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Household factors and the risk of severe COVID-like illness early in the U.S. pandemic

Denis Nash[1,2]*, Saba Qasmieh[1,2], McKaylee Robertson[1,2], Madhura Rane[1], Rebecca Zimba[1,2], Sarah G. Kulkarni[1], Amanda Berry[1], William You[1], Chloe Mirzayi[1,2], Drew Westmoreland[1], Angela Parcesepe[3,4], Levi Waldron[1,5], Shivani Kochhar[1], Andrew R. Maroko[1,5], Christian Grov[1,6], for the CHASING COVID Cohort Study Team[¶]

1 Institute for Implementation Science in Population Health (ISPH), City University of New York (CUNY), New York City, New York, United States of America, **2** Department of Epidemiology and Biostatistics, Graduate School of Public Health and Health Policy, City University of New York (CUNY), New York City, New York, United States of America, **3** Department of Maternal and Child Health, Gillings School of Public Health, University of North Carolina, Chapel Hill, North Carolina, United States of America, **4** Carolina Population Center, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina, United States of America, **5** Department of Environmental, Occupational, and Geospatial Health Sciences, Graduate School of Public Health and Health Policy, City University of New York (CUNY), New York City, New York, United States of America, **6** Department of Community Health and Social Sciences, Graduate School of Public Health and Health Policy, City University of New York (CUNY), New York City, New York, United States of America

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* denis.nash@sph.cuny.edu

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Abstract

Objective

To investigate the role of children in the home and household crowding as risk factors for severe COVID-19 disease.

Methods

We used interview data from 6,831 U.S. adults screened for the Communities, Households and SARS/CoV-2 Epidemiology (CHASING) COVID Cohort Study in April 2020.

Results

In logistic regression models, the adjusted odds ratio [aOR] of hospitalization due to COVID-19 for having (versus not having) children in the home was 10.5 (95% CI:5.7–19.1) among study participants living in multi-unit dwellings and 2.2 (95% CI:1.2–6.5) among those living in single unit dwellings. Among participants living in multi-unit dwellings, the aOR for COVID-19 hospitalization among participants with more than 4 persons in their household (versus 1 person) was 2.5 (95% CI:1.0–6.1), and 0.8 (95% CI:0.15–4.1) among those living in single unit dwellings.

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Conclusion

Early in the US SARS-CoV-2 pandemic, certain household exposures likely increased the risk of both SARS-CoV-2 acquisition and the risk of severe COVID-19 disease.

Introduction

Crowded indoor settings and sustained close contact are associated with an increased likelihood of SARS-CoV-2 spread [1, 2]. Stay-at-home orders and other non-pharmaceutical measures, such as bans on mass gatherings and physical distancing, were effective in curtailing community transmission [3, 4]. However, these measures may have resulted in shifting the transmission of SARS-CoV-2 to within household settings where, among unmasked and unvaccinated individuals, high attack rates can occur, with high rates of hospitalization and death [4–7]. Crowded households can be conducive to transmission due to difficulties in maintaining physical distance and effective isolation [8, 9], and when infected household members have pre-symptomatic or asymptomatic infection.

There is growing evidence suggesting that asymptomatic and pre-symptomatic infections contribute substantially to transmission of SARS-CoV-2 [10–12]. Younger age may be an important factor driving such spread. Studies have shown differences in the presentation of COVID-19 between adults and children, with children less likely than adults to be symptomatic and less likely to present with severe COVID-19 disease [13–16]. Counterintuitively, other studies have suggested that children may have viral load levels that are comparable to those of adults, and that they could play a role in driving SARS-CoV-2 transmission [17, 18]. One study in India found that children and young adults accounted for 30% of cases [19]. Moreover, the lack of mask use early in the US pandemic indoors among members of the same household who may have been asymptomatic or pre-symptomatic during the first several days of quarantine under stay-at-home orders could have resulted in a higher inoculum and increased disease severity [20–22].

Household studies are important for understanding the role of factors such as household crowding and household age composition on household SARS-CoV-2 transmission. A systematic review of 40 SARS-CoV-2 household transmission studies suggests that, while the secondary attack rate within households is high (18.8%, 95% CI 15.4%-22.2%), transmission rates are highest: a) when the primary household cases are symptomatic (19.9%, 95% CI: 14.0%–25.7%) vs asymptomatic; b) among adult contacts (31%, 95% CI: 19.4%–42.7%) vs children; and c) in households with only 1 other contact (45.2%, 95% CI 34.1%-51.8) vs those with 3 or more contacts [2]. Early studies in New York state showed high attack rates, hospitalizations, and deaths within the households of index cases [6]. And a household transmission study conducted in Tennessee and Wisconsin by the CDC found a very high and rapidly occurring secondary infection rate of 53% among household members of an index case, with >70% of secondary cases occurring within 5 days of symptom onset of the index case [5]. The effect of household transmission versus other community transmission on SARS-CoV-2 severity has not been systematically investigated.

Few household studies have examined the role of children on household transmission of SARS-CoV-2, and those that have relied on small sample sizes [5, 23, 24]. Understanding the risk of COVID-19 in crowded households and households with children (regardless of whether they are the primary case in the household) is important for elucidating the impact of stay-at-home orders and prolonged indoor contact on the risk severe infections. The objective of this study was to examine the effects of household characteristics, primarily the presence of children in the household and household crowding, on the risk of COVID hospitalization during the early phase of the SARS-CoV-2 pandemic in the US.

Methods

Study population

Study participants were individuals screened for enrollment into the Communities, Households, and SARS/CoV-2 Epidemiology (CHASING) COVID Cohort study who completed an initial baseline assessment. The CHASING COVID Cohort study is a national prospective cohort study of adults from the US and US territories that was launched on March 28, 2020 to understand the spread and impact of the SARS-CoV-2 pandemic within households and communities [25, 26]. The survey methodology is described in detail in a previous publication [27] and PDFs of all questoinnaires are available on the study's website [25]. Briefly, study participants were recruited online through social media platforms or through referrals using advertisements that were in both English and Spanish. The platform Qualtrics (Qualtrics, Provo, UT), an online survey platform widely used in social and behavioral research, was used for data collection.

The initial baseline assessment captured information on household characteristics, underlying risk factors, SARS-CoV-2 symptoms, and health-seeking behaviors such as testing and hospitalizations. A second version of the initial baseline questionnaire was launched on April 9, 2020 to capture healthcare and essential worker status. A total of 6,831 participants had completed an initial cohort screening interview by April 20, 2020. The study protocol was approved by the Institutional Review Board at the City University of New York (CUNY).

Variable definitions

Primary outcome. The main outcome was self-report of hospitalization for COVID symptoms reported in the two weeks prior to the interview. Symptoms assessed included any of the following: fever, chills, rigors, runny nose, myalgia, headache, sore throat, stomach ache, diarrhea, nasal congestion, nausea, vomiting, cough or coughing up blood or phlegm, shortness of breath. Those reporting any of these symptoms who reported also being hospitalized as a result of their reported symptoms were classified as having the outcome; all other participants were classified as not having the outcome.

Primary and secondary exposures. The primary exposure was the presence of any children under 18 years of age living in participants' household. Secondary exposures were the number of persons living in a household (1, 2–3, more than 4) and the type of property in which the participant lived. Property type was classified as either a multi-unit property (e.g. apartment, condominium, co-op, or building with two or more units), single-unit property (e.g. detached home, or townhouse), or other.

Covariates. *Socio-demographic and behavioral risk factors for COVID*. We identified socio-demographic, behavioral and employment factors as confounders of hypothesized exposure-outcome relationships, including age, gender, race/ethnicity, and annual combined income. Additionally, we included potential confounders such as having had close contact with someone who had coronavirus-like symptoms and/or having been involved in the diagnosis or care of someone with confirmed or suspected coronavirus infection. Finally, we considered potential employment-related confounders, including essential worker status, which was defined as having been involved in following roles in the two weeks prior to survey date: healthcare, law enforcement, fire department/first responder, delivery or pick-up services related to food or medications, or in public/private transportation.

Community transmission. As community transmission could confound the exposure-outcome relationship, we used lagged population-based, county-level death rates as a proxy for community transmission. We tabulated the number of COVID deaths per 100,000 population for each county using data from the New York Times Github website (from 01/21/2020 to 07/05/2020) [28]. Our proxy for community SARS-CoV-2 transmission was a 5-day moving average of COVID deaths per 100,000 population, lagged by 23 days. Specifically, to use county death rates as a proxy for community transmission in the county, we introduced a lag since COVID deaths follow several other milestones after infection (infection→ incubation→ symptoms→ progression/hospitalization→ death). We assumed that data on the number of deaths for a given day represented community transmission that was occurring 23 days earlier, specifically 5 days from infection to symptom onset (reflecting the average incubation period); 5 days from symptom onset to pneumonia; and 13 days from pneumonia diagnosis to death [29]. For those participants reporting symptoms, we then matched reported timing of symptom onset with community transmission levels 5 days earlier, corresponding to the average incubation period for SARS-COV-2 [30–32].

COVID-related illness. Frequencies of seven measures of COVID-related outcomes were generated to examine the health-seeking behaviors of all participants who 1) reported COVID symptoms; 2) met the CSTE case definition for COVID-like illness which was defined as reporting at least two of following symptoms: fever, chills, myalgia, headache, sore throat, or at least one of the following: cough, shortness of breath [33]; 3) reported seeing or calling a physician or healthcare professional for any of the COVID symptoms they reported, 4) sought but were unable to get a diagnostic test, 5) received diagnostic test, 6) received a laboratory-confirmed diagnosis, or 7) were hospitalized for any of the reported COVID symptoms. All measures were dichotomized as "yes" and "no" with those who reported "do not know" or"not sure" were classified as a "no".

Comorbid conditions. Participants were asked whether they have ever been told by a health professional that they had heart attack, angina or coronary heart disease, type 2 diabetes, high blood pressure, cancer, asthma, chronic obstructive pulmonary diseases, emphysema, or chronic bronchitis, kidney disease, HIV/AIDS, immunosuppression, and depression.

Statistical analysis. Descriptive statistics were generated to examine the socio-demographic, health and behavioral characteristics between households with and without children, and for hospitalized and non-hospitalized participants. Frequencies were generated for all categorical variables and Pearson's chi-squared test of independence was performed to assess group differences.

A multivariable logistic regression model was used to estimate the association between presence of children in households, number of people living in a household, and property types on the risk of hospitalization with COVID symptoms. We ran three models, all adjusted for age, gender, race/ethnicity, income, close contact, essential worker status, and the county-level community transmission rate. Models examining the exposures of the number of people living in household and property types models were also adjusted for presence of children in the household. These variables chosen were based on hypothesized causal associations and confounders, and direct acyclic graphs [34] were developed for each model.

Given the associations between household crowding with COVID transmission [8, 9], the crude and adjusted associations between 1) presence of children in household or 2) household size on hospitalizations due to COVID were stratified by property type. For each main effect model, we ran a model with an interaction term (i.e., presence of children*property type and household size*property type) and adjusted for the same covariates as the main effects models.

Finally, we compared the socio-demographic and behavioral characteristics, as well as comorbidities of participants who were hospitalized with COVID symptoms to those who were not. These included socio-demographic characteristics, and health and behavioral risk factors such as essential worker status, report of having comorbid conditions, and whether participants were in close contact with symptomatic, suspected or confirmed COVID cases. In addition, reported COVID symptoms were examined and ranked for both groups.

Sensitivity analyses. Three separate sensitivity analyses were performed to assess the potential impact of missing data and misclassification. First, to assess the potential impact of missing values of essential worker status in the initial baseline assessment, a complete case analysis was performed on the participants who had completed the second version of the baseline assessment and for whom essential worker status was known. Given the negative impact of the COVID-19 pandemic on care seeking (including emergency room care) [35], a second sensitivity analysis assessed the potential impact of excluding persons with COVID symptoms who were not hospitalized in the non-hospitalized group (i.e., differential outcome misclassification). For this analysis we excluded persons who reported symptoms from the denominator of non-hospitalized. The third sensitivity analysis examined the main effects of the exposures on those hospitalized that also had a laboratory confirmed diagnosis for COVID. For this analysis we restricted the outcome to include only those who reported being hospitalized and have received a laboratory-confirmed diagnosis for COVID.

SAS version 9.4 (SAS Institute, Cary, NC) was used for all statistical analyses. Data and surveys are publicly available [25, 26].

Results

A total of 6,831 participants completed cohort screening, including 5,348 (78%) who completed the second version of the assessment with the question on essential workers.

COVID-like illness outcomes

Between March 28, 2020 and April 20, 2020, 58.5% of the study population reported symptoms in the two weeks prior to their study interview, with 25.7% (n = 1754) of those meeting the case definition for COVID-like illness [33] (Fig 1). Twelve percent (n = 820) of the study population reported seeing a healthcare provider for these symptoms, 7.6% (n = 518) sought SARS--CoV-2 testing but did not receive it, 5.2% (n = 357) received a diagnostic test, 2.8% (n = 188) received a laboratory confirmed diagnosis of coronavirus, and 2.8% (n = 191) reported being hospitalized for COVID-like symptoms (69.6% (n = 133) of whom reported laboratory confirmation of their diagnosis, and were considered ‘confirmed’).

Compared to those without children <18 in the household (Table 1), participants with children were more likely to be under 49 years old (81.2% vs 60.5%), Hispanic (25.9% vs 13.9%), essential workers (26.5% vs 18.8%), and more likely to report having had close contact with someone with coronavirus-like symptoms or a confirmed case (23.3% vs 16.0%). Participants who completed the second version of the assessment were similar to those who completed the first (See S1 Table).

Multivariable analysis

Compared to participants without children in the home, those with children had 4.99 times the adjusted odds (95%CI: 3.16–7.89) in being hospitalized for COVID symptoms (Table 2). No associations were observed between households with more than four persons and hospitalization for COVID symptoms (aOR:1.10; 95%CI: 0.49–2.47) compared to one-person households. Participants who lived in a multi-unit property compared to those living in a single-unit had 4.62 (95%CI: 2.79–7.66) times higher adjusted odds of being hospitalized.

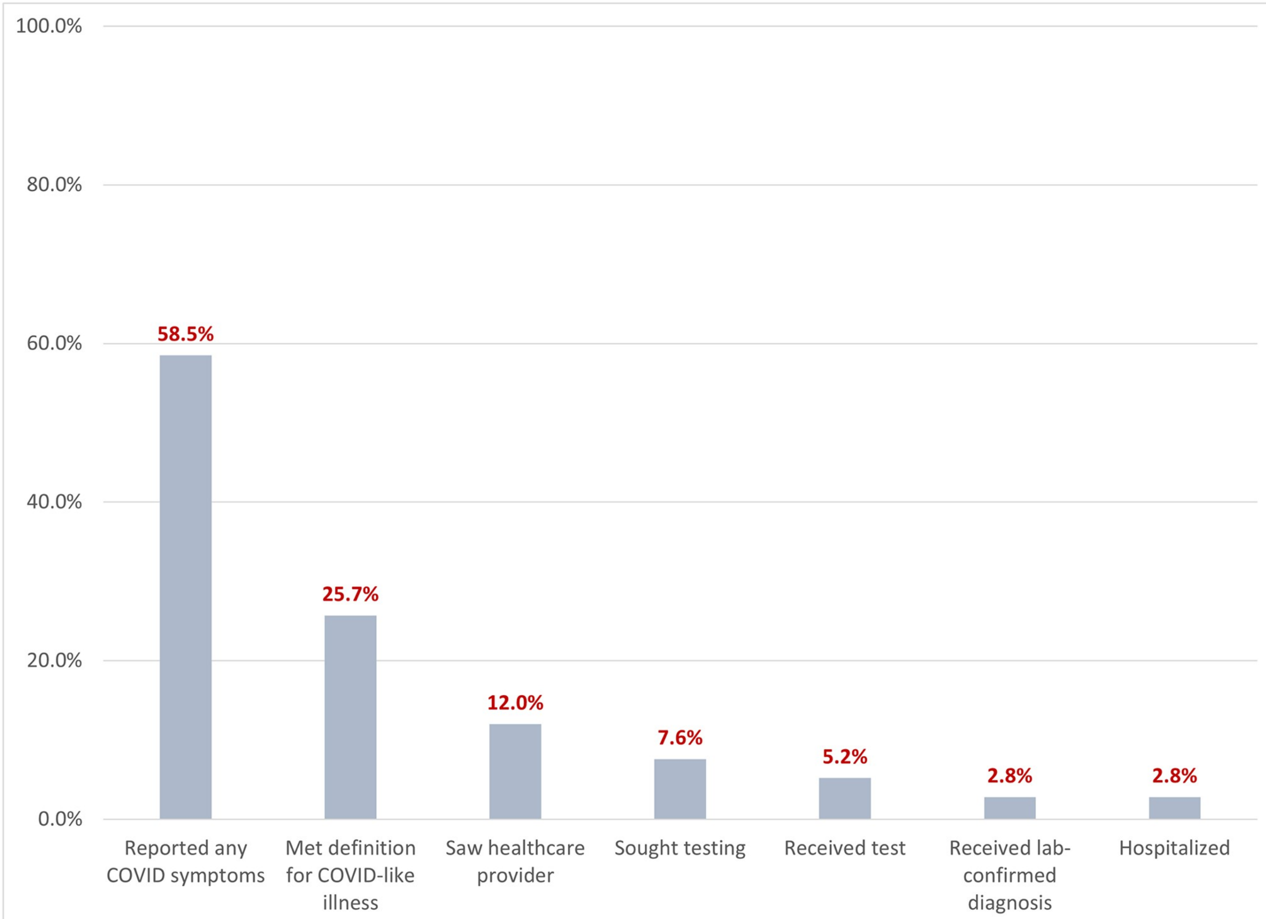

Fig 1. SARS-CoV-2 symptoms among persons screened for enrollment in the CHASING COVID Cohort Study, April 2020.

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When stratified by property type, compared to participants without children living in a multi-unit property, participants with children living in multi-unit property had 10.47 times the adjusted odds for being hospitalized for COVID symptoms (95%CI: 5.73–19.13). Participants living in households with more than 4 people in multi-unit property had 2.46 times the adjusted odds (95%CI: 0.99–6.08) of being hospitalized with COVID symptoms than participants living alone in a multi-unit property. No other statistically significant associations were observed between household sizes on hospitalization when stratified by property type.

Characteristics of hospitalized participants compared to those not hospitalized

A total of 191 participants were hospitalized for their reported symptoms (Table 3). Compared with all other participants (n = 6,638), those hospitalized were more likely to be between the age of 18 and 49 years of age (84.4% vs 59.8%), male (82.2% vs 50.2%), and Hispanic (70.7% vs 12.2%). Hospitalized participants were more likely to report a comorbid condition (85.4% vs 31.7%) and to have had contact with a symptomatic case or suspected or confirmed case (76.4% vs 14.2%). They were also more likely to be essential workers (80.1% vs 17.1%). Fever and sore throat were the two most commonly reported symptoms which were reported by

Table 1. Select socio-demographic, health and behavior characteristics among persons screened for enrollment in the CHASING COVID Cohort (N = 6831), April 2020.

	Presence of Children in Household			
	Total	Yes	No	p-value
	N (%)	n (%)	n (%)	
Total	6831	1547 (22.7%)	5284 (77.4%)	
Socio-demographic				
Age group (years)				
18–49	4133 (60.5%)	1256 (81.2%)	2877 (54.5%)	< 0.0001
50–59	1083 (15.9%)	192 (12.4%)	891 (16.9%)	
60+	1615 (23.6%)	99 (6.4%)	1516 (28.7%)	
Gender				
Male	3487 (51.1%)	575 (37.2%)	2912 (55.1%)	< 0.0001
Female	3134 (45.9%)	939 (60.7%)	2195 (41.5%)	
Gender non-binary	210 (3.1%)	33 (2.1%)	177 (3.4%)	
Race/ethnicity				
Hispanic	946 (13.9%)	401 (25.9%)	545 (10.3%)	< 0.0001
White non-Hispanic	4561 (66.8%)	828 (53.5%)	3733 (70.7%)	
Black non-Hispanic	721 (10.6%)	176 (11.4%)	545 (10.3%)	
Asian/Pacific Islander	326 (4.8%)	81 (5.2%)	245 (4.6%)	
Other	277 (4.1%)	61 (3.9%)	216 (4.1%)	
Annual household income				
< $50,000	3253 (47.6%)	665 (43.0%)	2588 (49.0%)	< 0.0001
$50,000- $99,000	1626 (23.8%)	298 (19.3%)	1328 (25.1%)	
≥ $100,000	1530 (22.4%)	446 (28.8%)	1084 (20.5%)	
Not reported	422 (6.2%)	138 (8.9%)	284 (5.4%)	
Health and behaviors				
Essential worker				
Yes	1286 (18.8%)	410 (26.5%)	876 (16.6%)	< 0.0001
No	4062 (59.5%)	865 (55.9%)	3197 (60.5%)	
Not asked	1483 (21.7%)	272 (17.6)	1211 (22.9%)	
Reported having comorbidities				
Yes	2271 (33.2%)	488 (31.5%)	1783 (33.7%)	0.11
No	4560 (66.8%)	1059 (68.5%)	3501 (66.3%)	
Had close contact with suspected/confirmed case				
Yes	1090 (16.0%)	361 (23.3%)	729 (13.8%)	< 0.0001
No	5741 (84.0%)	1186 (76.7%)	4555 (86.2%)	
Household Factors				
Property type				
Multi-unit property	2602 (38.1%)	451 (29.2%)	2151 (40.7%)	< 0.0001
Single-unit property	3856 (56.5%)	985 (63.7%)	2871 (54.3%)	
Other	373 (5.5%)	111 (7.2%)	262 (5.0%)	
Number of persons living in household				
1	1990 (29.1%)	0	1190 (37.7%)	< 0.0001
2–3	3157 (46.2%)	394 (25.5%)	2763 (52.3%)	
4+	1684 (24.7%)	1153 (74.5%)	531 (10.1%)	

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Table 2. Main effects of presence of children, number of persons in households and property type on hospitalization for COVID-like symptoms (N = 6831), April 2020.

Main exposures	Hospitalized for COVID-like symptoms		
	n (%)	cOR (95% CI)	aOR (95% CI)
Children in household*			
Yes	147 (9.5%)	12.51 (8.89–17.61)	4.99 (3.16–7.89)
No	44 (0.8%)	ref	ref
Number of persons in household **			
1	18 (0.9%)	ref	ref
2–3	34 (1.1%)	1.19 (0.67–2.12)	0.90 (0.45–1.79)
More than 4	139 (8.3%)	9.85 (6.00–16.17)	1.10 (0.49–2.47)
Property Type ***			
Multi-Unit	153 (5.9%)	8.86 (5.87–13.38)	4.62 (2.79–7.66)
Single-Unit	27 (0.7%)	ref	Ref
Other	11 (3.0%)	4.31 (2.12–8.76)	4.55 (2.00–10.36)
Interactions			
Presence of children stratified by property			
Children living multi-unit	131 (29.1%)	39.60 (24.83–63.14)	10.47 (5.73–19.13)
No children living in multi-unit	22 (1.0%)	ref	ref
Children living in single unit	12 (1.2%)	2.35 (1.10–5.04)	2.82 (1.23–6.47)
No children living in single unit	15 (0.5%)	ref	ref
Children living in 'other' type unit	4 (3.6%)	1.36 (0.39–4.75)	1.05 (0.27–4.14)
No children living in 'other' type unit	7 (2.7%)	ref	ref
Household size stratified by property type			
1 living in multi-unit	13 (1.1%)	ref	ref
2–3 living in multi-unit	16 (1.6%)	1.41 (0.68–2.95)	1.13 (0.48–2.64)
More than 4 living in multi-unit	124 (26.4%)	31.05 (17.32–55.68)	2.46 (0.99–6.10)
1 living in single unit	2 (0.3%)	ref	ref
2–3 living in single unit	15 (0.7%)	2.73 (0.62–11.98)	1.62 (0.36–7.38)
More than 4 living in single unit	10 (0.9%)	3.37 (0.74–15.41)	0.78 (0.15–4.10)
1 living in other type unit	3 (2.5%)	ref	ref
2–3 living in other type unit	3 (2.2%)	0.87 (0.17–4.41)	0.70 (0.10–5.10)
More than 4 living in other type unit	5 (4.2%)	1.71 (0.40–7.33)	0.85 (0.13–5.30)

* Presence of children effects are adjusted for age, gender, race/ethnicity, close contact, income, county mortality rate and essential worker status

**Household size effects are adjusted for presence of children, age, gender, race/ethnicity, close contact, income, county mortality rate and essential worker status

***Property type effects are adjusted for presence of children, age, gender, race/ethnicity, close contact, income, county mortality rate and essential worker status

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71.7% and 70.2% of participants, respectively. About 76.4% of hospitalized participants received a test, and 69.6% of them received a laboratory-confirmed diagnosis.

Discussion

Our study suggests that certain household exposures at the beginning of the SARS-CoV-2 pandemic in the US not only increased the risk of SARS-CoV-2 acquisition, but also increased the risk of severe COVID-19 disease, requiring hospitalization. Household crowding and having children in the home were both strong and independent risk factors for being hospitalized

Table 3. Characteristics of participants by status of hospitalization with COVID-like symptoms, April 2020.

	Hospitalized with COVID-symptoms		
Socio-demographic Factors	**Yes n (%)**	**No n (%)**	**p-value**
Age group (years)			
18–49	162 (84.8%)	3969 (59.8%)	<0.0001
50–59	8 (4.2%)	1075 (16.2%)	
60+	21 (11.0%)	1594 (24.0%)	
Gender			
Male	157 (82.2%)	3329 (50.2%)	<0.0001
Female	31 (16.2%)	3102 (46.7%)	
Non-binary	3 (1.6%)	207 (3.1%)	
Race/ethnicity			
Hispanic	135 (70.7%)	811 (12.2%)	<0.0001
White non-Hispanic	29 (15.2%)	4531 (68.3%)	
Black non-Hispanic	19 (10.3%)	702 (10.6%)	
Asian/Pacific Islander	2 (1.1%)	324 (4.9%)	
Other	6 (3.1%)	270 (4.1%)	
Annual household income level			
< $50,000	50 (26.2%)	3202 (48.2%)	<0.0001
$50,000- $99,000	14 (7.3%)	1612 (24.3%)	
≥ $100,000	123 (64.4%)	1407 (21.2%)	
Missing	4 (2.1%)	417 (6.3%)	
Health and behavioral Factors			
Reported having comorbidities			
Yes	165 (85.4%)	2105 (31.7%)	<0.0001
No	26 (13.6%)	4533 (68.3%)	
Had contact with symptomatic or suspected/confirmed case			
Yes	146 (76.4%)	944 (14.2%)	<0.0001
No	45 (23.6%)	5694 (85.8%)	
Essential Worker			
Yes	153 (80.1%)	1133 (17.1%)	<0.0001
No	29 (15.2%)	4032 (60.7%)	
Not asked	9 (4.7%)	1473 (22.2%)	
Reported symptoms (ranked)			
Fever	137 (71.7%)	314 (4.7%)	<0.0001
Sore throat	134 (70.2%)	924 (13.9%)	<0.0001
Headache	32 (16.8%)	1867 (28.1%)	0.001
Myalgia	31 (16.2%)	758 (11.4%)	0.040
Cough with phlegm	30 (15.7%)	831 (12.5%)	0.191
Shortness of breath	28 (14.7%)	571 (8.6%)	0.004
New cough	27 (14.4%)	769 (11.6%)	0.279
Runny nose	26 (13.6%)	1641 (24.7%)	0.0004
Diarrhea	22 (11.5%)	853 (12.9%)	0.587
Nasal congestion	21 (11.0%)	1415 (21.3%)	0.001
Chills	18 (9.4%)	360 (5.4%)	0.017
Nausea	15 (7.9%)	402 (6.1%)	0.306
Vomit	9 (4.7%)	82 (1.2%)	<0.0001
Cough with blood	3 (1.6%)	19 (0.3%)	0.002
Saw healthcare provider for symptoms			

(*Continued*)

Table 3. (Continued)

	Hospitalized with COVID-symptoms		
Socio-demographic Factors	**Yes n (%)**	**No n (%)**	**p-value**
Yes	173 (90.6%)	646 (9.7%)	<0.0001
No	18 (9.4%)	5992 (90.3%)	
Testing status			
Sought test	18 (9.4%)	500 (7.5%)	<0.0001
Received test	146 (76.4%)	211 (3.2%)	
Did not need or try	27 (14.1%)	5927 (89.3)	
Received lab-confirmed diagnosis			
Yes	133 (69.6%)	55 (0.8%)	<0.0001
No	58 (30.4%)	6583 (99.2%)	

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with SARS-CoV-2 early in the US pandemic, when there was no vaccine available and when mask use was still debated as a strategy for reducing risk. Our findings have implications for public health recommendations in areas and during times where the risk of household transmission of SARS-CoV-2 may be higher, such as immediately prior to and after issuing stay at home orders, when the point prevalence of SARS-CoV-2 in the affected communities may be at its highest level. Essential workers, families with children, and those living in crowded indoor settings may be at particularly high risk for being hospitalized with SARS-CoV-2, and tailored recommendations to reduce the risk of household transmission are needed when community transmission is high.

In unvaccinated populations, household transmission occurs rapidly after an index case introduces the infection and with high household attack rates, can originate from both children and adults [19], and are associated with high rates of hospitalization and death [2, 5].

Early in the US pandemic, even when mask use was recommended and became the norm outside the home, including in areas where stay at home orders had been put in place, mask use inside the home or other at-home risk mitigation measures were not recommended to reduce household transmission except in situations where there were ill/infected persons (i.e., recommended 10–14 days of isolation using a separate bedroom and bathroom). However, because of household crowding, a lack of space in households, or a need to go to work, provide childcare, or care for other household/family measures, isolation of ill/infected persons and quarantine of those who may have had high-risk exposures (e.g., to a confirmed case) is not always feasible, and other risk mitigation measures (e.g., mask wearing, opening windows) are therefore needed. The use of high quality KN95 and N95 masks in the general population with and without symptoms was uncommon.

A higher infectious dose, such as during a prolonged household exposure in more crowded, poorly ventilated homes, may result in a more severe course of SARS-CoV-2 infection. Mask use is an effective strategy to both reduce the risk of onward spread from an infected person to susceptibles, and also reduces the risk of infection to the mask wearer [36]. However, infections still can occur when masks are being used by infected and susceptible persons, but these infections may be more likely to result in asymptomatic or milder SARS-CoV-2 infection, because of a lower infectious dose [20]. It is therefore possible that a lack of mask use at home during quarantine and isolation results in a higher infectious dose of SARS-CoV-2 than would occur with masks, especially in smaller crowded homes, with more household members, including children.

Stay at home orders usually go into effect when community transmission (and point prevalence) is highest, and by definition, they increase the amount of time that household members spend together indoors. Given this, the high attack rates of SARS-CoV-2 within households, and the higher severity of SARS-CoV-2 infections that can result from prolonged unmasked, indoor exposures when entire households are quarantined, public health officials should consider recommending mask use and other risk mitigation strategies (e.g., open windows, reduced close contact, at-home testing) in all households with more than one person for a period of time immediately before and after stay at home orders go into effect.

Essential workers have several potential risks for SARS-CoV-2 infection, including commuting and exposure while at work, but they also may be at higher risk for acquiring or transmitting infection at home as well. In NYC and Chicago, a COVID-19 hotspot analysis found that hot spots had more household crowding, and tended to be middle income, working class neighborhoods that may have higher concentrations of essential workers [9]. A national prospective study found that household crowding and being an essential worker were associated with a higher risk of SARS-CoV-2 seroconversion [37].

Our study, which included substantial numbers of essential workers who were hospitalized, looked within households and described some of the risk factors for severe COVID-19 early in the US pandemic. Essential workers with young children need childcare, which could put their children at risk of infection. When children become infected, isolation may be even more challenging than for adults, and adults providing care for them are at higher risk, possibly of a more severe SARS-CoV-2 infection, especially when it is difficult to follow infection control practices, such as mask wearing at home by all household members.

Household studies have suggested a similar levels of infectiousness among children compared with adults [38–41]. One recent study from New York City showed a higher prevalence of SARS-CoV-2 infection during surges among adults with children <18 years in the household [42]. However, the literature on children in the household increasing the risk for severe COVID-19 outcomes, beyond the higher risk of infection that they pose to household members, is limited. Although one large study found no statistically significant association with severe disease and death [43].

In addition to the potential for a higher infectious dose in crowded households with children, there are other possible mechanisms by which children in the household might increase the risk of severe disease among adult household members. Children can be part of households with extended families, which can include elderly household members or those with comorbidities that increase the risk for severe disease. Additionally, since children with SARS-CoV-2 infection are more likely to be asymptomatic [41] or have less severe symptoms [44], when children introduce infection into the household, adult infections may go unrecognized for longer, leading to delayed care presentation and increased disease severity.

Our study has limitations worth noting. First, we used data collected at cohort enrollment in April-May 2020; therefore, temporality of some of the exposures and outcomes cannot be established. Second, this was not a household transmission study, and therefore we could not pinpoint household transmission as the likely source of the infection that resulted in infection and hospitalization among our study participants. We therefore cannot say whether and the extent to which household transmission occurred, and if it did, when a child in the household was the source of infection to our study participants. We also did not assess participants' mask use at home. Finally, while we controlled for several possible confounders of the association of household crowding and children in the home with SARS-CoV-2 risk, unmeasured confounding could partially explain our observed associations.

Our study also had some strengths. As a large epidemiologic cohort study, it was possible to examine the association of several potentially important household-level risk factors with a relatively rare outcome of SARS-CoV-2 hospitalization, while controlling for potential confounding factors. We also had a sociodemographically and geographically diverse sample that included several essential workers. Finally, our findings were robust to the three sensitivity analyses, which generated similar findings to the main analysis.

Conclusions

Early in the US SARS-CoV-2 pandemic prior to the availability of vaccines, certain household exposures may have increased both the risk of both SARS-CoV-2 acquisition and the risk of severe COVID-19 disease requiring hospitalization. These findings have implications for mask wearing and other mitigation strategies at home immediately prior to and immediately after 'stay at home' orders go into effect.

Supporting information

S1 Table. Select socio-demographic, health and behavior characteristics among C3 participants with children in household and who completed first version of assessment (N = 5348).
(PDF)

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Author Contributions

Conceptualization: Denis Nash, Sarah G. Kulkarni, Andrew R. Maroko.

Data curation: Denis Nash, McKaylee Robertson, Rebecca Zimba, Sarah G. Kulkarni, Amanda Berry, William You, Chloe Mirzayi, Drew Westmoreland, Angela Parcesepe, Shivani Kochhar, Andrew R. Maroko, Christian Grov.

Formal analysis: Denis Nash, Saba Qasmieh, McKaylee Robertson.

Funding acquisition: Denis Nash, McKaylee Robertson, Sarah G. Kulkarni, Levi Waldron, Christian Grov.

Investigation: Denis Nash.

Methodology: Denis Nash, Saba Qasmieh, McKaylee Robertson, Madhura Rane, Drew Westmoreland, Angela Parcesepe, Andrew R. Maroko.

Project administration: Denis Nash, Amanda Berry, Christian Grov.

Resources: Denis Nash.

Supervision: Denis Nash, McKaylee Robertson, Andrew R. Maroko.

Visualization: Denis Nash.

Writing – original draft: Denis Nash, Saba Qasmieh, McKaylee Robertson, Sarah G. Kulkarni.

Writing – review & editing: Denis Nash, Saba Qasmieh, Madhura Rane, Rebecca Zimba, Sarah G. Kulkarni, Amanda Berry, William You, Chloe Mirzayi, Drew Westmoreland, Angela Parcesepe, Levi Waldron, Shivani Kochhar, Andrew R. Maroko, Christian Grov.

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