ORIGINAL RESEARCH ARTICLE

Investigating the Relationship Between Environmental and Quantitative Housing Indicators and the COVID-19 Infection Rate: A Cross-Sectional Study in Urmia

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Abstract

Background Economic and social conditions, housing characteristics, and neighborhood environments substantially influence the spread of COVID-19. This study examined the relationship between environmental and quantitative housing indicators and COVID-19 infection among households in Urmia.

Methods This cross-sectional, descriptive-analytical study included individuals diagnosed with COVID-19 in 2020. Using Cochran's formula, 420 participants were randomly selected from approximately 35,000 hospitalized patients, and Moran's analysis was applied to confirm the randomness of the sample. Data sources included a demographic checklist, housing and environmental indicators, 2016 national census data, and Urmia's detailed urban development plan. Data were analyzed using SPSS, version 25.

Results Of the assessed residential units, 71% (n=298) had infection rates above 50%. COVID-19 infection was inversely associated with access to green space (p=0.025), indicating that households with greater proximity to green areas experienced lower infection rates. The regression model accounted for 32.4% of the variance in infection rates, with household crowding (t=7.279) and access to green space (t=−2.116) showing the strongest effects.

Conclusion Housing conditions play a significant role in the transmission of COVID-19. Improving safety standards in contemporary built environments may help mitigate the spread of infectious diseases. Urban planning and design policies should incorporate these findings to reduce infection rates and mortality during pandemics.

Keywords COVID-19, Environmental exposure, Housing, Iran, Urban health

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1 Introduction

In recent decades, the frequency of globally significant epidemics has increased, posing substantial threats to human health and social systems.[1-4] Coronavirus disease is a highly transmissible infectious condition[5] with a high reproductive rate that facilitates rapid spread.[6] Its widespread transmission has profoundly affected healthcare systems, economic structures, and social relationships.[4,7] The number of confirmed COVID-19 cases varies across countries, cities, and demographic groups.[8] As of January 2024, approximately 700 million confirmed cases and more than 7 million deaths have been reported worldwide. In Iran, over 7.6 million confirmed cases and more than 146,000 deaths have been recorded.[9]

Cities are particularly vulnerable to infectious diseases.[10] They accommodate the majority of the global population; since 2007, more than half of the world's population has lived in urban areas, and this figure is projected to reach 68% by 2050.[11] As dense population centers and hubs of travel and employment,[12] cities are susceptible to a range of stressors, including natural and human-made disasters.[13] Their high population density and reliance on public transportation create conditions conducive to the rapid transmission of infectious diseases.[14] During the COVID-19 pandemic, urban areas were the initial hotspots of transmission.[15] Thus, the COVID-19 pandemic can be regarded as an urban event, presenting major challenges for urban management and planning.[12] The pandemic also served as a critical test of how cities manage, plan, and adapt under high transmission risks.[16] In many countries, COVID-19 has temporarily reshaped urban environments and shifted perspectives on urban health. [16,17] Therefore, urban structures should be considered in epidemiological studies of COVID-19. [10]

COVID-19 remains characterized by many uncertainties.[18] As countries continue to confront the virus, researchers are working to identify its underlying spatial and epidemiological patterns and address unresolved questions.[19] The complexity of COVID-19 necessitates an interdisciplinary approach, with geography playing a central role by examining environmental factors and spatial patterns.[20] Geographical analysis of disease and healthcare focuses on the spatial distribution of diseases influenced by physical, environmental, social, economic, and cultural factors.[21] Growing evidence indicates that residential living conditions, socioeconomic factors, neighborhood characteristics, and household crowding significantly affect pandemic outcomes.[19] In New York City, a temporal analysis of COVID-19 cases showed that among income, occupation, race, gender, and household size, occupation had the strongest association with disease transmission.[20] Beyond sociodemographic and built environment factors, housing policies and conditions have also played a pivotal role in shaping pandemic impacts.[22] Housing is a fundamental component of urban environments,[23] and the COVID-19 pandemic posed multiple challenges related to housing.[24] Housing conditions have been shown to influence both the spread of pandemics and the effectiveness of response measures.[22]

Quantitative housing characteristics are important considerations in housing planning and are assessed through indicators such as household density per residential unit, individual density per unit, residential floor area, and number of rooms per unit[25] Given the role of cities, particularly housing, in COVID-19 transmission, this study aimed to examine the relationship between environmental and quantitative housing indicators and the COVID-19 infection rate among families in Urmia in 2020. These indicators may reflect crowding and neighborhood demographic conditions, offering new insights into the influence of socioeconomic and built environment factors on COVID-19 in Iran.

Study Area

Urmia is located in northwestern Iran at 37°32' N latitude and 45°2' E longitude, at an elevation of 1,332 meters above sea level. The city is situated between Lake Urmia and the mountain range along the western border of West Azerbaijan Province (Figure 1). According to the 2016 National Population and Housing Census, Urmia had a population of 736,224 residents living in 225,050 households. Reports from the Department of Urban Planning and Architecture indicate that the city comprises five urban districts, 15 sub-districts, and 66 neighborhoods. The first confirmed COVID-19 case in Urmia was identified on February 26, 2020, in a 55-year-old man with a travel history to Qom, the initial epicenter of the outbreak in Iran. Data from Urmia University of Medical Sciences indicate that more than 35,000 individuals were hospitalized due to COVID-19 in Imam Khomeini and Taleghani hospitals during 2020.

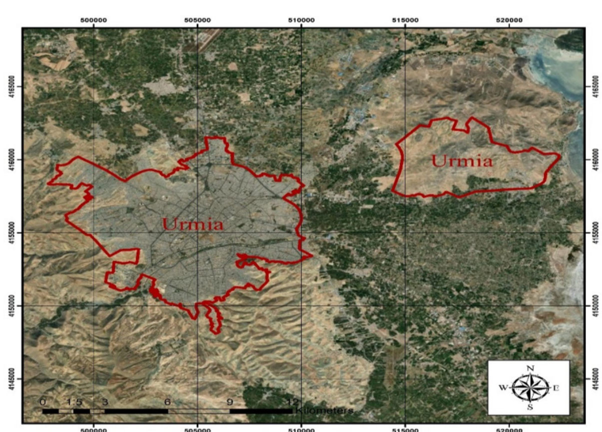

Figure 1 Map of Urmia city

2 Methods

This study employed a cross-sectional, descriptive-analytical design. The study population comprised individuals diagnosed with COVID-19 in 2020. Eligibility criteria included confirmed COVID-19 infection, residency in Urmia, and willingness to participate in the study. Using Cochran's formula, a minimum sample size of 380 was estimated from approximately 35,000 COVID-19 patients hospitalized at Imam Khomeini and Taleghani hospitals in Urmia during 2020. To increase the reliability and statistical power of the study, 420 participants were randomly selected.

$$n = \frac{\frac{z^2pq}{d^2}}{1+\frac{1}{N}\left(\frac{z^2pq}{d^2}-1\right)} = \frac{\frac{(1.96)^2 \times (0.5\times 0.5)}{(0.05)^2}}{1+\frac{1}{35000}\left(\frac{(1.96)^2\times(0.5\times0.5)}{(0.05)^2}-1\right)} = \frac{384}{1.01094} \cong 380$$

To verify the spatial randomness of the selected sample, Moran's I statistic was calculated using the geographic coordinates of participants' residences. The analysis showed no significant spatial autocorrelation (Moran's I = 0.023, p > 0.05), confirming that the sample was randomly and spatially independent (Figure 2).

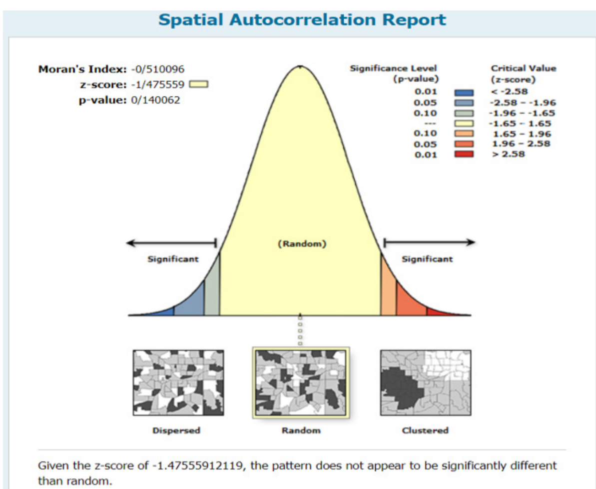

Figure 2 Results of Moran's Analysis

In this study, the dependent variable was the COVID-19 infection rate in Urmia in 2020. The independent variables included quantitative housing indicators (five variables) and environmental indicators (four variables). The quantitative housing indicators comprised the number of rooms per housing unit, the number of people per room, housing unit area, the number of residents per housing unit, and the number of households per housing unit. The environmental indicators included population density, number of building floors, building density, and access to green space.

Access to green space was defined as the mean Euclidean distance (in meters) from each participant's residence to the nearest public park, calculated using the Near tool in ArcGIS. Building density was measured as the total built-up area per hectare within each census block, extracted from municipal GIS databases.

Data were collected through telephone interviews, the 2016 Population Statistical Blocks, and the detailed urban development plan of Urmia. A structured checklist was used to record demographic characteristics, environmental indicators, and housing indicators.

Pearson's correlation coefficient was used to assess the direction and strength of associations between variables. Multiple regression analysis was performed in SPSS-25 to identify and predict relationships between the independent variables and the infection rate. Additionally, the proximity of participants' residences to the nearest green space was calculated in ArcGIS using the Near analysis tool.

3 Results

The findings showed that 298 participants (71%) reported an infection rate greater than 50% within their residential unit. In other words, more than half of the household members living in the same dwelling as the index COVID-19 case were also infected. Descriptive statistics for the qualitative and quantitative study variables are presented in Table 1 and Table 2.

Table 1 Description of Qualitative Study Variables

Variables	Categories	Frequency	Percentage (%)
Infection rate in the residential unit	Below 50%	122	29.0
	Above 50%	298	71.0
Number of building floors	1 or 2 floors	248	59.1
	3 or 4 floors	106	25.2
	5 floors and above	66	15.7
Housing unit area (m²)	Less than 75	30	7.1
	76 to 100	90	21.4
	101 to 120	70	16.7
	More than 120	230	54.8
Number of residents per housing unit	Less than 2	60	14.3
	3	122	29.0
	4	180	42.9
	5 and more	58	13.8
Access to green space	Less than 100	50	11.9
	101 to 200	76	18.1
	201 to 300	84	20.0
	301 to 400	66	15.7
	401 to 500	46	11.0
	More than 500	92	21.9

Table 2 Description of Quantitative Study Variables

Variables	Minimum	Maximum	Mean	Standard Deviation
Number of rooms per housing unit	0	4	2.23	0.74
Number of households per housing unit	1	2	1.07	0.25
Number of people per room	0	8	1.82	1.05
Building density	60	420	152.67	83.75
Population density	24	886	208.09	106.16

To assess the relationships between the independent variables and the infection rate, the infection rate was calculated for each residential unit based on the number of infected individuals relative to the total number of residents. Pearson correlation analysis showed that the infection rate exhibited a statistically significant association only with access to green space (r = –0.154, p = 0.025), indicating that residential units with greater access to green space had lower infection rates. No significant correlations were found between the infection rate and other variables, including the number of rooms, building floors, housing unit area, number of households per unit, building density, population density, or number of people per room (Table 3).

Linear regression analysis using the Enter method was conducted to evaluate the effect of each independent variable on the dependent variable while controlling for confounding factors. Prior to modeling, all regression assumptions were assessed. The Durbin–Watson statistic was 1.98, indicating no autocorrelation among residuals. Multicollinearity diagnostics showed that the variable "number of building floors" exceeded the acceptable threshold and was therefore removed. The remaining variables demonstrated no multicollinearity based on the Variance Inflation Factor (VIF). Using the number of individuals infected with COVID-19 as the dependent variable, the model yielded an R-squared of 0.346 and an adjusted R-squared of 0.324, indicating

Table 3 Pearson Correlation Test Results

Variables	Statistical Test	Infection Rate	Number of Rooms per Housing Unit	Number of Building Floors	Housing Unit Area	Number of Households per Housing Unit	Access to Green Space	Building Density	Population Density	Number of People per Room	Number of Infected Individuals
Infection Rate	Pearson	1	-	-	-	-	-	-	-	-	-
	p-value	-	-	-	-	-	-	-	-	-	-
Number of Rooms per Housing Unit	Pearson	-0.004	1	-	-	-	-	-	-	-	-
	p-value	0.958	-	-	-	-	-	-	-	-	-
Number of Building Floors	Pearson	0.25	0.165	1	-	-	-	-	-	-	-
	p-value	0.717	0.017	-	-	-	-	-	-	-	-
Housing Unit Area	Pearson	-0.052	0.388	-0.011	1	-	-	-	-	-	-
	p-value	0.456	0.000	0.869	-	-	-	-	-	-	-
Number of Households per Housing Unit	Pearson	-0.026	-0.033	-0.096	-0.024	1	-	-	-	-	-
	p-value	0.708	0.639	0.164	0.729	-	-	-	-	-	-
Access to Green Space	Pearson	-0.154	-0.091	-0.012	0.133	0.023	1	-	-	-	-
	p-value	0.025	0.189	0.860	0.05	0.743	-	-	-	-	-
Building Density	Pearson	0.008	0.203	0.908	0.013	-0.100	0.026	1	-	-	-
	p-value	0.905	0.003	0.000	0.851	0.149	0.703	-	-	-	-
Population Density	Pearson	-0.038	-0.123	-0.139	-0.088	-0.037	0.086	-0.124	1	-	-
	p-value	0.583	0.075	0.044	0.204	0.594	0.216	0.074	-	-	-
Number of People per Room	Pearson	-0.120	-0.586	-0.193	-0.059	0.295	0.073	-0.231	0.092	1	-
	p-value	0.083	0.001	0.005	0.393	0.001	0.291	0.001	0.184	-	-
Number of Infected Individuals	Pearson	-	-0.060	-0.042	0.181	0.192	0.010	-0.083	-0.030	0.577	1
	p-value	-	0.389	0.541	0.009	0.005	0.147	0.210	0.663	0.001	-

that approximately 32.4% of the variation in the number of infected individuals could be explained by the independent variables. The ANOVA results showed a significant regression model ($F = 15.28$, $p = 0.001$), confirming that the set of predictors collectively contributed to explaining the variance in the dependent variable (Table 4).

Table 4 ANOVA Analysis

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	124.976	7	17.854	15.278	0.001
Residual	236.052	202	1.169		
Total	361.029	209	-		

Independent variables: Number of people per room, number of rooms per housing unit, housing unit area, number of households per housing unit, access to green space, building density, population density.
Dependent variable: Number of individuals infected with COVID-19 in the residential unit.

Based on the regression coefficients and the estimated regression equation, the variables number of residents per housing unit (β = 7.279) and access to green space (β = –2.116) demonstrated the strongest effects on predicting the number of infected individuals within each residential unit (Table 5). Specifically, an increase in the number of residents per unit was associated with a significant rise in infection count, while greater access to green space showed a protective effect, reducing the number of infected individuals.

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4 Discussion

Cities have long been the primary centers of human settlement and are inherently vulnerable to the spread and outbreak of infectious diseases. The COVID-19 pandemic, as the most recent global health crisis, substantially affected numerous aspects of urban life. Housing, as a core urban function, plays a pivotal role in shaping the structural, economic, sociocultural, and environmental dimensions of a city. Residential environments create conditions conducive to the transmission of infectious diseases, particularly due to close social interactions within households and the prevalence of overcrowded living spaces. Households represent the initial and often most intense locus of viral transmission. However, neighborhood-level evidence on exposure risks has been inconsistent across geographic settings, with specific factors influencing infection rates in some regions but not in others.[10,26,27] This study investigated the relationship between environmental and housing indicators and the COVID-19 infection rate in Urmia in 2020.

The findings demonstrated that households with a larger number of residents were at substantially higher risk of COVID-19 infection, and the number of residents per housing unit emerged as the strongest predictor of transmission. This association must be interpreted with caution because household size inherently affects the number of infected individuals. Nevertheless, our results align with previous research. Ahmad et al. (2020) found that overcrowding was the primary predictor of COVID-19–related deaths in the United States[28] ,Similarly, Lee et al. (2021) and Hu et al. (2021) reported that crowded housing conditions were strongly linked to higher infection and mortality rates.[10,26] Villela (2021) also demonstrated a significant association between household overcrowding (people per room) and COVID-19 spread, particularly in cities with high-density living conditions.[29] Given that most housing units typically include only two rooms, and considering the negative correlation observed between housing area and the number of people per room, it is likely that increased crowding within rooms substantially elevates transmission risk. These findings underscore the critical importance of housing quality and spatial adequacy when developing preventive strategies during pandemics.

The pandemic also altered human interactions with urban green spaces. In this study, better access to green space was associated with a lower likelihood of infection. This is consistent with the findings of Lee et al. (2021), who

Table 5 Regression Coefficients for Model Variables

Dependent Variable: Number of Infected Individuals	Unstandardized Coefficients	Standardized Coefficients (Beta)	t	Sig.
-	B	SE	-	-
Constant	0.296	0.459	-	0.644
Number of People per Room	-0.024	0.097	-0.019	-0.249
Access to Green Space	-0.006	0.003	0.148	-2.116
Number of Rooms per Housing Unit	0.194	2.885	0.005	0.067
Housing Unit Area	0.001	0.001	-0.007	-0.103
Number of Residents per Housing Unit	0.672	0.092	0.585	7.279
Number of Households per Housing Unit	0.101	0.318	0.019	0.315
Building Density	0.007	0.001	-0.012	-0.210
Population Density	0.000	0.006	-0.010	-0.176

observed that COVID-19 incidence and mortality were lower in greener areas.[10] Kwok et al. (2021) similarly reported that urban geometry, including access to green space, influenced COVID-19 incidence in Hong Kong.[30] Additional studies have confirmed the role of green spaces in reducing infection risk and supporting broader physical and mental health outcomes.[15,31,32] Time spent outdoors typically poses a lower risk of transmission compared with indoor activities due to improved ventilation and lower viral persistence. Moreover, green spaces contribute to psychological well-being, physical activity, and social cohesion. However, maintaining hygiene and safety measures, such as disinfecting surfaces and preventing crowding, remains essential to minimizing infection risk during pandemics.

This study had several limitations, including limited participant cooperation and challenges posed by fear of contracting or transmitting COVID-19, which affected data collection. Nonetheless, a major strength of the study lies in its novelty. To the best of our knowledge, no prior research in Iran has comprehensively examined the role of environmental and housing indicators in COVID-19 infection rates, making this study one of the first in the country to address this gap. Because the study was conducted in Urmia under the specific conditions of the 2020 COVID-19 outbreak, the findings should be interpreted cautiously when generalizing to other settings or future epidemic phases with different environmental or socioeconomic contexts.

5 Conclusion

The COVID-19 pandemic has underscored the critical need for cities to learn from past public health crises and to enhance the resilience of their built environments. As the post-pandemic era reshapes urban life, affecting values, lifestyles, and spatial behaviors, strengthening the safety and adaptability of urban spaces becomes essential for reducing the risk of infectious disease transmission.

The findings of this study, which demonstrate significant associations between overcrowded housing conditions, access to green spaces, and COVID-19 infection rates, highlight the importance of integrating public health considerations into urban planning and housing policy. Reducing household overcrowding through revised housing regulations, expanding neighborhood green spaces, and updating per-capita green space standards are crucial steps for improving community health.

Furthermore, incorporating environmental health principles into urban development can help build more resilient cities. Urban planners should adopt adaptive zoning strategies, promote affordable and adequate housing, and embed pandemic risk assessments into future planning frameworks. Such measures can play a pivotal role in mitigating infection risks, reducing mortality, and enhancing preparedness for future outbreaks.

Declarations

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Artificial Intelligence Disclosure
The writing of this article, including its design, implementation, analysis, and reporting, was carried out without the use of artificial intelligence. AI (ChatGPT) was used only for editing and translating responses to the reviewers' comments.

Authors' Contributions
F. Dargahi and R. Hosseini conceived and designed the study, analyzed and interpreted the data, and contributed to manuscript writing. A. Jamili participated in data analysis, interpretation, and manuscript preparation. M. Rafieian and K. Skhaeian contributed to study conception, design, and manuscript writing. H. Pirnejad conducted the experiments, contributed required materials, and assisted in writing the manuscript. All authors reviewed and approved the final version of the manuscript.

Availability of Data and Materials
The data supporting the findings of this study are held by Urmia University of Medical Sciences. Due to institutional restrictions and licensing conditions, these data are not publicly available. However, they can be obtained from the corresponding author upon reasonable request and with permission from Urmia University of Medical Sciences.

Conflict of Interest
The authors declare no known financial or personal conflicts of interest that could have influenced the conduct, analysis, or reporting of this study.

Consent for Publication
Not applicable.

Ethical Considerations
The study adhered to all ethical requirements. Ethical approval was obtained from the Ethics Committee of Urmia University of Medical Sciences (IR.UMSU.REC.1400.171), along with authorization to conduct field research. Participants were informed about the study objectives and procedures and were assured that all personal information, including names and residential addresses, would remain confidential. Verbal informed consent was obtained before conducting telephone interviews, in accordance with national COVID-19 ethical guidelines. Participants were informed of their right to withdraw from the study at any time.

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