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Assessing health impact of COVID-19 and associated household socioeconomic factors in Papua New Guinea: evidence from the Comprehensive Health and Epidemiological Surveillance System

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ABSTRACT

Introduction The COVID-19 pandemic had an unprecedented impact on the health and well-being of populations worldwide. Few studies have used household data to explore the health risks associated with COVID-19 in low-income and middle-income countries. This study assessed population vulnerability to COVID-19 by examining household socioeconomic factors related to COVID-19 health risks in Papua New Guinea (PNG).

Methods Using household socioeconomic surveillance data from 2020, encompassing 37 880 residents living within the catchment areas of the Comprehensive Health and Epidemiological Surveillance System, the study assessed COVID-19 health risks based on the socioeconomic demographic characteristics of the surveillance population. Multinomial logistic regression analyses were conducted to determine associated factors and to estimate predictors of COVID-19 health risks.

Results Among the surveillance population, more than 9% reported experiencing COVID-19 health risks, including home-based quarantine (9.6%), centre-based quarantine (0.5%), positive COVID-19 test (0.1%), hospitalisation due to COVID-19 (0.3%) and death from COVID-19 (0.3%). People living in semimodern houses (OR 1.47 (95% CI 1.35 to 1.61)) (verse permanent houses), individuals living in houses with 1–2 bedrooms (OR 1.12 (95% CI 1.01 to 1.25)) (verse houses with 4+ bedrooms) and those belonging to the poorest wealth quintile (OR 1.16 (95% CI 1.024 to 1.314)) (verse the richest) were more susceptible to COVID-19 health risks. Protective factors against COVID-19 health risks included urban residence (OR 0.65 (95% CI 0.59 to 0.71)) (verse rurality), aged 0–4 years (OR 0.76 (95% CI 0.64 to 0.91)) (verse aged 55+ years), households with 7–8 members (OR 0.84 (95% CI 0.74 to 0.96)) (verse 10+ members), handwashing with soap (OR 0.3 (95% CI 0.28 to 0.33)) (verse without soap).

Conclusions The study provides insights into the susceptibility to COVID-19 health risks across socioeconomic groups in PNG. These findings have implications for development of public health policies and interventions that can be extrapolated to similar settings for enhancing preparedness for future public health emergencies.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ The health risks of the COVID-19 pandemic varied across socioeconomic statuses and demographic groups.

WHAT THIS STUDY ADDS

⇒ The study identifies specific factors associated with COVID-19 and provides valuable insights that can aid in the development of evidence-based public health policies and interventions.

⇒ The study provides information and insight into water, sanitation and hygiene services in Papua New Guinea (PNG).

⇒ The lessons learnt from the fight against the COVID-19 pandemic in PNG can be applied not only to future pandemic responses, but also to strengthen overall public health preparedness and emergency response efforts in similar settings.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ By understanding the factors that contribute to COVID-19 health risks at the household level, policy-makers and public health practitioners can implement targeted strategies to protect vulnerable populations while promoting health equity across the country.

INTRODUCTION

The COVID-19 pandemic is a global outbreak of coronavirus, an infectious disease caused by the SARS-CoV-2. The first cases of novel

coronavirus were first detected in China in December 2019, with the virus spreading rapidly to other countries across the world, leading to the WHO declaration of COVID-19 pandemic on 30 January 2020.[1] The emergency of the COVID-19 pandemic had presented unprecedented challenges to global public health.[1 2]

COVID-19 pandemic and national response

In response, numerous countries in the South Pacific Region swiftly implemented stringent measures, including border closures, travel restrictions, the implementation of social distancing measures and enhanced screening procedures, to contain the spread of the COVID-19.[2] Papua New Guinea (PNG) is the largest nation in the South Pacific region, with a total population of approximately 8 million as of 2020. The country's first reported COVID-19 case was officially recorded in Port Moresby (POM) on 20 March 2020, followed by the detection of the second case in East New Britain (ENB) Province on 6 April 2020.[3] Subsequently, wider spread of COVID-19 was reported in Central Province, Eastern Highlands Province (EHP) and East Sepik Province (ESP).[4] The Southern Region of PNG was hit hardest by the COVID-19 pandemic, followed by the Highlands, the Momase and the Islands regions. From 3 January 2020 to 9 December 2022, 46 427 confirmed cases of COVID-19 infection and 668 deaths were reported to the (WHO) in PNG. By 27 November 2022, the country had administered a total of 502 119 vaccine doses.[1 3] Among the 17 countries in the South Pacific Region, PNG ranked 6th in total accumulated COVID-19 cases, 5th in total accumulated COVID-19 deaths and 17th in total doses of COVID-19 vaccines administered per 100 population (see online supplemental table S1A).[1]

Socioeconomic status (SES), including living standards and housing conditions, plays a fundamental role as a social determinant of health. Public health has long been engaged in addressing living condition-related issues, such as unsafe water, poor sanitation, overcrowding and inadequate ventilation to mitigate the prevalence of infectious diseases, particularly airborne diseases.[5] Housing conditions have far-reaching implications on population health, contributing to a wide range of health issues, from respiratory tract infections and asthma to injuries and mental health challenges. The global impact of the COVID-19 pandemic on health and well-being has been substantial, shedding light on existing social inequities. Marginalised population groups, especially those with low SES, have exhibited heightened vulnerability to the health issues posed by the pandemic.[6 7]

Throughout the COVID-19 pandemic, public health practitioners faced many population health issues. Numerous studies explored the role of housing conditions. For instance, people's living environments offered promising avenues for mitigating the health issues of COVID-19.[8] However, the association between living conditions and health outcomes during the pandemic exhibited variations across age groups and household income levels.[9] Notably, household size emerged as the most influential factor contributing to the significant variation in COVID-19 incidence rates across social groups and the incidence rates were higher among individuals above the age of 65 years and those with incomes below the poverty line.[10]

The COVID-19 pandemic has brought hygiene to the forefront of disease prevention. The provision of water, sanitation and hygiene (WASH) services has become a vital intervention in curbing COVID-19 infections. A systematic review revealed that limited access to WASH services significantly increased the health issues associated with COVID-19.[11] Paradoxically, the pandemic itself has hampered access to WASH services, adversely affecting the overall health of the population. Ensuring the availability of safe and sufficient water, as well as promoting adequate sanitation and hygiene practices, is of paramount importance in safeguarding population health during the COVID-19 pandemic.[12 13]

Access to a water supply that supports adequate hygiene measures remains a significant challenge in many low-income and middle-income countries. The concurrent challenges of inaccessible WASH services and the COVID-19 pandemic have led to devastating problems in many countries. A review of WASH initiatives across 84 countries worldwide during the COVID-19 pandemic indicated that most governments took action to promote access to WASH services for all.[13] Hygiene promotion was widely adopted in 94% of the participating countries. However, support to enhance access to basic WASH services still lagged in 38% of countries, necessitating additional focus, particularly in rural areas.[13] WASH practices demonstrated a profound impact on child health and nutritional status in Bangladesh during the COVID-19 pandemic.[14]

The impact of the COVID-19 pandemic has varied across countries, with responses differing due to differences in available resources. There is a significant gap in our understanding when it comes to how the pandemic specifically affected the health of the population at the household level. Local variation in the household experience of health issues related to the COVID-19 pandemic in PNG has not been well studied. We hypothesise that individuals' vulnerability to COVID-19 health issues is influenced not only by their country's response but also by their household's resources. By examining individual health issues related to COVID-19 infection and their associations with household socioeconomic demographic characteristics, we aim to better understand the pandemic's impact on households, thereby addressing the existing gap in the literature on the health impact of COVID-19 pandemic at the household level in PNG. The findings of this study hold potential benefits for informing national responses to the COVID-19 pandemic and preparing for future health crises. This research contributes valuable insights into understanding the multifaceted impacts of the pandemic and its implications for population health and well-being.

Research objective and research questions

The objective of this study was to assess COVID-19-related health issues and identify associated factors in PNG using household socioeconomic and demographic surveillance data.

The study addressed the following research questions:

- Which social groups are vulnerable to COVID-19 health issues in PNG?
- What are the socioeconomic demographic factors associated with COVID-19 health issues?
- What are the implications of the study's findings for national responses to the prevention and control of the COVID-19 pandemic in PNG?

These research questions target key aspects of COVID-19 health issues, considering the specific context of PNG. By addressing these questions, our study can contribute valuable insights to inform public health strategies and responses against future pandemics.

METHODS

Data source and surveillance setting

Data for this study were obtained from the household socioeconomic data component of the Comprehensive Health and Epidemiological Surveillance System (CHESS). CHESS was developed in PNG from 2018 to 2022 based on the foundation of the Integrated Health and Demographic Surveillance System, which was established during the previous period 2011–2017. As a third-generation population-based surveillance system, CHESS seamlessly integrates household socioeconomic and demographic data with individual morbidity and mortality data in an electronic population database. The detailed methodology and design of CHESS have been previously described in other studies.[15 16]

Figure 1 shows the location of the 10 CHESS surveillance sites as of 2022. These sites are strategically located in six main provinces, which are representative of four geographical regions in PNG: Southern, Highlands, Momase and Islands. The National Capital District of PNG, POM, houses one of the surveillance sites, located in Hohola, an urban area known for its middle working-class population. In Central Province, the surveillance site is situated in Hiri, which is a semiurban area approximately an hour's drive west of POM. EHP hosts two surveillance sites—Goroka (urban site) and Asaro (rural site). ENB accommodates two surveillance sites in Kokopo (urban site) and Baining (rural site). On the northern coastline of PNG's mainland, ESP operates two surveillance sites in Maprik (rural site) and Wewak (urban site). The Madang catchment area, located in Newtown, a suburban area of Madang Township, and Sagang (rural site) complete the list of surveillance sites[17 18] (see online supplemental file: detailed methods).

Assessing COVID-19 health issues and household socioeconomic demographic factors

In this study, COVID-19 health issues were defined as any health issues related to COVID-19, experienced by a household member during the outbreaks in the locality. These health issues encompassed various scenarios, such as home-based or centre-based/healthcare facility-based quarantines, testing positive for COVID-19,

Figure 1 Surveillance sites of the Comprehensive Health and Epidemiological Surveillance System, Papua New Guinea Institute of Medical Research's CHESS, 2018–2022.

hospitalisation due to COVID-19 infection, and deaths resulting from COVID-19 infection. Hospitalisation and death are possibly health outcomes of COVID-19 infection. However, the numbers of observations on hospitalisations and deaths from COVID-19 recorded in this study were low. The primary objective of the study was to provide a comprehensive assessment of all health issues related to COVID-19 that household members had experienced during the first year of the pandemic. To achieve this objective, hospitalisations and deaths from COVID-19 infection were treated as part of the health issue assessment.

To assess and understand the variation of COVID-19 health issues across different subpopulations, the researchers employed a multinomial logistic regression (MLR) analysis. This analysis in SPSS is also known as multivariable logistic regression in other statistical software and typically used for modelling a dichotomous outcome variable with multiple independent variables. The MLR model was used to identify associated factors and predict the likelihood of COVID-19 health issues within these subpopulations. The outcome measure for the MLR model was a binary variable representing whether a household had experienced COVID-19 health issues during the pandemic. This variable was coded as 1 for 'yes' and 2 for 'no'. Various household socioeconomic demographic variables were considered as independent factors in the MLR model.

First, all key household SES variables were included in the MLR model, including urban–rural sector, sex, age group, household size, type of house, number of sleeping room, access to water and sanitation facilities (shared toilet, water for handwashing, soap/detergent for handwashing), access to information education and communication (radio, television, mobile phone, internet service), access to healthcare services (primary, secondary and tertiary), access to transportation means (public bus or boat, private car or boat and ambulance service) and household wealth quintile (HWQ).

Previous studies showed that limited access to WASH services increased the health issues associated with COVID-19. However, the MLR analysis in our study suggested that province, sex and availability of water for handwashing were not statistically significant in the MLR models. As such, these variables were excluded in the final MLR model for predicting the COVID-19 health issues. Significant variables, which demonstrated a notable association with experiencing COVID-19 health issues, remained in the final MLR model. These included urban–rural sector, age group, household size, type of house, handwashing with soap/detergent and HWQ.

All statistical analyses were performed using SPSS (V.20). The main effect was selected to produce estimates of ORs for the COVID-19-related health issues. Statistical likelihood tests were used to provide 95% CIs of the estimated ORs and a $p<0.05$ was considered as statistical significance.

Patient and public involvement

None.

RESULTS

The study included a total of 37 880 residents living in the CHESS sites recorded in the 2020 Household Socioeconomic Demographic Dataset. The distribution of residents across the provinces included 1850 in POM, 10 781 in Central Province, 11 354 in EHP, 4458 in Madang, 4840 in ESP and 4597 in ENB.

Household socioeconomic demographic characteristics of surveillance population

Table 1 presents the household socioeconomic demographic characteristics of the surveillance population. Approximately 24.6% of the surveillance population resided in urban areas, while 75.4% lived in rural areas. The population consisted of 50.8% males and 49.2% females. The majority of the population were young, with 33.2% falling within the age group of 0–14 years (children), 63.1% between 15 and 64 years old (working age), and 3.7% aged 65 years and above (elderly). The mean household size was 6.6 persons per household, with an SD of ±3.6. About 26% of the surveillance population lived in traditional and adapted houses, while 74% lived in semimodern and modern houses. The diversity of cultures and geographical regions of PNG results in a range of house designs. Constructions of traditional houses are adapted to the local environment, taking into account factors such as climate, topography and available building materials. A traditional house is typically constructed using locally available materials such as timber, bamboo, thatch, palm leaves and bush materials. Some common types of traditional houses include stilt houses and round houses. Many traditional houses in PNG have thatched roofs made from palm leaves or grass. These roofs are effective in shedding rainwater. Some traditional houses have a circular layout, with a central support post and a conical roof, providing insulation. These houses are dwellings for an extended family or accommodate multiple households. Adapted houses may include modern construction materials while facilities and appliances for the kitchen, bathroom and toilet are more likely to be integrated into semimodern houses in urban areas.

On average, there were 2.6 (SD: ±1.1) sleeping rooms per house. Approximately 17% of the surveillance population used shared toilets, and 61% had access to water for handwashing. However, about 52% of the population did not have access to soap or detergent for handwashing. In terms of access to information, communication and education, the majority (83.6%) had access to mobile phone service and about 11.7% had access to the internet. Approximately 45% had access to a radio, and 32% had access to a TV. Most of the surveillance population had access to health facilities, with over 73% having access to primary healthcare services and over 24% having access to

Table 1 Key socioeconomic demographic characteristics of surveillance population by province, Papua New Guinea Institute of Medical Research's CHESS, 2021

		Port Moresby	Central	Eastern Highlands	Madang	East Sepik	East New Britain	All sites
Sector	Urban	1850 (100.0%)	0 (0.0%)	3030 (26.7%)	1848 (41.5%)	1263 (26.1%)	1339 (29.1%)	9304 (24.6%)
	Rural	0 (0.0%)	10781 (100.0%)	8324 (73.3%)	2610 (58.5%)	3577 (73.9%)	3258 (70.9%)	28576 (75.4%)
Sex	Male	956 (51.7%)	5685 (52.7%)	5522 (48.6%)	2339 (52.5%)	2445 (50.5%)	2282 (49.6%)	19229 (50.8%)
	Female	894 (48.3%)	5096 (47.3%)	5832 (51.4%)	2119 (47.5%)	2395 (49.5%)	2315 (50.4%)	18651 (49.2%)
Age group	0–14	561 (30.3%)	3551 (32.9%)	3491 (30.7%)	1630 (36.6%)	1696 (35.0%)	1654 (36.0%)	12583 (33.2%)
	15–64	1222 (66.1%)	6803 (63.1%)	7314 (64.4%)	2717 (60.9%)	3015 (62.3%)	2838 (61.7%)	23909 (63.1%)
	65–100	67 (3.6%)	427 (4.0%)	549 (4.8%)	111 (2.5%)	129 (2.7%)	105 (2.3%)	1388 (3.7%)
	Mean (±SD)	28.19 (±18.2)	27.2 (±18.8)	29.5 (±19.0)	25.0 (±18.1)	25.6 (±18.0)	26.3 (±17.8)	27.3 (±18.6)
Household size (person)	1–2	9 (0.5%)	178 (1.7%)	1356 (11.9%)	146 (3.3%)	135 (2.8%)	192 (4.2%)	2016 (5.3%)
	3–4	87 (4.7%)	1111 (10.3%)	4133 (36.4%)	881 (19.8%)	1225 (25.3%)	1175 (25.6%)	8612 (22.7%)
	5–6	249 (13.5%)	2633 (24.4%)	3796 (33.4%)	1326 (29.7%)	1592 (32.9%)	1522 (33.1%)	11118 (29.4%)
	7–8	280 (15.1%)	2289 (21.2%)	1330 (11.7%)	1173 (26.3%)	1214 (25.1%)	1086 (23.6%)	7372 (19.5%)
	9–10	265 (14.3%)	1710 (15.9%)	251 (2.2%)	578 (13.0%)	176 (3.6%)	389 (8.5%)	3369 (8.9%)
	10+	960 (51.9%)	2860 (26.5%)	488 (4.3%)	354 (7.9%)	498 (10.3%)	233 (5.1%)	5393 (14.2%)
	Mean (± SD)	11.6 (±5.3)	8.4 (± 4.0)	4.6 (± 1.8)	6.5 (±2.5)	5.7 (±2.8)	5.7 (± 2.0)	6.6 (± 3.6)
Type of house	Traditional	47 (2.5%)	163 (1.5%)	3684 (32.4%)	1119 (25.1%)	1847 (38.2%)	114 (2.5%)	6974 (18.4%)
	Adapted house	73 (3.9%)	527 (4.9%)	1439 (12.7%)	47 (1.1%)	367 (7.6%)	300 (6.5%)	2753 (7.3%)
	Semipermanent	129 (7.0%)	3500 (32.5%)	4998 (44.0%)	785 (17.6%)	2097 (43.3%)	2856 (62.1%)	14365 (37.9%)
	Permanent	1601 (86.5%)	6591 (61.1%)	1233 (10.9%)	2507 (56.2%)	529 (10.9%)	1327 (28.9%)	13788 (36.4%)
No of sleeping room	1	92 (5.0%)	2121 (19.7%)	3468 (30.5%)	692 (15.5%)	311 (6.4%)	437 (9.5%)	7121 (18.8%)
	2	402 (21.7%)	2731 (25.3%)	4557 (40.1%)	1795 (40.3%)	1254 (25.9%)	1525 (33.2%)	12264 (32.4%)
	3	778 (42.1%)	3317 (30.8%)	2065 (18.2%)	1674 (37.6%)	1396 (28.8%)	1274 (27.7%)	10504 (27.7%)
	4	281 (15.2%)	1724 (16.0%)	723 (6.4%)	236 (5.3%)	1390 (28.7%)	923 (20.1%)	5277 (13.9%)
	5+	297 (16.1%)	888 (8.2%)	541 (4.8%)	61 (1.4%)	489 (10.1%)	438 (9.5%)	2714 (7.2%)
	Mean (±SD)	3.1 (± 1.0)	2.7 (± 1.2)	2.2 (± 1.1)	2.4 (± 0.9)	3.1 (± 1.1)	2.9 (± 1.1)	2.6 (± 1.1)
Access to water and sanitation facilities	Shared toilet	154 (8.3%)	1636 (15.2%)	1575 (13.9%)	1080 (24.2%)	1542 (31.9%)	525 (11.4%)	6512 (17.2%)
	Available water	1413 (76.4%)	8192 (76.0%)	5797 (51.1%)	2682 (60.2%)	2700 (55.8%)	2267 (49.3%)	23051 (60.9%)
	Unavailable soap	1508 (81.5%)	8342 (77.4%)	5963 (52.5%)	1772 (39.7%)	263 (5.4%)	1976 (43.0%)	19824 (52.3%)

Continued

Table 1 Continued

		Port Moresby	Central	Eastern Highlands	Madang	East Sepik	East New Britain	All sites
	Radio	1114 (60.2%)	4328 (40.1%)	4114 (36.2%)	2757 (61.8%)	3475 (71.8%)	1266 (27.5%)	17054 (45.0%)
	Television	1306 (70.6%)	5726 (53.1%)	3012 (26.5%)	758 (17.0%)	198 (4.1%)	1067 (23.2%)	12067 (31.9%)
	Mobile phone	1760 (95.1%)	10222 (94.8%)	8792 (77.4%)	3568 (80.0%)	3240 (66.9%)	4078 (88.7%)	31660 (83.6%)
Access to IEC	Internet	407 (22.0%)	151 (1.4%)	936 (8.2%)	1791 (40.2%)	30 (0.6%)	1111 (24.2%)	4426 (11.7%)
	None	73 (3.9%)	127 (1.2%)	439 (3.9%)	14 (0.3%)	167 (3.5%)	148 (3.2%)	968 (2.6%)
	Primary	1327 (71.7%)	10630 (98.6%)	5370 (47.3%)	3524 (79.0%)	4041 (83.5%)	2866 (62.3%)	27758 (73.3%)
Access to healthcare facility	Secondary	449 (24.3%)	24 (0.2%)	2746 (24.2%)	41 (.9%)	139 (2.9%)	1208 (26.3%)	4607 (12.2%)
	Tertiary	1 (0.1%)	0 (0.0%)	2799 (24.7%)	879 (19.7%)	493 (10.2%)	375 (8.2%)	4547 (12.0%)
Available transportation means to health facility	Public bus/boat	426 (23.0%)	2467 (22.9%)	5229 (46.1%)	1611 (36.1%)	1762 (36.4%)	3379 (73.5%)	14874 (39.3%)
	Private car/boat	216 (11.7%)	1166 (10.8%)	2616 (23.0%)	104 (2.3%)	1490 (30.8%)	365 (7.9%)	5957 (15.7%)
	Ambulance	0 (0.0%)	0 (0.0%)	4836 (42.6%)	0 (0.0%)	2050 (42.4%)	3 (0.1%)	6889 (18.2%)
	Poorest	30 (1.6%)	915 (8.5%)	1798 (15.8%)	1389 (31.2%)	1401 (28.9%)	2043 (44.4%)	7576 (20.0%)
	Poor	68 (3.7%)	1129 (10.5%)	2394 (21.1%)	1016 (22.8%)	1625 (33.6%)	1343 (29.2%)	7575 (20.0%)
	Middle	126 (6.8%)	1591 (14.8%)	3150 (27.7%)	801 (18.0%)	1374 (28.4%)	535 (11.6%)	7577 (20.0%)
Household wealth quintile	Rich	349 (18.9%)	2542 (23.6%)	3323 (29.3%)	652 (14.6%)	338 (7.0%)	367 (8.0%)	7571 (20.0%)
	Richest	1277 (69.0%)	4604 (42.7%)	689 (6.1%)	600 (13.5%)	102 (2.1%)	309 (6.7%)	7581 (20.0%)
Total		1850 (100.0%)	10781 (100.0%)	11354 (100.0%)	4458 (100.0%)	4840 (100.0%)	4597 (100.0%)	37880 (100.0%)

CHESS, Comprehensive Health and Epidemiological Surveillance System; IEC, information, communication and education.

secondary and tertiary health facilities. In terms of transportation means during the pandemic, 39% reported using public buses and boats, while 16% used private cars and boats and less than 20% reported having access to ambulance services. These findings provide an overview of the household socioeconomic demographic characteristics and living conditions of the population living in the surveillance sites. They serve as essential baseline information for assessing the associations between these characteristics and COVID-19 health issues in the subsequent analyses (see online supplemental file 2: additional results).

Household experience of COVID-19-related health issues

Table 2 presents the household experience of COVID-19 health issues in 2020 within the surveillance population. Overall, 9.1% of the population reported experiencing health issues related to COVID-19. The proportion of the surveillance population that reported COVID-19 health issues was higher in rural areas (10.0%) compared with urban areas (6.6%). Among the provinces, EHP had the highest proportion of reported COVID-19 health issues at 16%, followed by Central Province at 13.3%. In contrast, the prevalence of COVID-19 health issues was much lower in ESP and Madang, with rates of only 1%.

The prevalence of COVID-19 health issues was similar between males and females, both at around 9%. However, certain household socioeconomic demographic characteristics showed variations in the proportion of reported COVID-19 health issues. Notably, the proportion of COVID-19 health issues was higher among individuals living in semimodern houses (11.5%) and one-bedroom houses (12.1%). Households without soap or detergents for handwashing had a higher proportion of COVID-19 health issues, reaching 13.7%.

Among the specific COVID-19 health issues, home-based quarantine was reported by 9.6% of the surveillance population. Higher proportions were reported in rural areas (10.0%) and in EHP (14.8%). Similar patterns were observed for those living in semi-modern houses (10.9%) and one-bedroom houses (11.9%), as well as those without soap or detergent for handwashing (13.1%). However, the proportions of the population experiencing centre-based quarantine, testing positive with COVID-19, hospitalisation due to COVID-19 and death from COVID-19 were all less than 0.5%.

These findings provide valuable insights into the prevalence and distribution of COVID-19 health issues within the surveillance population across different regions and household characteristics. Understanding these patterns is crucial for targeted interventions and public health measures to address the impact of COVID-19 on vulnerable subpopulations effectively.

Household socioeconomic and demographic factors of COVID-19-related health issues

Table 3 presents the household socioeconomic demographic factors associated with COVID-19 health issues. The study identified several significant factors that were linked to the likelihood of experiencing COVID-19 health issues within the surveillance population.

Factors associated with higher COVID-19 health issues were identified as follows. People living in semimodern houses had significantly higher COVID-19 health issues compared with those living in modern houses (OR 1.47 (95% CI 1.35 to 1.61)). The COVID-19 health issues were higher among individuals from lower HWQ, with the poorest quintile having a 16% higher likelihood compared with the richest quintile (OR 1.16 (95% CI 1.02 to 1.31)).

Subpopulations experienced lower COVID-19 health issues included children aged 0–4 years, who had significantly lower COVID-19 health issues compared with those in the age group of 55 years and above (OR 0.76 (95% CI 0.64 to 0.91)). Individuals living in urban areas had significantly lower COVID-19 health issues compared with rural residents (OR 0.65 (95% CI 0.59 to 0.71)). Households with 7–8 members had lower COVID-19 health issues compared with households with 10 or more members (OR 0.84 (95% CI 0.74 to 0.96)). Individuals from households with soap or detergent for handwashing had significantly lower COVID-19 health issues compared with those without soap or detergent (OR 0.3 (95% CI 0.28 to 0.33)).

These findings highlight the importance of household socioeconomic demographic factors in influencing the likelihood of experiencing COVID-19 health issues. Understanding these associations can inform targeted interventions and public health strategies to protect vulnerable subpopulations effectively.

DISCUSSION

The findings of this study are crucial in understanding the impact of COVID-19 pandemic on the health of the population in PNG. By using household socioeconomic and demographic data from the CHESS, the study was able to assess the health issues associated with COVID-19 and identify key factors at the household level that contribute to these issues. The overall prevalence of COVID-19 health issues in the surveillance population was found to be 9.1%, indicating a significant proportion of the population being affected by the pandemic. The study revealed that certain subpopulations were more vulnerable to COVID-19 health issues, including rural residents, older individuals (aged 55+ years), those living in semimodern houses, households with 10 or more members and households without access to soap or detergent for handwashing (see figures 2 and 3). These factors serve as critical markers for identifying households at higher health issues of COVID-19 in the communities.

On the other hand, the study identified factors that were associated with lower COVID-19 health issues. These included living in urban areas, being a child aged 0–4 years, residing in permanent houses, with 3+ bedrooms, having a smaller household size (7–8 members or less),

Table 2 Household experience of COVID-19-related health issues by socioeconomic demographic characteristics, Papua New Guinea Institute of Medical Research's CHESS, 2021

		Health-related issues	Home-based quarantined	Centre-based quarantined	Tested positive	Hospitalised	Dead from COVID-19	Total population
Sector	Urban	614 (6.6%)	608 (6.5%)	28 (0.3%)	7 (0.1%)	82 (0.9%)	83 (0.9%)	9304 (100.0%)
	Rural	3006 (10.5%)	2851 (10.0%)	160 (0.6%)	46 (0.2%)	47 (0.2%)	38 (0.1%)	28 576 (100.0%)
Province	Port Moresby	90 (4.9%)	118 (6.4%)	6 (0.3%)	1 (0.1%)	1 (0.1%)	1 (0.1%)	1850 (100.0%)
	Central	1430 (13.3%)	1389 (12.9%)	26 (0.2%)	9 (0.1%)	9 (0.1%)	1 (0.0%)	10 781 (100.0%)
	Eastern Highlands	1814 (16.0%)	1681 (14.8%)	128 (1.1%)	41 (0.4%)	75 (0.7%)	112 (1.0%)	11 354 (100.0%)
	Madang	16 (0.4%)	19 (0.4%)	19 (0.4%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	4458 (100.0%)
	East Sepik	65 (1.3%)	45 (0.9%)	0 (0.0%)	0 (0.0%)	42 (0.9%)	0 (0.0%)	4840 (100.0%)
	East New Britain	205 (4.5%)	207 (4.5%)	9 (0.2%)	2 (0.0%)	2 (0.0%)	7 (0.2%)	4597 (100.0%)
Age group	0–4	201 (7.6%)	194 (7.3%)	14 (0.5%)	1 (0.0%)	6 (0.2%)	4 (0.2%)	2655 (100.0%)
	5–14	849 (9.4%)	814 (9.1%)	40 (0.4%)	5 (0.1%)	18 (0.2%)	18 (0.2%)	8990 (100.0%)
	15–34	1276 (9.9%)	1211 (9.4%)	73 (0.6%)	24 (0.2%)	53 (0.4%)	42 (0.3%)	12 866 (100.0%)
	35–54	888 (10.2%)	853 (9.8%)	40 (0.5%)	5 (0.1%)	31 (0.4%)	32 (0.4%)	8734 (100.0%)
	55+	406 (8.8%)	387 (8.3%)	21 (0.5%)	18 (0.4%)	21 (0.5%)	25 (0.5%)	4635 (100.0%)
Sex	Male	1897 (9.9%)	1811 (9.4%)	100 (0.5%)	24 (0.1%)	63 (0.3%)	58 (0.3%)	19 229 (100.0%)
	Female	1723 (9.2%)	1648 (8.8%)	88 (0.5%)	29 (0.2%)	66 (0.4%)	63 (0.3%)	18 651 (100.0%)
No of household members	1–4	1117 (10.5%)	1035 (9.7%)	81 (0.8%)	21 (0.2%)	18 (0.2%)	28 (0.3%)	10 628 (100.0%)
	5–6	1122 (10.1%)	1064 (9.6%)	74 (0.7%)	11 (0.1%)	55 (0.5%)	72 (0.6%)	11 118 (100.0%)
	7–8	585 (7.9%)	570 (7.7%)	0 (0.0%)	15 (0.2%)	8 (0.1%)	15 (0.2%)	7372 (100.0%)
	9–10	312 (9.3%)	305 (9.1%)	7 (0.2%)	0 (0.0%)	9 (0.3%)	0 (0.0%)	3369 (100.0%)
	10+	484 (9.0%)	485 (9.0%)	26 (0.5%)	6 (0.1%)	39 (0.7%)	6 (0.1%)	5393 (100.0%)
Type of house	Traditional/adapted	856 (8.8%)	800 (8.2%)	62 (0.6%)	30 (0.3%)	54 (0.6%)	40 (0.4%)	9727 (100.0%)
	Semi modern	1645 (11.5%)	1572 (10.9%)	83 (0.6%)	10 (0.1%)	47 (0.3%)	67 (0.5%)	14 365 (100.0%)
	Permanent	1119 (8.1%)	1087 (7.9%)	43 (0.3%)	13 (0.1%)	28 (0.2%)	14 (0.1%)	13 788 (100.0%)
No of sleeping room	1	863 (12.1%)	849 (11.9%)	22 (0.3%)	12 (0.2%)	7 (0.1%)	13 (0.2%)	7121 (100.0%)
	2	1381 (11.3%)	1276 (10.4%)	102 (0.8%)	10 (0.1%)	32 (0.3%)	23 (0.2%)	12 264 (100.0%)
	3	702 (6.7%)	690 (6.6%)	35 (0.3%)	18 (0.2%)	31 (0.3%)	40 (0.4%)	10 504 (100.0%)
	4+	674 (8.4%)	644 (8.1%)	29 (0.4%)	13 (0.2%)	59 (0.7%)	45 (0.6%)	7991 (100.0%)
Water for handwashing	Available	2804 (12.2%)	2663 (11.6%)	106 (0.5%)	36 (0.2%)	102 (0.4%)	101 (0.4%)	23 051 (100.0%)
	Unavailable	816 (5.5%)	796 (5.4%)	82 (0.6%)	17 (0.1%)	27 (0.2%)	20 (0.1%)	14 829 (100.0%)

Continued

Table 2 Continued

		Health-related issues	Home-based quarantined	Centre-based quarantined	Tested positive	Hospitalised	Dead from COVID-19	Total population
Soap, detergent for handwashing	Available	895 (5.0%)	867 (4.8%)	85 (0.5%)	14 (0.1%)	42 (0.2%)	16 (0.1%)	18 056 (100.0%)
	Unavailable	2725 (13.7%)	2592 (13.1%)	103 (0.5%)	39 (0.2%)	87 (0.4%)	105 (0.5%)	19 824 (100.0%)
Household wealth quintile	Poorest	722 (9.5%)	690 (9.1%)	20 (0.3%)	0 (0.0%)	26 (0.3%)	31 (0.4%)	7576 (100.0%)
	Poor	685 (9.0%)	652 (8.6%)	52 (0.7%)	16 (0.2%)	32 (0.4%)	27 (0.4%)	7575 (100.0%)
	Middle	758 (10.0%)	692 (9.1%)	54 (0.7%)	34 (0.4%)	28 (0.4%)	32 (0.4%)	7577 (100.0%)
	Rich	821 (10.8%)	787 (10.4%)	33 (0.4%)	3 (0.0%)	38 (0.5%)	26 (0.3%)	7571 (100.0%)
	Richest	634 (8.4%)	638 (8.4%)	29 (0.4%)	0 (0.0%)	5 (0.1%)	5 (0.1%)	7581 (100.0%)
Total		3459 (9.1%)	3620 (9.6%)	188 (0.5%)	53 (0.1%)	129 (0.3%)	121 (0.3%)	37 880 (100.0%)

CHESS, Comprehensive Health and Epidemiological Surveillance System.

handwashing with soap or detergent, and belonging to the richest HWQ. Understanding these factors can help inform public health interventions aimed at reducing the spread and impact of COVID-19 among subpopulations at higher risks.

Housing condition

People living in poor housing conditions were disadvantaged in COVID-19 pandemic.[19] Poor housing condition was associated with higher COVID-19 incidence and mortality.[20] The data on housing conditions in this study provide valuable insights into the current challenges faced during the COVID-19 era and offer potential opportunities for positive changes in the PNG society. Our study suggests that houses with three or more sleeping rooms could offer a safer option for home-based quarantine during the pandemic. Home-based quarantine could be a viable option for a significant proportion of the population, especially when COVID-19 widely spreads into the community, where the capacity of centre-based quarantine is limited.

On the other hand, the study highlights the significant proportion of the population living in traditional, adapted and semimodern houses, which often lack adequate space and ventilation (see figures 2 and 3). These types of housing conditions can be particularly concerning during the COVID-19 pandemic, as they may not facilitate proper social distancing and increase the issue of COVID-19 transmission among household members. The COVID-19 virus easily passes from one to other household members in a close setting.[21] This finding suggests that home quarantine may not be a feasible option for people living in traditional, adapted and semimodern houses, as it could potentially lead to increased COVID-19 transmission within the community. Home quarantine seems unlikely to work in this situation, if not, saying it could increase the issue of COVID-19 transmission in the community. Instead, centre-based quarantine may be a more suitable approach for infected individuals living in these housing conditions. People who are infected with COVID-19 and live in traditional, adapted, semimodern houses are therefore at priority for centre-based quarantine to mitigate the health issues of the disease. Low SES is associated with higher COVID-19 incidences, but the outbreaks did not happen more often in less well-off areas or are more severe, but they last longer, indicating more sustained spread of infections in neighbourhoods with worse housing conditions after local outbreaks.[22] This suggests that in scarce resource settings, containment measures targeting to areas with poor housing conditions would have the greatest benefit.

Furthermore, the study also highlights the importance of considering household size when implementing quarantine measures. The transmission of COVID-19 was reported higher in a high population density and overcrowding contributed to the spread of COVID-19.[18 23] Overcrowded households were a stronger predictor of COVID-19 mortality during the pandemic and they might

Table 3 Household socioeconomic demographic factors associated with COVID-19-related health issues, Papua New Guinea Institute of Medical Research's CHESS, 2021

		N	Percentage	Sig.	OR	95% CI	
Sector	Urban	9304	24.6	0.000	0.650	0.591	0.714
	Rural	28576	75.4		Ref.		
Age group	0–4	2655	7.0	0.003	0.762	0.636	0.912
	5–14	8990	23.7	0.655	1.030	0.906	1.171
	15–34	12866	34.0	0.286	1.068	0.947	1.205
	35–54	8734	23.1	0.204	1.086	0.956	1.233
	55+	4635	12.2		Ref.		
No of household member	1–4	10628	28.1	0.902	1.008	0.885	1.148
	5–6	11118	29.4	0.935	0.995	0.879	1.126
	7–8	7372	19.5	0.012	0.844	0.739	0.964
	9–10	3369	8.9	0.472	0.945	0.811	1.102
	10+	5393	14.2		Ref.		
Type of house	Traditional/adapted house	9727	25.7	0.081	1.105	0.988	1.236
	Semi modern house	14365	37.9	0.000	1.473	1.350	1.608
	Permanent house	13788	36.4		Ref.		
Handwashing	With soap/detergent	18056	47.7	0.000	0.300	0.276	0.326
	Without soap/detergent	19824	52.3		Ref.		
No of sleeping room	1	7121	18.8	0.068	1.123	0.992	1.271
	2	12264	32.4	0.050	1.118	1.002	1.247
	3	10504	27.7	0.000	0.678	0.605	0.759
	4+	7991	21.1		Ref.		
Household wealth quintile	Poorest	7576	20.0	0.019	1.160	1.024	1.314
	Poor	7575	20.0	0.000	1.289	1.135	1.464
	Middle	7577	20.0	0.000	1.386	1.221	1.574
	Rich	7571	20.0	0.000	1.474	1.309	1.660
	Richest	7581	20.0		Ref.		
Total		37880					

CHESS, Comprehensive Health and Epidemiological Surveillance System.

be more vulnerable to the effects of COVID-19, leading to changing disparities over time.[24]

Our study reconfirmed that larger households had higher risk of experiencing COVID-19 health issues. This finding supports the implementation of centre-based quarantine policies, especially in areas with larger household sizes to separate COVID-19 patients and infected individuals from their families and households. In light of clear connection between household size and COVID-19-related health issues, eviction should be considered for households with 10 or more people to prevent the COVID-19 transmission in the communities in PNG. Our finding also reaffirmed that social distancing and lower population density were associated with the decreased COVID-19 infection.[25] These findings could inform public policy and planning interventions in communities during the pandemic.

Various movements and organisations have called for actions to embrace recent trends and changes in the home environment to improve housing conditions.[6] The data on housing conditions emphasise the need for reconsolidating new housing standards in PNG that integrate both traditional architectural practices and modern facilities. This could involve better planning and development of new residential areas, to ensure adequate space and ventilation for households. PNG authorities can work towards improving housing conditions and promoting better public health outcomes, not just during the COVID-19 pandemic but also in the long term. Our data on housing conditions provide important insights into the challenges faced during the COVID-19 pandemic in PNG. It highlights the importance of considering housing conditions when implementing quarantine measures and other public health interventions. By addressing housing disparities and improving housing conditions, PNG can enhance its preparedness for future health crises and create a healthier and more resilient population.

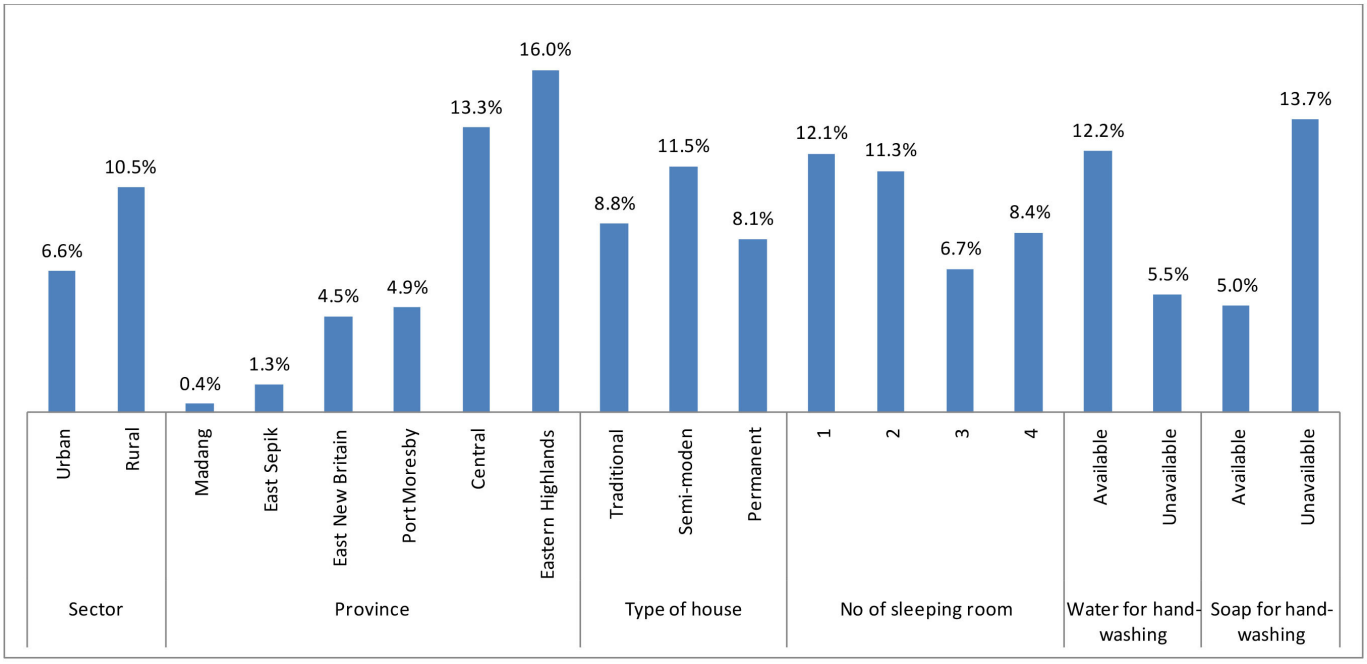

Figure 2 Proportion of households reported experience of COVID-19-related health issues by key socioeconomic groups in Papua New Guinea, Papua New Guinea Institute of Medical Research's CHESS, 2021. CHESS, Comprehensive Health and Epidemiological Surveillance System.

Water sanitation and hygiene

Washing hands with soap for at least 20 s, using water from an improved source has been identified as a simple and effective intervention in reducing the transmission of the virus.[26] The data on WASH services in PNG highlight the importance of these services in mitigating the COVID-19 pandemic and preventing the spread of infectious diseases.

Handwashing has been included in education sessions in a number of schools and communities in PNG.[27] Provision of soap, detergent and sanitiser have been included in the national response to the COVID-19 pandemic as

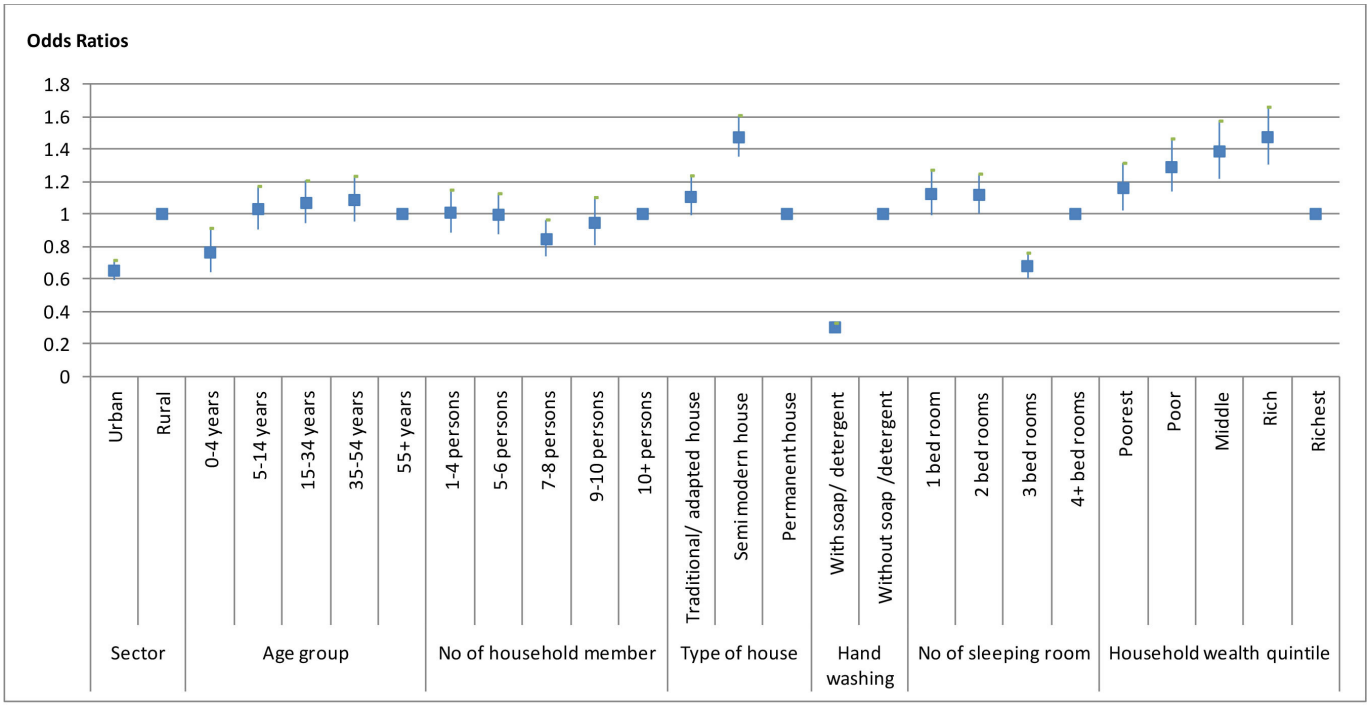

Figure 3 ORs and 95% CIs of household socioeconomic demographic factors of COVID-19-related health issues in Papua New Guinea, Papua New Guinea Institute of Medical Research's CHESS, 2021. CHESS, Comprehensive Health and Epidemiological Surveillance System.

part of public health interventions to prevent COVID-19 transmission.[4] However, the study reveals that access to water and soap for handwashing is limited, with only 60% of the surveillance population having access to water and about 50% had soap or detergent for washing hands. Additionally, around 17% of the population used shared toilets, which may further contribute to the increased risk of COVID-19 transmission. The findings of the study emphasise the need for improving access to WASH service and utilisation of improved water and sanitation facilities, particularly in rural areas, contributing to enhancement of the national response to COVID-19 outbreak in the future.

Improving WASH service not only helps in preventing the spread of COVID-19, but also other waterborne infectious diseases such as typhoid, malaria and diarrhoea.[18 28] Promoting the provision of WASH services in schools, healthcare facilities and communities is vital for effective prevention and control of the wide spread of COVID-19 infections. Scaling up education on handwashing, especially among young people in schools and communities, is crucial in the context of the COVID-19 pandemic. Public health interventions that include the provision of soap, detergent and sanitisers have been included in the national response, but it is essential to ensure that these resources are accessible to all segments of the population.

In the long term, PNG needs to strengthen its capacity for surveillance of water quality and management of water sources. Improving access to and utilisation of water and sanitation facilities should be included in the national responses to health crisis situations and COVID-19 pandemic in particular. Monitoring and evaluation of WASH programmes can be incorporated into socioeconomic development plans at the national and subnational levels. By investing in WASH, PNG can significantly reduce the spread of waterborne diseases, improving overall public health outcomes. Challenges such as inadequate human resources and financial shortages need to be addressed. Community engagement, along with strengthened national capacity, will be essential in successfully implementing and sustaining WASH programme and preventing future health crises in PNG. Community engagement is the key to the success of WASH programme.[11]

Limitations

While the study provides valuable insights into household experience of COVID-19 health issues and household socioeconomic factors in PNG, it is essential to recognise the limitations when interpreting the findings. The study has several limitations that need to be acknowledged. First, the household SES data were collected from the surveillance population, which may not be fully representative of the entire population of PNG. The surveillance sites may not capture the diversity and characteristics of all regions and communities within the country, potentially limiting the generalisation of the findings.

Second, the quality of household SES data collected in this study may not be consistent across the surveillance sites. The interruptions and disruptions caused by lockdowns, isolations and COVID-19 infections among the CHESS staff members affected the fieldwork and data collection. Incomplete interviews, cancellations and postponements could have led to missing or inaccurate data, potentially impacting the reliability of the findings.[29 30] Third, the COVID-19 questions included in the household SES questionnaire may have limitations in capturing individuals' perceptions and responses to COVID-19 health issues accurately. Assessing perceptions and responses to COVID-19 is complex and may require more comprehensive and detailed survey instruments (online supplementary file 1).

Moreover, the study may have faced challenges in collecting data on sensitive topics such as COVID-19 health issues. Respondents might have been hesitant to disclose certain information, leading to underreporting or biased responses. Additionally, the study's reliance on the principal component analysis to construct the HWQ may have some limitations. While this method is a common method used for wealth index construction, it relies on specific variables and assumptions, and the resulting HWQ may not fully capture all aspects of household wealth accurately.

Furthermore, the study's time frame may have impacted the accuracy of the findings. As the data were collected in 2021, reflecting the household SES in 2020, the study's results may not fully represent the current COVID-19 situation in PNG, which might have evolved over time.[31–41] Lastly, the study's focus on household-level data may have limited the ability to explore individual-level factors and their associations with COVID-19 health issues comprehensively (online supplementary file 2). Future research may benefit from more representative sampling, improved data collection methods, and a broader scope of individual and community-level factors.

CONCLUSIONS

In conclusion, our study highlights the significance of household SES and housing conditions as crucial factors in determining COVID-19 health issues in PNG. The study emphasises the importance of addressing social determinants of health in the national responses to the pandemic. Access to safe housing, sanitation and hygiene facilities is essential in preventing and controlling infectious diseases like COVID-19. The study's findings emphasise the need for targeted interventions among vulnerable groups, including older adults and households with larger family sizes. The findings also call for policies to improve living conditions and access to WASH, especially in rural areas.

Strengthening the primary healthcare system and enhancing community engagement are essential in the national response to COVID-19 pandemic. Moreover, the study underscores the importance of reliable and

accurate data collection, particularly during challenging circumstances like the COVID-19 pandemic. The limitations identified in this study call for improved data collection methods and quality control measures in future research. This study has contributed to the growing body of knowledge on COVID-19 and its social determinants, supporting evidence-based decision-making and the development of effective public health policies in PNG.

Lessons learnt from the fight against COVID-19 in PNG can be adapted to similar settings to prepare for future pandemics. Primary healthcare services and community engagement play integral roles in PNG's response to the COVID-19 pandemic. Integrating COVID-19 prevention into existing healthcare infrastructure and services, and scaling up ambulance services are essential strategies to improve public health outcomes. By prioritising housing conditions, implementing evidence-based interventions, countries can better preparedness for public health emergencies. Strengthening community engagement and social networks will be crucial in preventing and mitigating the public health threats and build more resilient communities against future health crises. Comprehensive assessments of COVID-19 health issues and the impacts of COVID-19 on the population health and public health system in PNG are needed in future studies.

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Contributors BNP designed CHESS, conceptualised the study, analysed and interpreted the data, drafted and submitted the manuscript. TA, RE, DM, SM, BD, VG, NB, MK, LK, NA, RJ, VDS and GSJ conducted and supervised the fieldwork, data collection, analysed the data and provided inputs for the manuscript. THH and ADO conceptualised the study, provided feedback and edited the manuscript. WP oversight the study and approved the submission of this manuscript. WP oversight the study and approved the submission. All authors contributed to the article and approved the submitted version for publication.

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Patient consent for publication Consent obtained directly from patient(s).

Ethics approval This study involves human participants and CHESS has ethics approvals from Internal Review Board of PNG Institute of Medical Research (IRB's Approval no. 18.05) and the Medical Research Advisory Committee of Papua New Guinea (MRAC's Approval no. 18.06). These approvals covered all the data components under the CHESS, including household socioeconomic status data, which were used in this manuscript. Informed consent was sought from an adult household member, most often from the household heads. They were informed about their right to withdraw from the study at any stage. Participants gave informed consent to participate in the study before taking part.

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Author note BNP accepts full responsibility for the work and/or the conduct of the study, had access to the data, and controlled the decision to publish.

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