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Impact of Unqualified Housing on Childhood Pneumonia: A Spatial Study in Urban and Rural of Bojonegoro, Indonesia

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ABSTRACT

Unhealthy housing poses significant risks for children's respiratory health, such as pneumonia. Indoor and outdoor environmental factors can vary between urban and rural areas. Spatial vulnerability mapping is a potential tool for developing an early warning system for policymaking in pneumonia control. The purpose of this study was to determine the spatial vulnerability of unqualified housing factors among childhood pneumonia in both urban and rural areas of Bojonegoro, Indonesia. This study employed a cross-sectional design with spatial analysis to determine the correlation and distribution map of eight housing factors of childhood pneumonia in comparison between urban and rural areas. 60 mothers of under-five children as samples for interview and housing factors assessment. Six (54.5%) and four (28.6%) villages had high prevalence cases in urban and rural areas, respectively. Concentrated in the city center and home industries of Bojonegoro sub-district, then livestock and agriculture area of Sukosewu sub-district. Humidity in urban (P=0.03; PR=16.50) and rural (P=0.04; PR=12.60), lighting in urban (P=0.01; PR=23.00) and rural (P=0.04; PR=12.60), house occupancy density in urban and rural (P=0.04; PR=12.60), and ventilation area in rural (P=0.03; PR=25.00) were correlated to childhood pneumonia. Six urban and four rural villages exhibited a high prevalence of pneumonia cases. Unqualified humidity, lighting, house occupancy density, and ventilation area impact childhood pneumonia. It is recommended to improve natural or mechanical housing ventilation, adjust the total housing occupants, and update national healthy housing standards. The use of spatial analysis effectively identified housing-related risk factors for pneumonia, providing critical insights for developing targeted interventions in Bojonegoro.

Keywords: Childhood, Housing, Pneumonia, Spatial

INTRODUCTION

Pneumonia remains a major global health challenge and continues to be the leading cause of death among toddlers worldwide. This acute infection targets lung tissue, particularly the alveoli, and is caused by a variety of bacteria, viruses, and fungi, including Streptococcus pneumoniae and Haemophilus influenzae bacteria. The coverage of childhood pneumonia in Indonesia in 2022 reached 38.78%, where East Java Province was runner-up with a case coverage of 63.9% (Kemenkes RI, 2023). The high coverage of pneumonia cases in Bojonegoro Regency is a cause for concern. The percentage of childhood pneumonia cases in Bojonegoro has increased, reaching 4,316 toddlers (78.6%) from 2018 to 2022. In 2022, 155 cases (4.8%) were reported in the urban area of Bojonegoro sub-district and 182 cases (7%) in the rural area of Sukosewu sub-district. This data highlights the urgent need for targeted interventions to address this issue (Dinkes Bojonegoro, 2023).

The condition of the home environment presents substantial risks for respiratory illnesses across four categories: outdoor air pollution, indoor pollution, non-structural home factors, and structural home factors. Factors such as inadequate ventilation, use of wood or coal for cooking, lack of air filtration in urban areas, exposure to cigarette smoke, and damp or overcrowding house significantly impact respiratory health, particularly in under-five children, leading to conditions like pneumonia (Hasanah et al., 2021; Meng et al., 2021; Wimalasena et al., 2021; Wu et al., 2020). Bojonegoro is facing a critical issue with 155,142 houses (40.6%) failing to meet national health standards. This requires urgent attention to ensure the well-being of the community (Dinkes Bojonegoro, 2023).

Spatial analysis using Geographic Information System (GIS) is part of a modern epidemiological study in area-based disease management that helps to describe disease mapping related to demographic, socio-economic, and even environmental factors such as river flow, humidity, temperature, rainfall, elevation and others (Achmadi, 2014). The mapping results can be developed into an Early Warning System (EWS) as a basis for policymaking in disease control. Conducting monthly case predictions with graphic visualization, description of case alert categories with color maps and even providing emergency call centers. Generally, these have been widely developed and used by the government for endemic cases of dengue fever (Auliyah & Lazuardi, 2021).

A vulnerability mapping study on toddler pneumonia was previously carried out in Bojonegoro. The study used a spatial approach employing the hybrid genetic algorithm K-means (GA-Kmeans) to cluster risk factors such as the number of toddlers, estimated number of sufferers, actual number of sufferers, nutritional status, and environmental factors. The results classified pneumonia vulnerability in each sub-district as low, medium, or high. The study found high vulnerability in 10 sub-districts, including Bojonegoro sub-district (Fariza et al., 2018). A spatial study on toddler pneumonia in Pelalawan, Riau Province analyzed individual, environmental, and behavioral factors using Geographically Weighted Logistic Regression (GWLR) (Harnani et al., 2020).

The cases of pneumonia at the Bergas Health Center in Semarang were found to be clustered and were influenced by the proximity of a 2-kilometer buffer zone from industrial areas, infrequent opening of windows, unhealthy living conditions, and the presence of smoking in households (Utami, 2020). The purpose of this study was to determine the spatial vulnerability of unqualified housing factors among childhood pneumonia in both urban and rural areas of Bojonegoro, Indonesia.

RESEARCH METHODS

This study is an ecological study design and a cross-sectional approach. The study's independent variables include housing factors such as ventilation area, wall type, floor type, humidity, lighting, house occupancy density, use of cooking fuel, and use of mosquito coils. The dependent variable is the distribution of childhood pneumonia cases in Bojonegoro.

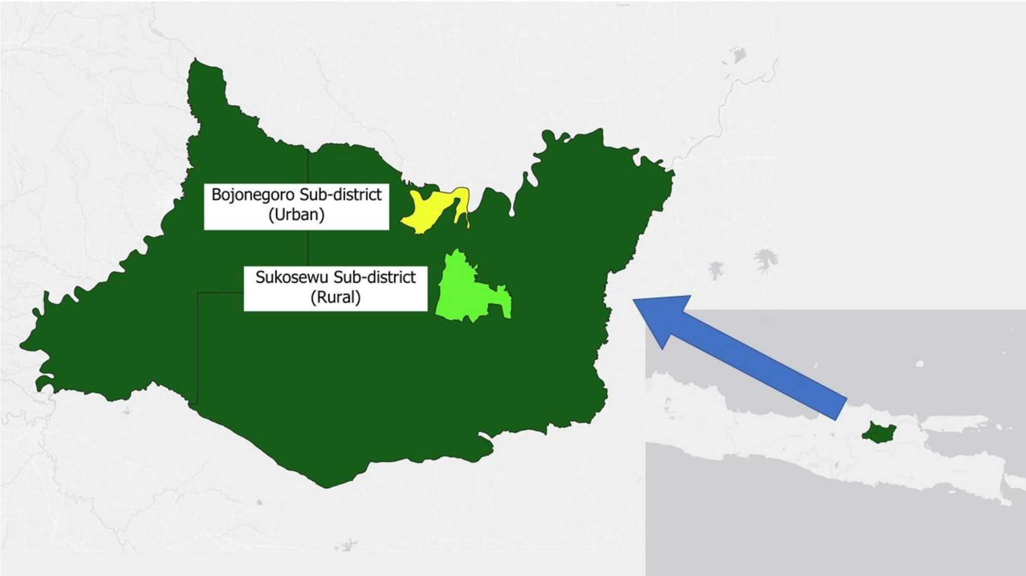

Figure 1. Map of study area

The study was carried out in Bojonegoro District, focusing on the Bojonegoro Health Center area as an urban representation and the Sukosewu Health Center area as a rural representation, as depicted in Figure 1. The sample consisted of a total of 60 under-five children from both urban and rural areas, with an equal 1:1 ratio, and the interviews were conducted with the mothers or caregivers of children. Sampling technique used simple random sampling and lottery techniques, with case criteria from the list of toddler pneumonia patients at the health center whose names came out in the lottery and the controls were neighbors of the cases who were non-pneumonia.

Secondary data collection involved obtaining aggregate data on cases per village during 2022 from the Health Center Control Program Report. Primary data collection methods include interviews, observations, and direct measurements of eight housing factors recorded in the questionnaire sheet and informed consent as ethical clearance. Housing ventilation area and floor area were measured using a roll meter, while housing temperature and humidity were measured using a Thermohygrometer. Housing lighting was measured using a digital Luxmeter.

Eight housing factors are modified based on national healthy housing standards in Indonesian Ministry of Health Regulation No. 1077/MENKES/PER/V/2011 about Guidelines for Indoor Air Housing. This research achieved ethical approval from the Research Ethics Committee of Universitas Kadiri (No. 031/09/IX/EC/KEP/UNIK/2024).

The analysis of this study includes univariate analysis, bivariate analysis, and spatial analysis comparing urban and rural areas. Univariate analysis was conducted to determine the distribution and frequency of variables, while bivariate analysis aimed to establish the relationship between independent and dependent variables using the chi-square test. Spatial analysis was used to identify the spatial distribution of regional vulnerability to pneumonia using GIS with map overlay techniques, overlaying the childhood pneumonia prevalence map with significant housing factors from the bivariate analysis. Spatial analysis was carried out using QGIS 3.22. The digital map of the administrative area of Bojonegoro Regency was obtained from Geospatial Information Agency website in shapefile (.shp) format.

RESULTS AND DISCUSSION

Spatial mapping was conducted to determine the spatial distribution of childhood pneumonia prevalence cases. Figure 2 shows six (54.5%) and four (28.6%) villages with high prevalence cases in urban and rural areas, respectively. Urban pneumonia cases were found high in Sukorejo, Kalirejo, Ngrowo, Kepatihan, Campurejo villages while Mulyoagung was the highest about 3.87 per 1,000 population. It was concentrated in the city center and home industries as part of Bojonegoro sub-district. Rural pneumonia cases were found high in Jumput, Tegalkodo, Semawot villages while Sidorejo was the highest about 7.29 per 1,000 population. It was densely populated livestock and agriculture area as part of Sukosewu sub-district.

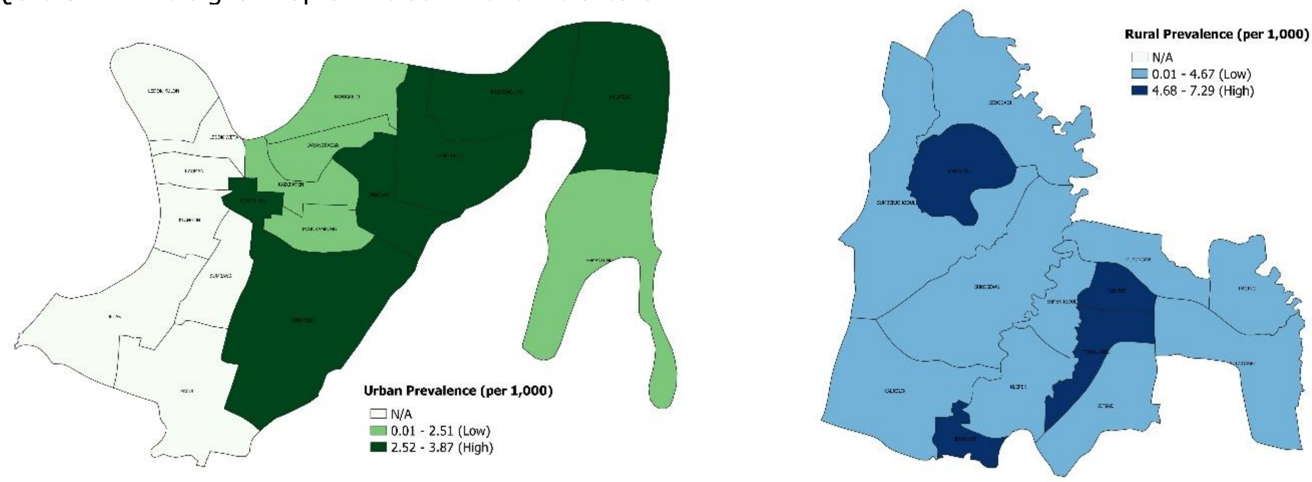

Figure 2. Spatial map of childhood pneumonia prevalence cases in urban (left) and rural (right) areas

Six villages with high prevalence pneumonia cases in urban areas, concentrated in the city center and home industries. The city center generally has population with high industrial activity and transportation mobility, resulting in outdoor air pollution. $PM_{2.5}$, SO_2, and O_3 as air pollutant were associated with increased pneumonia hospitalizations in Qingdao, China (Wang et al., 2022). Meanwhile, four villages with high prevalence pneumonia cases in rural areas located in livestock and agriculture area. Intensive poultry farming is linked to waste materials and NH_3, N_2O, and CH_4 emissions to greenhouse gases. It has significant impacts and threats to environmental footprints and human health. Residents of rural livestock farming areas in United States and Netherlands has increased risk of pneumonia due to air pollution exposure from farming or zoonotic infections (Gržinić et al., 2023; Smit, 2022). The spatial distribution pattern of pneumonia prevalence in Bojonegoro appears random. This is different from spatial pattern of pneumonia cases in Depok and Samarinda which are categorized as clustered using LISA and ANN methods, although poor housing conditions are not an influential risk factor (Rahmadani & Nasriyah, 2022; Yuliawati et al., 2024).

Univariate analysis was conducted to determine the distribution and frequency of variables. Table 1 shows that unqualified housing factors in urban area were ventilation area <10% (66.7%), humidity <40% or >60% (76.7%), lighting <60 lux (80%), overcrowding house (73.3%), and use of mosquito coils (66.7%). Meanwhile, unqualified housing factors in rural area were ventilation area <10% (90%), wooden-made wall type (53.3%), humidity <40% or >60% (73.3%), lighting <60 lux (73.3%), overcrowding house (73.3%), use of cooking fuel (53.3%), and use of mosquito coils (40%).

Table 1
Frequency and distribution of housing factors in urban and rural area

Housing Factors	Urban		Rural	
	n	%	n	%
Ventilation area				

Housing Factors	Urban		Rural	
	n	%	n	%
<10% of floor area	20	66.7	27	90
≥10% of floor area	10	33.3	3	3
Floor type				
Soil	1	3.3	5	16.7
Ceramic, tile	29	96.7	25	83.3
Wall type				
Wood	4	13.3	16	53.3
Brick	26	86.7	14	46.7
Humidity				
<40% or >60%	23	76.7	22	73.3
40-59%	7	23.3	8	26.7
Lighting				
<60 lux	24	80	22	73.3
≥60 lux	6	20	8	26.7
House occupancy density				
<8m2/person	22	73.3	22	73.3
≥8m2/person	8	26.7	8	26.7
Use of cooking fuel				
Firewood	1	3.3	16	53.3
Gas, electric	29	96.7	14	46.7
Use of mosquito coil				
Yes	20	66.7	12	40
No	10	33.3	18	60

Bivariate analysis was conducted to determine the correlation between independent and dependent variables. Table 2 shows significant correlations between humidity (P=0.03; PR=16.50 (1.35-201.29)), lighting (P=0.01; PR=23.00 (1.77-298.44)), house occupancy density (P=0.04; PR=12.60 (1.07–148.12)) and childhood pneumonia in urban area. Comparison to rural area, significant correlations between ventilation area (P=0.03; PR=(1.52–410.86)), humidity (P=0.04; PR=12.60 (1.07-148.12)), lighting (P=0.04; PR=12.60 (1.07-148.12)), house occupancy density (P=0.04; PR=12.60 (1.07–148.12)) and childhood pneumonia.

Table 2

Bivariate analysis of housing factors and childhood pneumonia in urban and rural area

Housing Factors	Urban		Rural	
	P-value	PR (CI: 95%)	P-value	PR (CI: 95%)
Ventilation area	0.58	2.25 (0.26–18.92)	0.03	25.00 (1.52–410.86)
Floor type	1.00	1.16 (1.00–1.34)	1.00	1.19 (1.00–1.41)
Wall type	0.45	0.39 (0.03 –5.07)	0.31	4.09 (0.37–44.78)
Humidity	0.03	16.50 (1.35-201.29)	0.04	12.60 (1.07-148.12)
Lighting	0.01	23.00 (1.77-298.44)	0.04	12.60 (1.07-148.12)
House occupancy density	0.04	12.60 (1.07–148.12)	0.04	12.60 (1.07-148.12)
Use of cooking fuel	1.00	1.16 (1.00-1.34)	0.31	4.09 (0.37– 44.78)
Use of mosquito coil	0.09	8.14 (0.72-91.88)	0.13	1.28 (1.00–1.64)

Figure 3 shows that unqualified housing factors concentrated in areas with high pneumonia vulnerability in urban area. Mulyoagung and Ngrowo villages show high levels of unqualified house occupancy density, humidity, and lighting. Figure 4 shows that unqualified housing factors are found evenly in low and high-prevalence rural area. Semawot, Sidodadi, Klepek, and Kalicilik villages show high levels of unqualified ventilation area, house occupancy density, humidity, and lighting. Vulnerability spatial mapping is based on prevalence of pneumonia cases in urban areas, where darker colors indicate higher vulnerability to pneumonia. Unqualified housing factors are represented by symbols, with larger symbols indicating lower housing quality.

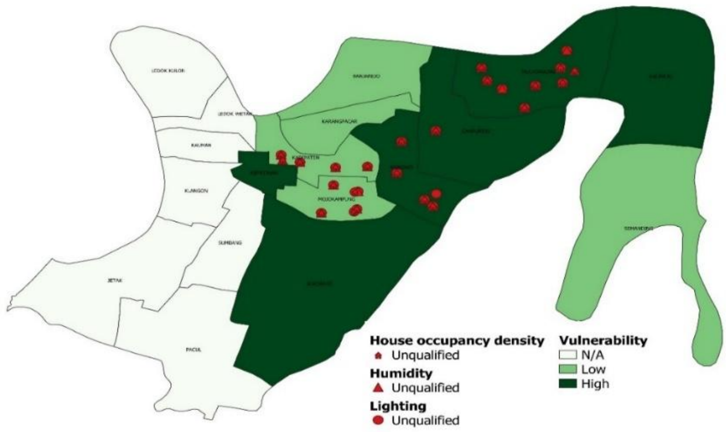

Figure 3. Spatial mapping of humidity, lighting and house occupancy density and childhood pneumonia in urban areas

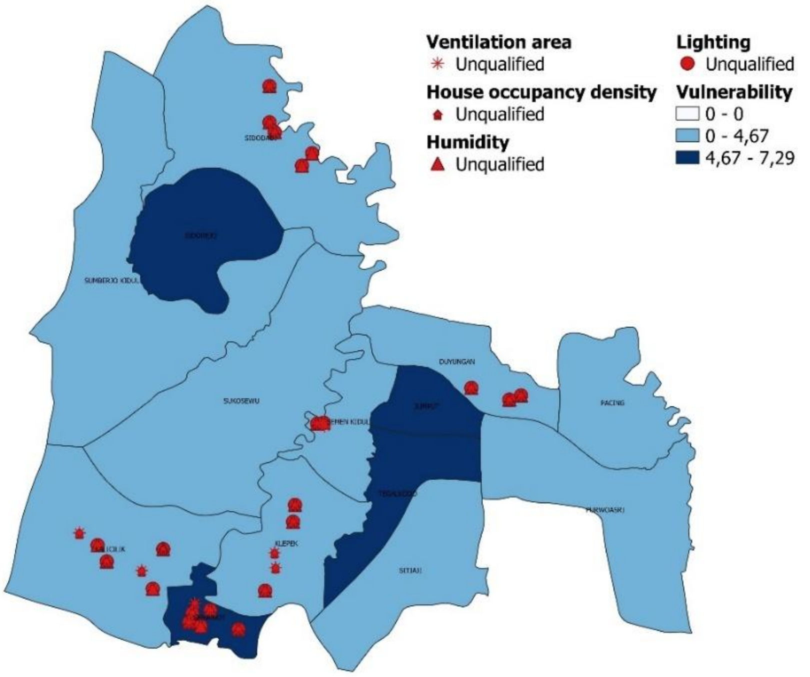

Figure 4. Spatial mapping of ventilation area, humidity, lighting and house occupancy density and childhood pneumonia in rural areas

Humidity was found to be correlated with childhood pneumonia in both urban and rural areas, both statistically and spatially. In addition, the condition of houses that are relatively close to each other in urban area reduces air circulation in the house. High humidity can promote the growth of bacteria and fungi, while low moisture levels can cause respiratory tract irritation. Similar to quality of house humidity, house ventilation and occupancy density are risk factors for pneumonia in slum areas of Palembang City (Rohimawati & Ardillah, 2021). Then in another study area, humidity, light intensity, and density in the house environment affect pneumonia in children <60 months (Prihant et al., 2022). The use of air treatment equipment like air purifiers can help reduce the impact of household dampness on childhood pneumonia among preschoolers. However, the use of air humidifiers and air conditioners may amplify these effects (Liu et al., 2024).

Lighting was found to be correlated with childhood pneumonia in both urban and rural areas, both statistically and spatially. Light exposure affects the dynamic and adaptability Pseudomonas aeruginosa pneumonia-associated isolates. Its pathogenicity potential is influenced by differential production of virulence factors (Mesquita et al., 2021). Homes have both natural and artificial light, which can affect human health. Adequate natural light at home is good for health, protecting against tuberculosis, leprosy, depression, mood, and sleep problems. Sunlight has disinfectant properties, weakening and damaging bacteria, which can help to keep homes healthier. In contrast, using fuel-based lighting at home commonly in LMICs can lead to respiratory diseases because it releases harmful pollutants when burned, especially in homes with poor ventilation (Osibona et al., 2021; Tran et al., 2020).

House occupancy density was found to be correlated with childhood pneumonia in both urban and rural areas, both statistically and spatially. Main risk factors for pneumonia among toddlers in Nganjuk Regency were house cleaning and room occupancy density. Toddlers living in houses with room densities that were unqualified to national standards were 4.191 times more likely to experience pneumonia than those whose room occupancy was qualified (Mirasa et al., 2024). Some children in the family mean overcrowding house condition. Not only the children, but also the elderly or non-nuclear family who live in just one house. Overcrowding can accelerate the transmission of airborne diseases like pneumonia (Umar et al., 2024). The robust linkage between housing crowdedness, ventilation, and neighbourhood conditions in urban areas to infectious respiratory health diseases in Indonesia (Indriyani et al., 2022).

Ventilation area was found to be correlated with childhood pneumonia in rural areas, both statistically and spatially. Fresh and healthy air is essential for house occupants, especially toddlers. In Surabaya, the ventilation-to-area ratio and house lighting were found to be associated with the incidence of pulmonary tuberculosis. This could be attributed to poor integration and awareness of building permit regulations and national health standards (Muhammad et al., 2020). Poor-quality housing features, such as disrepair, poor ventilation, overcrowding, and cold temperatures, lead to poor indoor air quality. Poor ventilation creates moisture and dampness, allowing mold and house dust mites to thrive. Children in rented housing, often from lower-income backgrounds, face serious respiratory health risks due to these substandard living conditions (Holden et al., 2023). Relationships between the environmental condition of houses such as ventilation area, floor type, wall type, and presence of smoke holes towards the incidence of pneumonia in Riau Island also urges to pay attention (Sinaga et al., 2023).

Use of cooking fuel and mosquito coil was observed to respondent's houses, but no significant correlation to pneumonia cases in both urban and rural area. Contrast to study about acute respiratory disease among toddlers in the Koeloda Health Center, East Nusa Tenggara, showed that use of cooking fuel related to incidence of ARI than ventilation area, floor type, and room occupancy density (Bupu et al., 2024). Limited results in association between indoor wood or coal burning exposure and respiratory outcomes in children, such as wheeze, cough, rhinitis and influenza (Guercio et al., 2021). In Brazil, spatial analysis showed that children hospitalized due to community-acquired pneumonia were concentrated in socially vulnerable regions with low income, poor housing conditions, and homelessness, while fewer cases occurred in the more developed and economically privileged areas of the city (Pina et al., 2020).

CONCLUSION

Six urban and four rural villages exhibited a high prevalence of pneumonia cases. Concentrated in the city center and home industries of Bojonegoro sub-district, then livestock and agriculture area of Sukosewu sub-district. Humidity, lighting, and house occupancy density were correlated to childhood pneumonia in urban and rural areas, including inadequate ventilation in rural. It is recommended to improve natural or mechanical housing ventilation, adjust the total housing occupants, and policy update national healthy housing standards. It can be concluded that housing factors are risk factors for childhood pneumonia in Bojonegoro Regency. The use of spatial analysis effectively identified housing-related risk factors for pneumonia, providing critical insights for developing targeted interventions in Bojonegoro. Collaboration between local government and the community is crucial to promoting healthy households.

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AUTHORS' CONTRIBUTION

N.L.S and Y.A.M in study conception; M.H in study design; A.R.P.A.A and E.L.A in data collection. N.L.S, S.N, M.S.A.P, A.R.P.A.A in data analysis and interpretation. N.L.S and M.S.A.P in manuscript preparation. All authors have read and agreed to the published version of the manuscript.

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