Family and household characteristics associated with seropositive cases to SARS-CoV-2 across Mexican households

Nancy López-Olmedo, PhD Nutrition Epidemiology,[1] Dalia Stern, PhD Nutrition Epidemiology,[1,2] Francisco Canto-Osorio, MSc Nutrition,[1] Tonatiuh Barrientos-Gutiérrez, PhD Epidemiology,[1] Celia Alpuche-Aranda, PhD Medical Sciences.[3]

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Abstract

Objective. To assess the association of family and housing characteristics with the number of seropositive cases to SARS-CoV-2 in households. **Materials and methods.** We analyzed 874 households from Encuesta Nacional de Salud y Nutrición (Ensanut) 2020 Covid-19 using Poisson regression models. **Results.** The number of seropositive family members was higher among families composed of children/adolescents, adults and older adults, households with more than two members per bedroom, and among households with closed windows. No association was found for bathroom availability and piped water. **Conclusions.** Family composition and housing characteristics can impose significant structural barriers to safe home confinement.

Keywords: Disease by Coronavirus 2019-nCoV; Inmoglobulin G; housing

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Resumen

Objetivo. Determinar la asociación de la estructura familiar y de las características de la vivienda con el número de casos positivos a SARS-CoV-2 a nivel hogar. **Material y métodos.** Se analizaron 874 hogares de la Encuesta Nacional de Salud y Nutrición (Ensanut) 2020 Covid-19 utilizando modelos de regresión de Poisson. **Resultados.** El número de miembros seropositivos fue mayor en los hogares compuestos por niños/adolescentes, adultos y adultos mayores, donde más de dos miembros ocupaban la misma habitación y en los hogares donde se observaron ventanas cerradas. **Conclusiones.** La composición familiar y las características de la vivienda pueden representar barreras importantes para el confinamiento seguro en casa.

Palabras clave: Enfermedad por Coronavirus 2019-nCoV; Inmoglobulina G; vivienda

From March 24 to May 30, 2020, the Federal health authorities in Mexico recommended restricting operations in public institutions and private companies and staying at home to help contain the coronavirus disease 2019 (Covid-19).[1-3] Mobility decreased to 67%, yet, 75% of people still reported having to leave their house.[4,5] As in other low and middle-income countries, a large proportion of the Mexican population lives in multigenerational and

(1) Centro de Investigación en Salud Poblacional, Instituto Nacional de Salud Pública. Cuernavaca, Morelos, Mexico.
(2) Consejo Nacional de Ciencia y Tecnología. Mexico City, Mexico.
(3) Centro de Investigación sobre Enfermedades Infecciosas, Instituto Nacional de Salud Pública. Cuernavaca, Morelos, Mexico.

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Corresponding author: Celia Alpuche-Aranda. Centro de Investigación sobre Enfermedades Infecciosas, Instituto Nacional de Salud Pública. Av. Universidad 655, col. Santa María Ahuacatitlán. 62100, Cuernavaca, Morelos, Mexico.
email: celia.alpuche@insp.mx

crowded households with limited sanitary conditions and participate in informal and precarious jobs, forcing household members to work even under stay-at-home orders.[6]

Home confinement is a key non-pharmacological intervention for the Covid-19 response. Nevertheless, the effectiveness of this intervention may be reduced if household conditions increase the probability of transmission. Across the world, SARS-CoV-2 household transmission has been heterogeneous, ranging from 0% in South Korea to 45% in Treviso, Italy.[7] Understanding the drivers of household transmission is key to increase the effectiveness and safety of home confinement.

Prior studies have shown that the number of SARS-CoV-2 seropositive members at home increases the more the family size.[7] Although evidence is still limited, transmission seems to be higher in adults than in children and between spouses than among other family members.[7] Less is known about the association between housing characteristics and seropositivity in households. However, potential proposed risk factors include a smaller number of bedrooms, poor sanitary services, and the use of air conditioning systems over natural ventilation.[8,9]

We aimed to assess the potential association of family and housing characteristics with the number of seropositive cases to SARS-CoV-2 in Mexican households. Using data from the *Encuesta Nacional de Salud y Nutrición* (Ensanut) 2020 Covid-19, we selected households with at least two blood samples and at least one seropositive household member as a proxy of household transmission. Then, we compared family and household characteristics by the number of seropositive members and fitted adjusted models to identify potential conditions that could increase household transmission.

Materials and methods

Study design and population

Mexico's 2020 Ensanut was dedicated to the analysis of Covid-19. This is a representative survey of the national, urban/rural, and regional levels. Data collection spanned from August to November 2020 and obtained sociodemographic and health characteristics through questionnaires from 10 216 households and 36 024 individuals. Participants were selected at random at each household to obtain a blood sample from each of the following age groups: 1-4 years, 5-9 years, 10-19 years, 20-34 years, 35-49 years, and 50 or more years. A total of 9 640 participants from 5 648 households provided a blood sample (44% response rate).[10] Given our aim of assessing the number of seropositive cases to SARS-CoV-2 at the household level as a proxy for family transmission, we selected a group of 874 households where at least two members provided a blood sample and where at least one member was IgG positive to SARS-CoV-2, representing 5 576 886 households in Mexico.

Study variables

Number of seropositive cases to SARS-CoV-2 at the household level. Anti-SARS-CoV-2 antibodies were determined through immunoglobulin G detection against protein N using the Roche Elecsys test. For this analysis, we created a variable that indicated the number of household members positive to SARS-CoV-2.

Family and housing characteristics. We considered the family and households characteristics collected as part of the 2020 Ensanut that, based on literature, can be associated with the seropositivity to SARS-CoV-2 in households.[7,11,12]

Family structure. Households were classified into three categories depending on whether they were composed of children (0-9 years), adolescents (10-19 years), adults (20-59 years), and/or older adults (≥60 years). Family composition was then classified as follows: 1) adults and/or older adults; 2) children/adolescents and adults, and 3) children/adolescents, adults, and older adults.

Housing characteristics

Number of household members per bedroom. The number of members divided by the number of bedrooms, classified as non-response, <2, 2, or >2 members per bedroom.

Household services. Household services were reported by the head of the household and included the availability of a bathroom connected to the sewer system, access to piped water, and the need to share the bathroom with members of a different household.

Natural ventilation. To assess the use of natural ventilation, Ensanut interviewers observed open windows during their visit to the household. They reported if open windows were visible as "yes", "no", or "no windows visible".

Covariates

Number of household members. The total number of household members was classified as 2, 3-4, ≥5 members.

Socioeconomic level. A socioeconomic index was estimated by applying principal component analysis to eight household characteristics, services, and assets,

and five electrical devices.[13] The socioeconomic index was divided into low, medium, and high levels, using tertiles as cut-off points.

Region of residence. Ensanut defined nine regions to group the states where participating households were located. Regions include Pacific-North, Border, Pacific-Center, Center-North, Center, Mexico City, State of Mexico, South Pacific, and Peninsula.[14]

Statistical analysis

A descriptive analysis was conducted using percentages and 95% confidence intervals to present the distribution of seropositive members in households (1, 2, or ≥3) by family structure and housing characteristics. A Poisson regression model with robust standard errors[15,16] was fit to determine the association between family structure and housing characteristics and the number of seropositive household members, adjusting for socioeconomic level and region. We also adjusted the model for the sampling design variables to account for the survey design. Given that the number of seropositive cases in households is highly correlated to household size, we included a fixed effect for household size in the model to restrict comparisons to households with the same total number of household members. All statistical analyses were carried out in Stata 14.0.*

Results

Among households with more than one member and at least one IgG anti-SARS-CoV-2 seropositive case, 49.6% had only one seropositive member, 36.2% had two, and 14.2% had three or more seropositive members (table I). Families composed of adults and older adults had a lower frequency of three and more seropositive members (4.7%), compared to households with children/adolescents and adults (15.6%), and to families with children/adolescents, adults, and older adults (18.7%). Households with more than two members per room had a higher prevalence of three and more seropositive members (18.3%), compared to households with two (12.5%) and less than two members per room (11.6%).

Table II[5] presents the adjusted association between the number of seropositive household members and the familial composition and housing characteristics. Families composed of children/adolescents, adults, and older adults had, on average, 1.07 (95%CI: 1.03, 1.11) times as many members with anti-SARS-CoV-2 antibodies as families composed of adults and older adults. Households with more than two members per bedroom had, on average, 1.07 (95%CI: 1.05, 1.09) times the number of members with antibodies than households with less than two members per bedroom. The average number of seropositive members in households with natural ventilation was 6% lower than in households without it (95%CI: 0.92, 0.97).

Discussion

A higher number of seropositive members was observed in families with children/adolescents, adults, and older adults. The survey design did not allow us to identify the index case; however, it would be expected that fewer children and adolescents were in the index case because they have received virtual learning since March 2020, reducing their contact with non-household members. This might not be the case for adolescents who left their houses to conduct non-educational activities.[17]

A higher number of household members per bedroom was associated with a higher number of SARS-CoV-2 seropositive members in the household. Close interactions are expected to last longer if bedrooms are shared, facilitating disease transmission.[12] In Mexico, more than 50% of households have more than 3.7 inhabitants, and 9.7% of families live in overcrowded conditions, which could have facilitated infection.[18,19] We also observed a lower number of seropositive household members in houses with open windows, suggesting that natural ventilation could help reduce the probability of infection.

Our study has important limitations. We did not have complete coverage of household members or the specific infection dates, as required by household transmission studies. Therefore, we do not rule out that some individuals acquired the infection through other non-household members. Yet, we restricted comparisons to households with the same total number of members and, given the random selection of members, were able to examine the number of seropositive cases across households. Also, we cannot rule out the possibility of selection bias given the response rate. The sensitivity analysis by Abreu and colleagues suggest that individuals with Covid-19 related symptoms were more likely to provide a blood sample. However, the impact on the seroprevalence was small after accounting for this potential bias.* While household transmission studies with complete coverage of household members will be

* StataCorp, Stata Statistical Software, release 14, 2015

* Basto-Abreu A, Carnalla M, Torres-Ibarra L, Romero-Martínez M, Martinez-Barnetche J, López Martínez I, *et al*. SARS-CoV-2 antibody prevalence in Mexico: results from a national representative survey from August to November 2020. 2021;under review.

Table I
Family structure and housing characteristics by the number of household members with anti-SARS-CoV-2 antibodies (n=874, N=5.6 million households). Mexico, Ensanut 2020 Covid-19

	Household members with anti-SARS-CoV-2 IgG antibodies					
	1		*2*		*≥3*	
	%	*95%CI*	*%*	*95%CI*	*%*	*95%CI*
Total	49.6	(46.0,53.2)	36.2	(32.9,39.7)	14.2	(12.0,16.7)
Family structure						
Adults and/or older adults	57.0	(49.6,64.1)	38.3	(31.4,45.8)	4.7	(2.6,8.3)
Children/adolescents and adults	49.5	(44.9,54.0)	35.0	(30.7,39.5)	15.6	(12.3,19.6)
Children/adolescents, adults, and older adults	44.1	(37.9,50.5)	37.2	(31.1,43.9)	18.7	(14.3,24.1)
Housing characteristics						
Number of members per bedroom						
<2	52.3	(47.4,57.2)	36.1	(31.4,41.1)	11.6	(8.3,15.8)
2	54.3	(45.6,62.7)	33.3	(25.7,41.8)	12.5	(8.2,18.5)
>2	44.7	(39.4,50.1)	37.0	(31.8,42.5)	18.3	(14.6,22.7)
No response of the number of bedrooms	22.5	(6.1,56.6)	63.1	(36.5,83.5)	14.4	(5.1,34.3)
Bathrooms with direct water discharge						
Yes	49.3	(45.1,53.5)	36.3	(32.5,40.3)	14.4	(11.7,17.6)
No	51.5	(45.2,57.7)	35.0	(29.1,41.4)	13.5	(9.8,18.4)
Did not answer	22.5	(6.1,56.6)	63.1	(36.5,83.5)	14.4	(5.1,34.3)
Shared bathrooms with other households						
Yes	46.7	(34.6,59.2)	32.3	(22.6,43.9)	21.0	(12.9,32.3)
No	49.9	(46.2,53.7)	36.3	(32.8,39.9)	13.8	(11.5,16.4)
Did not answer	42.2	(20.6,67.3)	47.1	(26.0,69.2)	10.7	(3.8,26.9)
Open windows						
Yes	50.2	(45.8,54.5)	35.5	(31.5,39.8)	14.3	(11.7,17.3)
No	47.8	(40.5,55.1)	37.9	(30.8,45.6)	14.3	(9.9,20.2)
No windows visible	49.6	(39.4,59.9)	37.4	(27.2,48.8)	13.0	(6.6,23.9)
Piped water						
Yes	49.6	(46.0,53.2)	36.3	(32.9,39.9)	14.1	(11.8,16.6)
No	58.4	(34.8,78.8)	24.0	(11.3,44.0)	17.5	(4.7,47.5)
Did not answer	22.5	(6.1,56.6)	63.1	(36.5,83.5)	14.4	(5.1,34.3)
Covariates						
Household size						
2	64.6	(51.3,76.0)	35.4	(24.0,48.7)	0.0	-
3-4	51.7	(46.9,56.5)	38.7	(34.2,43.3)	9.6	(7.0,13.1)
≥5	45.4	(40.4,50.5)	34.1	(29.6,38.8)	20.5	(17.0,24.7)
Socioeconomic level						
Low	47.2	(41.4,53.0)	36.3	(31.4,41.5)	16.5	(12.7,21.3)
Medium	51.3	(45.1,57.5)	38.4	(32.3,44.9)	10.3	(7.2,14.4)
High	50.3	(43.7,57.0)	33.8	(27.8,40.4)	15.9	(11.7,21.3)

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Region						
Pacific-North	35.2	(25.9,45.7)	48.4	(39.1,57.8)	16.4	(10.7,24.3)
Border	54.2	(45.0,63.0)	30.2	(23.6,37.8)	15.6	(10.2,23.2)
Pacific-Center	54.9	(41.9,67.2)	32.1	(18.8,49.1)	13.0	(6.1,25.6)
Center-North	57.5	(44.0,69.9)	28.2	(16.7,43.6)	14.2	(7.3,26.0)
Center-North	56.4	(47.4,65.0)	30.3	(23.2,38.5)	13.3	(7.8,21.8)
Mexico City	45.2	(33.1,57.8)	39.6	(30.8,49.0)	15.3	(8.1,26.9)
State of Mexico	54.3	(42.5,65.7)	37.0	(27.6,47.5)	8.7	(4.5,16.3)
South Pacific	47.2	(38.3,56.3)	34.7	(27.8,42.4)	18.1	(11.2,27.8)
Peninsula	42.4	(34.1,51.2)	43.2	(34.6,52.2)	14.4	(11.2,18.3)

Ensnaut: *Encuesta Nacional de Salud y Nutrición*

Table II

Association of family structure and housing characteristics with the number of household members with anti-SARS-CoV-2 antibodies (n=874, N=5.6 million households). Mexico, Ensanut 2020 Covid-19

	*Multivariable model**	
	IRR	*95%CI*
Family structure		
Adults and/or older adults	REF	
Children/adolescents and adults	1.03	(0.98, 1.08)
Children/adolescents, adults, and older adults	1.07	(1.03, 1.11)
Housing characteristics		
Number of members per bedroom		
<2	REF	
2	1.04	(1.00, 1.09)
>2	1.07	(1.05, 1.09)
Bathrooms with direct water discharge		
No	REF	
Yes	1.01	(0.97, 1.05)
Shared bathrooms with other households		
No	REF	
Yes	0.95	(0.89, 1.02)
Open windows		
No	REF	
Yes	0.94	(0.92, 0.97)
Piped water		
No	REF	
Yes	1.04	(0.94, 1.15)

SARS-CoV-2: severe acute respiratory syndrome coronavirus 2: Ensanut: *Encuesta Nacional de Salud y Nutrición*; Covid-19: coronavirus disease 2019; IRR: incidence rate ratio; CI: confidence intervals.
*Adjusted for socioeconomic level (low, medium, and high) and region (Pacific-North, Border, Pacific-Center, Center-North, Center, Mexico City, State of Mexico, South Pacific, and Peninsula), and sampling design variables. The model includes fixed-effect on household size.
Source: Ensanut 2020 Covid-19.[5]

needed to confirm our results, our analysis provides a first assessment of the potential role of familial composition and housing characteristics in SARS-CoV-2 infection.

Home confinement is a useful tool for disease transmission control. Yet, structural conditions in low- and middle-income countries could decrease its effectiveness. In our analysis, multigenerational and crowded households seemed to be at higher risk of infection. Our findings reiterate the importance of safe isolation at home in well-ventilated rooms, which may not be possible for an important proportion of the Mexican population. Given the structural limitations of families in our country, voluntary isolation centers should be made available, especially for multigenerational and crowded households.[6]

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Declaration of conflict of interests. The authors declare that they have no conflict of interests.

References

1. Diario Oficial de la Federación. Acuerdo por el que se establecen las medidas preventivas que se deberán implementar para la mitigación y control de los riesgos para la salud que implica la enfermedad por el virus SARS-CoV2 (COVID-19) [Internet]. Mexico City: Secretaría de Gobernación, 2020 [cited May 6, 2021]. Available from: https://www.dof.gob.mx/nota_detalle.php?codigo=5590339&fecha=24/03/2020
2. Lazcano-Ponce E, Alpuche-Aranda C. Alfabetización en salud pública ante la emergencia de la pandemia por Covid-19. Salud Publica Mex. 2020;62:331-40. https://doi.org/10.21149/11408
3. Félix-Arellano EE, Schilmann A, Hurtado-Díaz M, Texcalac-Sangrador JL, Riojas-Rodríguez H. Revisión rápida: contaminación del aire y morbimortalidad por Covid-19. Salud Publica Mex. 2020;62:582-9. https://doi.org/10.21149/11481
4. Gobierno de México, Conacyt. Índice de movilidad. Mexico City: Conacyt, 2021 [cited May 11, 2021]. Available from: https://coronavirus.conacyt.mx/visualizaciones/nacionales/#indice-de-movilidad
5. Shama-Levy T, Gómez Acosta LM, Mundo Rosas V, Lucia CN, Gaona Pineda EB, Avila Arcos MA, *et al*. ENSARS-COV-2. Resultados de la evaluación basal de la encuesta nacional de las características de la población durante la pandemia de covid-19. Cuernavaca: INSP, 2020 [cited May 22, 2021]. Available from: https://www.insp.mx/avisos/5463-resultados-encuesta-ensars-coronavirus-ensanut.html?fbclid=IwAR0UurRQVmG6Upnej3DSPoXZvXdmZmOsEZTC5gEozrj51aNSm2RMCJmABFQ
6. Pérez-Ferrer C, López-Olmedo N, Bautista-Arredondo S, Colchero MA, Stern D, Zepeda-Tello R, *et al*. Ciclos de trabajo-confinamiento para reducir la transmisión de Covid-19: evidencia y recomendaciones en elcontexto de México. Salud Publica Mex. 2021;63(2):314-31. https://doi.org/10.21149/12105
7. Madewell ZJ, Yang Y, Longini IMJ, Halloran ME, Dean NE. Household transmission of SARS-CoV-2: a systematic review and meta-analysis. JAMA Netw open. 2020;3(12):e2031756. https://doi.org/10.1001/jamanetworkopen.2020.31756
8. Dutta S, Kaur RJ, Bhardwaj P, Charan J, Bist SKS, Detha MD, *et al*. Household transmission of COVID-19: a cross-sectional study. Infect Drug Resist. 2020;13:4637-42. https://doi.org/10.2147/IDR.S285446
9. Lewis NM, Chu VT, Ye D, Conners EE, Gharpure R, Laws RL, *et al*. Household transmission of SARS-CoV-2 in the United States. Clin Infect Dis. 2020;ciaa1166. https://doi.org/10.1093/cid/ciaa1166
10. Romero-Martínez M, Barrientos-Gutiérrez T, Cuevas-Nasu L, Bautista-Arredondo S, Colchero A, Gaona B, *et al*. Metolodología Encuesta Nacional de Salud y Nutrición 2020 sobre Covid-19. Salud Publica Mex. 2021;63(3):444-451. https://doi.org/10.21149/12580
11. Li F, Li Y-Y, Liu M-J, Fang L-Q, Dean NE, Wong GWK, *et al*. Household transmission of SARS-CoV-2 and risk factors for susceptibility and infectivity in Wuhan: a retrospective observational study. Lancet Infect Dis. 2021;21(5):617-28. https://doi.org/10.1016/S1473-3099(20)30981-6
12. Morawska L, Tang JW, Bahnfleth W, Bluyssen PM, Boerstra A, Buonanno G, *et al*. How can airborne transmission of COVID-19 indoors be minimised? Environment international. 2020;142:105832. https://doi.org/10.1016/j.envint.2020.105832
13. Shamah-Levy T, Mejía-Rodríguez F, Méndez Gómez-Humarán I, De la Cruz-Góngora V, Mundo-Rosas V, Villalpando-Hernández S. Trend in the prevalence of anemia in Mexican women of childbearing age from 2006-2016. Ensanut MC 2016. Salud Publica Mex. 2018;60(3):301-8. https://doi.org/10.21149/8820
14. López-Olmedo N, Stern D, Canto-Osorio F, Barrientos-Guitérrez T, Alpuche-Aranda C. Supplementary Table 1: Family and household characteristics and SARS-CoV-2. Figshare, 2021 [cited September 14, 2021]. https://doi.org/10.6084/m9.figshare.16620415.v2
15. Mansournia MA, Nazemipour M, Naimi AI, Collins GS, Campbell MJ. Reflection on modern methods: demystifying robust standard errors for epidemiologists. Int J Epidemiol. 2021;50(1):346-51. https://doi.org/10.1093/ije/dyaa260
16. Yelland LN, Salter AB, Ryan P. Performance of the modified Poisson regression approach for estimating relative risks from clustered prospective data. Am J Epidemiol. 2011;174(8):984-92. https://doi.org/10.1093/aje/kwr183
17. Stern D, Lajous M, De la Rosa B, Goldstein E. On the increasing role of older adolescents and younger adults during the SARS-CoV- 2 epidemic in Mexico. Salud Publica Mex. 2021;63(3):422-8. https://doi.org/10.21149/11817
18. Instituto Nacional de Estadística y Geografía. Viviendas particulares habitadas 2017. Mexico City: INEGI, 2018 [cited May 11, 2021]. Available from: https://www.inegi.org.mx/contenidos/saladeprensa/boletines/2018/EstSociodemo/enh2018_05.pdf
19. Instituto Nacional de Estadística y Geografía. Comunicado de prensa num. 251/18: Encuesta Nacional de Hogares 2017. Mexico City: INEGI, 2018 [cited May 11, 2021]. Available from: https://www.inegi.org.mx/temas/vivienda/