporating existing and emerging findings, is critical to slow the transmission of COVID-19 in the communities most susceptible to contraction.

With limited publicly available data, healthcare systems are key contributors to understanding all relevant patient and population level characteristics to inform population health strategies. As new findings emerge, more scientific studies are needed to demonstrate the significance of disparities in risk of contraction between populations, distinct from mortality risk, and their relevance to persistent health disparities across race, ethnicity, socioeconomic status, language, age, and geography.[13] Public health approaches, including biologic, behavioral, political and structural interventions, should account for the sociocultural influences and structural mechanisms that contribute to increased risk of contraction when developing targeted public health practices and policies at the community and national level.

Methods

Study Design and Setting

This study was conducted at Providence, the third largest not-for-profit health system in the U.S., servicing more than five million people across seven states located in the Western and Southwestern portion of the U.S.

Data Source

Data were collected from the Providence enterprise data warehouse, including patient demographic, social, and behavioral history information, chronic conditions documented in clinical history, current conditions, prescribed medications, laboratory testing, and acute and ambulatory healthcare utilization. Recognizing that social determinants of health account for a larger portion of health outcomes than medical care determinants,[14] electronic medical record (EMR) data was supplemented with publicly available data, including the U.S. Census Bureau's 2018 American Community Survey (ACS) and CDC air quality data. Patient addresses were geocoded, and social determinant of health information, at the census block group or tract level, were matched at the patient level.

Participants and Procedures

Patients residing in Alaska, Washington, Oregon, Montana, and California (Los Angeles and parts of Orange County) who were tested for acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection between February 28, 2020 and April 27, 2020 were included in the modeling. Testing mechanisms included swabs from respiratory specimens appropriate for viral RNA testing from eight testing platforms.

Table 1: Study Participant Demographics and Characteristics

Outcomes and Predictors

The principle dependent variable for our model was COVID-19 contraction, as indicated by a positive lab test. Relative risk of contraction was calculated as a ratio of the individual predicted probabilities to the population mean. The score showed a patient's risk relative to an average population risk.

The examined risk factors were informed by a comprehensive review of prior scientific studies that documented the risk factors of mortality and the CDC list of groups at higher risk for severe illness.[8] Distributions of all continuous variables including age, BMI, number of medications, and neighborhood financial insecurity were examined for normality and transformed into categorical attributes. Comorbidities were determined by problem list documentation or clinical encounter diagnoses using standard International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM) nomenclature and further summarized into a measure of disease severity using total number of chronic conditions. Substance, tobacco, and alcohol consumptions were captured from social history assessments and clinician documentation. We added covariates into the model, derived from patient level data to act as a proxy for experiencing prolonged close physical proximity to others. Covariates include transportation insecurity, relationship status, employment, housing insecurity, and age-stratified communal living. To assess disparities in contraction, age, gender, race, ethnicity, and language, were added to the model. We used Glottolog, a repository for the world's languages, to assign language groups. Geographic regions and clinical symptoms were included for risk adjustment. Census data on educational attainment and financial insecurity were used to assess socioeconomic status. Missing data was recoded as unknown and included in the analysis. Detailed covariate definitions and data sources are shown in the supplement.

Statistical Methods and Modeling

Descriptive statistics were used to summarize study participants. Continuous variables were described by means and standard deviations, while categorical variables were described using frequencies and percentages. We conducted bivariate analysis to assess a significant effect of each factor on the outcome using the chi-square and the student t-test, when appropriate. All covariates with p<0.25 in the bivariate analysis were considered for model inclusion since use of a more traditional level of 0.05 often fails to identify variables whose association with the outcome could become stronger in the presence of other variables.[15] In addition, all variables of known clinical importance found in previous studies that could make an important contribution were included to improve upon previous models.[1] Risk of contraction for all independent predictors was quantified with odds ratios (OR) and 95% confidence intervals.

The multivariable logistic regression model was used to build a prediction model to estimate the likelihood of contraction. Stepwise selection with backward elimination was used to allow broader inclusion of variables of interest and determine joint predictive capability. Initial parameters for the model were identified in the training set and then tested at the subsequent step, with data randomly partitioned into two independent data subsets: 80% for training and building the model and another 20% for testing. The model's predictive performance, discrimination, and calibration were evaluated using the area under the receiver operating characteristics curve (ROC) and Hosmer-Lemeshow (HL) goodness-of-fit statistic. The observed and expected frequencies within each decile of risk was compared.[15]All data manipulation and modeling were completed in SAS EG (SAS Institute, Carry NC).

Results

A total of 34,503 patients were included in the study. The average age was 50 years old (SD 20), 59.6% (21,209) were female, 12% (4,183) were identified as non-white race, and 66% (22,610) had at least one comorbidity. Within the study population, 7.5% (2,578) tested positive and 92.5% (31,925) tested negative for COVID-19. Of patients testing positive, 36% (924) were hospitalized and 9% (240) died during the study period. Notable differences in testing rates of COVID-19 were observed for the number of chronic conditions and polypharmacy factors. Smaller variations were seen for employment, language, BMI, serious mental illness, substance use, age-stratified communal living, and housing insecurity. Little to no variation existed for gender, race, ethnicity, religious affiliation, and air quality (Table 1).

Table 2 shows which of the twenty-nine sociodemographic, clinical, and environmental covariates were associated with the greatest odds of contraction in the multivariable model. Other factors were significant in the model, but associated with less risk, requiring further discussion and study.

Sociodemographic Risk Factors

Comparatively, individuals between 50 and 59 years of age (OR 1.69; 95% CI 1.41-2.02, p<0.0001) or male gender (OR 1.32; 95% CI 1.21-1.44, p<0.0001) were more likely to contract COVID-19. Lower level of education, specifically high school education or less (OR 1.02; 95% CI 1.01-1.14, p=0.04) was associated with higher levels of contraction, as was being employed (OR 1.85; 95% CI 1.39-2.46, p=0.02), or retired (OR 2.06; 95% CI 1.54-2.76, p<0.0001). Asian race (OR 1.43; 95% CI 1.18-1.72, p= 0.0002), Black/African American race (OR 1.51; 95% CI 1.25-1.83, p<0.0001), and Latino ethnicity (OR 2.07; 95% CI 1.77-2.41, p<0.0001) were more likely than whites to contract COVID-19. Individuals who identified as being married or having a significant other were at higher risk of contraction (OR 1.12; 95% CI 1.01-1.25, p=0.04), whose primary language is not English (OR 2.09; 95% CI 1.7-2.57, p<0.0001), and who self-reported their religious affiliation as Christian denomination (OR 1.28; 95% CI 1.15-1.43, p<0.0001) were more likely to contract COVID-19.

Clinical Risk Factors

Clinical risk factors including being very severely obese (OR 1.58; 95% CI 1.31-1.91, p<0.0001), or having been diagnosed with diabetes (OR 1.40; 95% CI 1.22-1.61, p<0.0001), chronic kidney disease (OR 1.03; 95% CI 1.01-2.3, p=0.04), dementia (OR 2.01; 95% CI 1.61-2.51, p<0.0001), or HIV/AIDS (OR 1.43; 95% CI 1.03-2.63, p=0.03) were associated with higher risk of COVID-19 contraction than those who were not identified as having those conditions. Having an external primary care provider (OR 1.23; 95% CI 1.1-1.37, p= 0.0004) or an unknown primary care provider (OR 1.27; 95% CI 1.11-1.46, p= 0.0005) were associated with higher risk of contraction than those who have a primary care provider within the health care system. Receiving electronic communication through the EMR was associated with a lower risk of contraction (OR 0.72; 95% CI 0.66-0.8, p<0.0001).

Environmental Risk Factors

Individuals living in areas with low air quality (OR 1.01; 95% CI 1.0-1.04, p=0.05) were at higher risk of contraction, as were those experiencing financial insecurity (OR 1.10; 95% CI 1.01-1.25, p=0.04), or living in areas with transportation insecurity (OR 1.11; 95% CI 1.02-1.23, p=0.03). Individuals living in senior living facilities were more likely than those living in non-communal environments to contract the virus (OR 1.69; 95% CI 1.23-2.32, p= 0.001). Individuals who live in a neighborhood with high rates of housing insecurity (OR 1.32; 95% CI 1.16-1.5, p< 0.0001) were at higher risk of contraction compared to those living in neighborhoods without housing insecurity.

The model performed consistently across training and testing data sets with a ROC of 0.78 and the HL chi-square of 4.4 (p=0.81). The probabilities of contraction partitioned into "deciles of risk" (i.e. equal groups from smallest to the largest) did not highlight any "underperforming" areas.

Discussion

To our knowledge, this is the first study conducted that examines a multitude of clinical, sociodemographic, and environmental risk factors that can contribute to higher rates of contraction and applies the factors to develop a predictive model that can assess disparities of risk in populations. This retrospective risk of contraction study identified several risk factors also associated with serious illness in prior studies, including older age and greater risk progression with age,[3] male gender,[16] comorbidities of diabetes,[7] and chronic kidney disease,[17] higher BMI,[18] and immunosuppression.[19] However, factors found in previous studies for risk of mortality, including hypertension,[3] and other variables associated with groups at higher risk identified by the CDC including those with cardiovascular disease, liver disease, lung disease, or asthma,[8] were not significant factors associated with contraction. Being prescribed more than ten medications or having a greater number of chronic conditions was associated with less risk of contraction, suggesting behavioral differences between groups based on perceived risk. Further research is needed to understand differences between risks associated with serious illness and mortality and contraction, as well as factors that may facilitate or impede engagement in physical distancing or other preventative health behaviors, which may vary widely based on barriers, structural inequities, or personal choice.

Healthcare access through a relationship with a primary care provider was associated with a lower risk of contraction; however, this may be a result of higher rates of testing for COVID-19 compared to individuals with no primary care provider. Receiving secure electronic communication through the EMR suggests that access to health advice and education may reduce risk. Further research is needed to identify how healthcare access, utilization, and health communications could reduce risk for vulnerable groups. Serious mental illness and drug use were associated with lower risk; however further study is necessary to understand known mechanisms for risk of contraction. Variability in risk across regional geography necessitates continued study. The findings of this study indicate that risk factors such as socioeconomic status, race, ethnicity, environmental living conditions, and healthcare access are intersecting variables across populations, and may collectively contribute to disparities in the risk of contraction among vulnerable groups.

Older age is associated with both higher risk of contracting COVID-19 and higher mortality[20] compared to younger cohorts. Older adults living in senior communities are also at higher risk of contraction, which could be due to dependency on caregivers to complete activities of daily living, which make physical distancing a challenge. Dementia was also associated with risk of contraction, likely due to a higher reliance on daily caregiving.

Higher risk of contraction among black, indigenous, and/or people of color may be associated with other sociodemographic and environmental characteristics found to also be significant in this study. African Americans and Latinos are more likely to live in communities with poor air quality,[21] work in jobs that cannot telecommute,[22] and lack access to healthcare[23] which may increase the risk of contraction and contribute to racial disparities in mortality. Chronic conditions such as obesity, stroke, and diabetes, and premature death also affect racial and ethnic groups disproportionately compared to whites, although differ comparatively between groups.[13] More research is needed to identify the risk and protective factors for contraction, including within-group variation and among indigenous communities. Communities of color are also more likely to experience lower socioeconomic status,[24] and be employed as essential workers.[10] For vulnerable groups, lack of personal transportation is both a barrier to healthcare access[25] and increases exposure to others, contributing to disparities in contraction.

Given the known mechanism for community transmission, variables selected as approximations for social and living conditions that might increase the risk of contraction, such as being in a married relationship or having a significant other, being employed, lacking access to a personal vehicle for transportation, and living in overcrowded housing were significant factors for increased risk also evident in disparities across socioeconomic status and race. Religious affiliation was also associated with increased risk, which may be attributed to attendance of large religious services or other behaviors associated with religious identity.

Having limited English proficiency (LEP) can be a barrier to accessing health services and understanding health information, which can be exacerbated when written translations and trained translators are not available.[26] Over the course of the pandemic, health information has changed rapidly, which can adversely affect indigenous and immigrant communities. During the Ebola epidemic in West Africa, language barriers were an obstacle to slowing the spread of the disease.[27] People with LEP are also more likely to have low health literacy compared to English speakers and are at a higher risk of poor health.[28] Anti-immigrant policies also impose barriers to accessing healthcare and discourage care seeking, particularly among undocumented immigrants.[29] Culturally and linguistically appropriate interventions are essential, including communication materials of varying formats and reading levels developed through transcreation, where native language speakers work in tandem with English speakers, as well as the use of community health workers that can engage with underserved groups.[30]

People experiencing housing insecurity may experience challenges with physical distancing, especially when housing is crowded, or may be less able to engage in hand washing when facilities or running water may be limited.[31] Both factors could facilitate the spread of the virus. Additional research is needed to understand the impact of housing insecurity, living conditions, and environments on COVID-19 contraction.

Study Limitations

The model did not include any patient data outside the Providence Health System. Although the organization serves a diverse patient population across seven states, the generalizability of the study results may be limited to the entire U.S population. Furthermore, inconsistent availability and reliability of the testing could bias the results. With limited testing available and evolving screening guidelines, clinical discernment, and personal bias could impact which individuals received testing and thus, influence rates of testing in certain populations. When developing this model, we intended for the study to include all major covariates; however, since COVID-19 research is changing, it is likely that there are other factors associated with the likelihood of contraction that are not well known yet and, thus not present in the observed data. We were not able to account for people's behaviors, which could bias the results. Additional research is needed to understand additional factors correlated with higher instances of COVID-19 related to inpatient utilization and risk of mortality.

Conclusions

The findings of associated risk factors, as well as the models to predict risk, have important implications for healthcare systems, public health departments, and city and state governments to further reduce the risk of contraction and spread of COVID-19 in communities that may be disproportionately impacted. The ability to assess the risk of contraction can inform targeted public health approaches given known health outcomes, healthcare utilization patterns, social and cultural practices, and underlying social determinants of health that exist within those populations. Linguistically and culturally appropriate prevention education, healthcare access including routine care and COVID-19 testing, and efforts to address substandard housing and poor working conditions are essential to reducing risk among vulnerable groups, especially communities of lower socioeconomic status which experience a greater incidence of infectious diseases.[32] Now, and as the nation recovers, addressing the disparities in contraction that contribute to rates of serious illness and mortality among vulnerable communities are needed to alleviate the disproportionate burden of the pandemic and persisting health disparities.

Abbreviations

CDC, BMI, EMR, LEP, ROC, OR, ICD, NYU, ACS, IRB

Declarations

Ethics of Approval and Consent to Participate

The Providence Institutional Review Board (IRB) approved this study for all gathered data and analysis. In accordance with 45 CFR 46.116(d), a waiver of informed consent a Waiver of Authorization were approved in accordance with 45 CFR 164.512(i)(2)(ii) on 4/2/2020 under Expedited Review Procedures. The IRB was satisfied that the use or disclosure of protected health information involved no more than a minimal risk to the privacy of individuals.

Consent for Publication

Not applicable

Availability of Data and Materials

The datasets generated and analyzed during the current study are not publicly available as stipulated by the Providence IRB that all patient level data would reside within Providence secured computer network, only accessible to the study investigators, and locked up on Providence property. The publicaly available data source was accessed via a proprietary data vendor, which cannot be shared publicaly due to their contractual agreement. The underlying publicaly available data sources include the 2018 American Community Survey and the Centers for Disease Control and Prevention Air Quality.

Competing Interests

The authors declare that they have no competing interests.

Funding

This was an internally funded study, with no external financial interest. The study was aimed to improve patient and population outcomes and support the healthcare system's response to COVID-19. The corresponding authors had full access to all data in the study and had final responsibility for the decision to submit for publication.

Author's Contributions

YR and JB were responsible for study design, data collection, data management, and data analysis. All authors were responsible for data interpretation. YR, HM and WH wrote the first draft of the manuscript. HM, and JC were responsible for the scientific literature review. All authors contributed to the final draft. All authors read and approved the final manuscript.

Acknowledgements

Uma Kodali Bhavani and Hanna Amanuel

Author's Information

All authors work in the area of Population Health, focusing on care management approaches for patients, communities and populations, especially the most poor and vulnerable.

References

1. Wynants L, Van Calster B, Bonten MMJ, et al. Prediction models for diagnosis and prognosis of covid-19 infection: systematic review and critical appraisal. BMJ. 2020;369:1-10; doi:10.1136/bmj.m1328
2. Zhou F, Yu T, Du R, et al. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. Lancet. 2020;395(10229):1054-1062; doi:10.1016/S0140-6736(20)30566-3
3. Kahathuduwa CN, Dhanasekara CS, Chin S-H. Case fatality rate in COVID-19: a systematic review and meta-analysis. [Published online ahead of print 6 April 2020]. medRxiv. 2020; doi:10.1101/2020.04.01.20050476
4. Du RH, Liang LR, Yang CQ, et al. Predictors of mortality for patients with COVID-19 pneumonia caused by SARS-CoV-2: a prospective cohort study. Eur Respir J. 2020;55(5); doi:10.1183/13993003.00524-2020

5. Chen R, Liang W, Jiang M, et al. Risk factors of fatal outcome in hospitalized subjects with coronavirus disease from a nationwide analysis in China. [Published online ahead of print 15 April 2020] Chest. 2020;S0012-3692(20)30710 8; doi:10.1016/j.chest.2020.04.010
6. Li X, Xu S, Yu M, et al. Risk factors for severity and mortality in adult COVID-19 inpatients in Wuhan. [Published online ahead of print 12 April 2020]. J Allergy Clin Immunol. 2020; doi:10.1016/j.jaci.2020.04.00
7. Hu L, Chen S, Fu Y, et al. Risk factors associated with clinical outcomes in 323 COVID-19 patients in Wuhan, China. [Published online ahead of print 3 May 2020]. Clin Infect Dis. 2020;ciaa539; doi:10.1101/2020.03.25.20037721
8. Centers for Disease Control. People who are at higher risk for severe illness. National Center for Immunization and Respiratory Diseases (NCIRD), Division of Viral Diseases. 2020. https://www.cdc.gov/coronavirus/2019-ncov/need-extra-precautions/people-at-higher-risk.html. Accessed 3 May 2020.
9. Butler-Jones D, Wong T. Infectious disease, social determinants and the need for intersectoral action. Can Commun Dis Rep. 2016;42(Suppl 1):S118-S120; doi: 10.14745/ccdr.v42is1a04
10. Khalatbari-Soltani S, Cumming RG, Delpierre C, Kelly-Irving M. Importance of collecting data on socioeconomic determinants from the early stage of the COVID-19 outbreak onwards. [Published online ahead of print 8 May 2020]. J Epidemiol Community Health. 2020;jech-2020-214297; doi:10.1136/jech-2020-21429
11. Koma W, Artiga S, Neuman T, et al. Low-income and communities of color at higher risk of serious illness if infected with coronavirus. Kaiser Family Foundation. 2020. https://www.kff.org/disparities-policy/issue-brief/low-income-and-communities-of-color-at-higher-risk-of-serious-illness-if-infected-with-coronavirus/. Accessed 8 May 2020.
12. Wadhera RK, Wadhera P, Gaba P, et al. Variation in COVID-19 hospitalizations and deaths across New York City boroughs. [Published online ahead of print 29 April 2020]. JAMA. 2020;e207197; doi:10.1001/jama.2020.7197
13. National Academies of Sciences, Engineering, and Medicine; Health and Medicine Division; Board on Population Health and Public Health Practice. Chapter 2: the state of health disparities in the United States. In: Baciu A, Negussie Y, Geller A, et al., editors. Communities in Action: Pathways to Health Equity. Washington (DC): National Academies Press (US); 2017. p. 57-88. doi:10.17226/24624.
14. McGovern L, Miller G, Hughes-Cromwick P. The relative contribution of multiple determinants to health. Heal Aff Heal Policy Br. 2014;21. https://www.rwjf.org/content/dam/farm/reports/issue_briefs/2014/rwjf415185. Accessed 8 May 2020.
15. Hosmer Jr DW, Lemeshow S, Sturdivant RX. Applied logistic regression. 2nd Columbus, Ohio: John Wiley & Sons, Inc; 2013.
16. Zhang J, Yu M, Tong S, Liu LY, Tang L V. Predictive factors for disease progression in hospitalized patients with coronavirus disease 2019 in Wuhan, China. [Published online ahead of print 28 April 2020]. J Clin Virol. 2020;127:104392; doi:10.1016/j.jcv.2020.104392
17. Henry BM, Lippi G. Chronic kidney disease is associated with severe coronavirus disease 2019 (COVID-19) infection. [Published online ahead of print 28 March 2020]. Int Urol Nephrol. 2020:1-2; doi:10.1007/s11255-020-02451-9
18. Peng YD, Meng K, Guan HQ, et al. Clinical characteristics and outcomes of 112 cardiovascular disease patients infected by 2019-nCoV. Zhonghua Xin Xue Guan Bing Za Zhi. 2020;48(0):E004; doi:10.3760/cma.j.cn112148-20200220-00105
19. Feng Y, Ling Y, Bai T, et al. COVID-19 with different severity: a multi-center study of clinical features. [Published online ahead of print 10 April 2020]. Am J Respir Crit Care Med. 2020;10.1164/rccm.202002-0445OC; doi:10.1164/rccm.202002-0445oc
20. Chen N, Zhou M, Dong X, et al. Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study. Lancet. 2020;395(10223):507-513; doi:10.1016/S0140-6736(20)30211-7
21. Rosofsky A, Levy JI, Zanobetti A, Janulewicz P, Fabian MP. Temporal trends in air pollution exposure inequality in Massachusetts. Environ Res. 2018;161:76-86; doi:10.1016/j.envres.2017.10.028
22. S. Bureau of Labor Statistics. Table 1. Workers who could work at home, did work at home, and were paid for work at home, by selected characteristics, averages for the period 2017-2018. 2019.https://www.bls.gov/news.release/flex2.t01.htm. Accessed 8 May 2020.
23. Riley WJ. Health disparities: gaps in access, quality and affordability of medical care. Trans Am Clin Climatol Assoc. 2012;123:167-174. https://pubmed.ncbi.nlm.nih.gov/23303983/. Accessed 3 May 2020.
24. Williams DR, Priest N, Anderson NB. Understanding associations among race, socioeconomic status, and health: Patterns and prospects. Heal Psychol. 2016;35(4):407-411; doi:10.1037/hea0000242
25. Syed ST, Gerber BS, Sharp LK. Traveling towards disease: Transportation barriers to health care access. J Community Health. 2013;38(5):976-993; doi:10.1007/s10900-013-9681-1

26. Institute of Medicine (US) Committee on Health Literacy. Introduction. In: Kindig DA, Panzer AM, Nielsen-Bohlman L, editors. Health Literacy: A Prescription to End Confusion. Washington DC: National Academies Press; 2004. p. 19-30. doi:10.17226/10883
27. Assessment Capacities Project (ACAPS). Ebola outbreak, Sierra Leone: communication: challenges and good practices. 2016. https://www.acaps.org/sites/acaps/files/products/files/v_sierra_leone_communication_challenges_and_good_practice_dec_2015_2-ilovepdf-compressed_ul.pdf. Accessed 3 May 2020.
28. Sentell T, Braun KL. Low health literacy, limited English proficiency, and health status in Asians, Latinos, and other racial/ethnic groups in California. J Health Commun. 2012;17(Suppl 3):82-99; doi:10.1080/10810730.2012.712621
29. Martinez O, Wu E, Sandfort T, et al. Evaluating the impact of immigration policies on health status among undocumented immigrants: a systematic review. J Immigr Minor Health. 2015;17(3):947-970; doi:10.1007/s10903-013-9968-4
30. Andrulis DP, Brach C. Integrating literacy, culture, and language to improve health care quality for diverse populations. Am J Health Behav. 2007;31(Suppl 1):S122-S133; doi:10.5555/ajhb.2007.31.supp.S122
31. Jacobs DE. Environmental health disparities in housing. Am J Public Health. 2011;101 Suppl 1(Suppl 1):S115-S122; doi:10.2105/AJPH.2010.300058
32. Institute of Medicine (US) Committee on Capitalizing on Social Science and Behavioral Research to Improve the Public's Health. Introduction. Smedley BD, Syme SL, editors. Promoting Health: Intervention Strategies from Social and Behavioral Research. Washington (DC): National Academies Press (US); 2000. p. 1-5. doi: 10.17226/9939

Tables

Table 1: Study Participant Demographics and Characteristics

	Tested patients (N=34,503)		Tested Positive (N=2,578)		Tested Negative (31,925)	
	N	%	N	%	N	%
Sociodemographic						
Age						
<18	1393	4.0	35	1.4	1358	4.3
18-29	4494	13.0	268	10.4	4226	13.2
30-39	5803	16.8	304	11.8	5499	17.2
40-49	5468	15.8	411	15.9	5057	15.8
50-59	5663	16.4	523	20.3	5140	16.1
60-69	5467	15.8	467	18.1	5000	15.7
70-79	3522	10.2	296	11.5	3226	10.1
80+	2693	7.8	274	10.6	2419	7.6
Gender						
Female	21209	59.6	1352	52.4	19219	60.2
Male	13924	40.4	1225	47.5	12699	39.8
Education						
Education <12 years	9565	27.7	826	32.0	8739	27.4
Employment						
Student	1148	3.3	51	2.0	1097	3.4
Employed	16570	48.0	1311	50.9	15259	47.8
Not Employed	5872	17.0	362	14.0	5510	17.3
Retired	7284	21.1	637	24.7	6647	20.8
Unknown	3629	10.5	217	8.4	3412	10.7
Race						
White	24799	71.9	1437	55.7	23362	73.2
American Indian | Alaska Native	465	1.3	13	0.5	452	1.4
Asian	1713	5.0	209	8.1	1504	4.7
Black | African American	1649	4.8	159	6.2	1490	4.7
Native Hawaiian | Pacific Islander	356	1.0	25	1.0	331	1.0
Unknown	5521	16.0	735	28.5	4786	15.0
Ethnicity						
Other Ethnic Groups	30938	89.7	1940	75.3	28998	90.8
Hispanic or Latino	3565	10.3	638	24.7	2927	9.2
Religious Affiliation						
Agnostic	10938	31.7	661	25.6	10277	32.2
Christian	14483	42.0	1219	47.3	13264	41.5
Other Religion	1181	3.4	103	4.0	1078	3.4
Unknown	7901	22.9	595	23.1	7306	22.9
Relationship						
Single	12940	37.5	790	30.6	12150	38.1
Divorced or Legally Separated	5248	15.2	383	14.9	4865	15.2
Married or Significant Other	15173	44.0	1305	50.6	13868	43.4
Unknown	1142	3.3	100	3.9	1042	3.3
Language						
English	32277	93.5	2085	80.9	30192	94.6
Sino-Tibetan	286	0.8	55	2.1	231	0.7
Spanish	1022	3.0	291	11.3	731	2.3
Other Languages	918	2.7	147	5.7	771	2.4
Clinical						
Body Mass Index						
Normal	7088	20.5	444	17.2	6644	20.8
Underweight	554	1.6	30	1.2	524	1.6
Moderately Obese	5667	16.4	452	17.5	5215	16.3
Overweight	8009	23.2	670	26.0	7339	23.0
Severely Obese	3080	8.9	243	9.4	2837	8.9
Very Severely Obese	2835	8.2	208	8.1	2627	8.2
Unknown	7270	21.1	531	20.6	6739	21.1
Number of Chronic Conditions						
0	11893	34.5	1017	39.4	10876	34.1
1-2	12185	35.3	924	35.8	11261	35.3
3-4	6563	19.0	406	15.7	6157	19.3
5+	3862	11.2	231	9.0	3631	11.4
Clinical Diagnosis						
Diagnosis of Diabetes	4942	14.3	456	17.7	4486	14.1

Diagnosis of Kidney Disease	65	0.2	6	0.2	59	0.2
Diagnosis of HIV/AIDS	141	0.4	13	0.5	128	0.4
Diagnosis of Dementia	1039	3.0	135	5.2	904	2.8
Polypharmacy						
0 Prescriptions	8933	25.9	826	32.0	8107	25.4
1-9 Prescriptions	18066	52.4	1370	53.1	16696	52.3
10-19 Prescriptions	5307	15.4	298	11.6	5009	15.7
20-29 Prescriptions	1549	4.5	61	2.4	1488	4.7
30+ Prescriptions	648	1.9	23	0.9	625	2.0
Mental Health and Substance Use						
History of Illicit Drug Use	4375	12.7	137	5.3	4238	13.3
History of Tobacco Use	5606	16.2	162	6.3	5444	17.1
Diagnosis of Serious Persistent Mental Illness	4507	13.1	177	6.9	4330	13.6
Diagnosis of Substance Use Disorder	3605	10.4	112	4.3	3493	10.9
Primary Care Affiliation						
Internal Primary Care Provider	14682	42.55	894	34.7	13788	43.2
External Primary Care Provider	12456	36.1	1026	39.8	11430	35.8
Unknown Primary Care Provider	7365	21.35	658	25.5	6707	21.0
Electronic Communication through the EMR	22158	64.2	1337	51.9	20821	65.2
Symptoms						
Fever	20565	59.6	1995	77.4	18570	58.2
Cough	24506	71.0	2062	80.0	22444	70.3
Breath	21587	62.6	1857	72.0	19730	61.8
Chills	694	2.0	88	3.4	606	1.9
Myalgia	955	2.8	145	5.6	810	2.5
Environmental						
Region						
Oregon	10486	30.4	454	17.6	10032	31.4
Alaska	1837	5.3	86	3.3	1751	5.5
Puget Sound	6273	18.2	704	27.3	5569	17.4
Southern California	3852	11	605	23.5	3247	10.2
Washington | Montana	12055	34.9	729	28.3	11326	35.5
Age-Stratified Communal Living						
Non-Communal Living	24581	71.2	1766	68.5	22815	71.5
Adult Community	1619	4.7	143	5.5	1476	4.6
Adult and Youth	5294	15.3	400	15.5	4894	15.3
Multigenerational	1970	5.7	177	6.9	1793	5.6
Senior Living	489	1.4	58	2.2	431	1.4
Other	550	1.6	34	1.3	516	1.6
Financial Insecurity	9993	29.0	768	29.8	9225	28.9
Housing Insecurity	6743	19.5	709	27.5	6034	18.9
Transportation Insecurity	10429	30.2	810	31.4	9619	30.1
Low Air Quality	9664	28.0	754	29.2	8910	27.9

Table 2: Final Multivariable Model Results

	OR	95% CI	p-value
Sociodemographic			
Age			
18-29	--	--	--
<18	0.33	[0.22-0.49]	<.0001
30-39	0.88	[0.73-1.05]	0.1574
40-49	1.27	[1.06-1.52]	0.011
50-59	1.69	[1.41-2.02]	<.0001
60-69	1.65	[1.36-2.01]	<.0001
70-79	1.59	[1.24-2.05]	0.0003
80+	1.64	[1.24-2.17]	0.0005
Gender			
Female	--	--	--
Male	1.32	[1.21-1.44]	<.0001
Education			
Education <12 years	1.02	[1.01-1.14]	0.0435
Employment			
Student	--	--	--
Employed	1.85	[1.39-2.46]	<.0001
Not Employed	1.41	[1.05-1.91]	0.024
Retired	2.06	[1.54-2.76]	<.0001
Unknown	1.37	[1-1.87]	0.0494
Race			
White	--	--	--
American Indian | Alaska Native	0.63	[0.36-1.12]	0.1156
Asian	1.43	[1.18-1.72]	0.0002
Black| African American	1.51	[1.25-1.83]	<.0001
Native Hawaiian | Pacific Islander	1.02	[0.66-1.57]	0.9438
Unknown	1.34	[1.18-1.52]	<.0001
Ethnicity			
Other Ethnic Groups	--	--	--
Hispanic or Latino	2.07	[1.77-2.41]	<.0001
Religious Affiliation			
Agnostic	--	--	--
Christian	1.28	[1.15-1.43]	<.0001
Other Religion	1.01	[0.77-1.24]	0.1453
Unknown	1.10	[0.97-1.25]	0.8752
Relationship			
Single	--	--	--
Divorce or Legally Separated	1.08	[0.93-1.26]	0.3293
Married or Significant Other	1.12	[1.01-1.25]	0.0357
Unknown	0.96	[0.74-1.24]	0.7468
Language			
English	--	--	--
Sino-Tibetan	1.98	[1.38-2.84]	0.0002
Spanish	1.60	[1.31-1.94]	<.0001
Other Languages	2.09	[1.7-2.57]	<.0001
Clinical			
Body Mass Index			
Normal	--	--	--
Underweight	0.80	[0.54-1.2]	0.2857
Moderately Obese	1.25	[1.08-1.45]	0.0033
Overweight	1.28	[1.12-1.46]	0.0003
Severely Obese	1.45	[1.21-1.73]	<.0001
Very Severely Obese	1.58	[1.31-1.91]	<.0001
Unknown	0.99	[0.84-1.16]	0.8867
Number of Chronic Conditions			
0	--	--	--
1-2	0.83	[0.74-0.93]	0.001
3-4	0.63	[0.54-0.74]	<.0001
5+	0.55	[0.44-0.69]	<.0001
Clinical Diagnosis			
Diagnosis of Diabetes	1.40	[1.22-1.61]	<.0001
Diagnosis of Kidney Disease	1.03	[1.01-2.3]	0.0385
Diagnosis of HIV/AIDS	1.43	[1.03-2.63]	0.0252
Diagnosis of Dementia	2.01	[1.61-2.51]	<.0001

Polypharmacy			
0 Prescriptions	--	--	--
1-9 Prescriptions	0.76	[0.68-0.86]	<.0001
10-19 Prescriptions	0.60	[0.5-0.71]	<.0001
20-29 Prescriptions	0.43	[0.32-0.59]	<.0001
30+ Prescriptions	0.42	[0.26-0.66]	0.0002
Mental Health and Substance Use			
History of Illicit Drug Use	0.63	[0.53-0.77]	<.0001
History of Tobacco Use	0.46	[0.38-0.54]	<.0001
Diagnosis of Serious Persistent Mental Illness	0.77	[0.65-0.92]	0.003
Diagnosis of Substance Use Disorder	0.70	[0.56-0.87]	0.001
Primary Care Provider Affiliation			
Internal Primary Care Provider	--	--	--
External Primary Care Provider	1.23	[1.1-1.37]	0.0004
Unknown Primary Care Provider	1.27	[1.11-1.46]	0.0005
Electronic Communication through the EMR	0.72	[0.66-0.8]	<.0001
Symptoms			
Symptoms of Fever	2.39	[2.15-2.65]	<.0001
Symptoms of Cough	1.44	[1.28-1.62]	<.0001
Shortness of Breath	1.34	[1.21-1.49]	<.0001
Symptoms of Chills	1.40	[1.09-1.79]	0.0086
Myalgia	1.80	[1.47-2.2]	<.0001
Environmental			
Region			
Oregon	--	--	--
Alaska	1.31	[1-1.7]	0.0469
Puget Sound	2.83	[2.44-3.28]	<.0001
Southern California	2.39	[2.06-2.78]	<.0001
Washington Montana	1.49	[1.29-1.73]	<.0001
Age-Stratified Communal Living			
Non-Communal Living	--	--	--
Adult Community	1.30	[1.07-1.58]	0.0082
Adult and Youth	1.07	[0.95-1.21]	0.2835
Multigenerational	1.07	[0.9-1.28]	0.4563
Senior Living	1.69	[1.23-2.32]	0.0011
Other	1.12	[0.77-1.64]	0.5492
Financial Insecurity	1.10	[1.01-1.25]	0.0392
Housing Insecurity	1.32	[1.16-1.5]	<.0001
Transportation Insecurity	1.11	[1.02-1.23]	0.0285
Low Air Quality	1.01	[1-1.04]	0.0502

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- supplement1.docx