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Covid-19 Vaccination Uptake Among Remote Communities In Malaysia: A Cross-Sectional Study

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Introduction

A novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) epidemic outbreak started in Wuhan City, Hubei Province, China, in December 2019 and subsequently spread globally with a 3.4% mortality rate of 87,137 confirmed cases as of March 1, 2020 and currently in February 16, 2024 it caused 0.9% mortality rate of 703,305,215 nationwide confirmed cases [1,2]. The coronavirus disease 2019, or COVID-19, was named the disease by the World Health Organization (WHO) and poses a significant threat to public health, including Malaysia. The virus's global spread was attributed to sustained human-to-human transmission, leading to exported cases worldwide and WHO announced it as a pandemic on March 11, 2020 [1,3,4].

It is a newly discovered novel strain of coronavirus detected on December 31, 2019 [1]. Utilising the angiotensin-converting enzyme 2 (ACE2) receptor, like SARS-CoV, the virus predominantly spreads through the respiratory tract [5]. Clinical symptoms exhibited by COVID-19 patients included fever, cough, fatigue, and, in some cases, gastrointestinal infection symptoms [6]. Vulnerability to infection and a propensity for severe outcomes, such as acute respiratory distress syndrome (ARDS) and cytokine storms, were observed notably in the elderly and those with underlying diseases [7]. The SARS-CoV-2 was initially treated as secondary and tertiary prevention under the level of disease prevention aiming for early diagnosis from prompt, optimised and sustained care, rehabilitation, and disability prevention [8]. Subsequently, when the virus characteristic was established the prevention level focused on primordial and primary prevention, including the health education, health promotion, new vaccine development and immunisation [8].

The genetic sequence of SARS-CoV-2, the virus that causes COVID-19, was published on January 11, 2020, triggering intense global research and development activity to develop a vaccine against the disease. The development of COVID-19 vaccines represents an unparalleled collaborative endeavour globally.9 Most vaccine developers are from private/industry organisations, with North America leading in development activity [9]. The most advanced candidates have entered clinical development, including mRNA-1273 from Moderna, Ad5-nCoV from CanSino Biologicals, and INO-4800 from

Inovio [9]. Most candidates aim to induce neutralising antibodies against the viral spike (S) protein, preventing uptake via the human ACE2 receptor [10]. International cooperation and planning were needed to ensure vaccine creation, production, and fair distribution of COVID-19 vaccines went smoothly [9]. By the beginning of 2021, the goal is to have a vaccine that can be used in emergencies. The landscape is a helpful resource that can help with essential parts of researching and developing the COVID-19 vaccine. It serves as a guide for continuous portfolio management at the Coalition for Epidemic Preparedness Innovations (CEPI) [9].

Developed by WHO and UNICEF, the Global Immunization Vision and Strategy (GIVS) plans to improve national immunisation programs and protect as many people as possible from more COVID-19 through immunisations, including new vaccines available to everyone qualified. This study look at the advantages and disadvantages of public vaccine programs worldwide [11]. ASEAN member states have taken several thorough steps to combat the COVID-19 pandemic, such as showing a shared dedication to national and regional plans [12]. In Indonesia, National Economic Recovery (PEN) was initiated by allocating Rp 126.2 trillion in additional financial incentives [12]. The government has also increased PCR test manufacturing and is approaching the introduction of a possible COVID-19 vaccine, with broad availability expected by the first quarter of 2021 [13]. In European countries such as Italy, The immunisation method was staged, beginning in February 2021 with the elderly aged 80 years or older and gradually expanded to younger age groups, with priority groups identified for vulnerable individuals [14].

Malaysia initially recorded a moderate increase in reported COVID-19 infections until March 2020, after a four-day religious gathering was hosted in Sri Petaling, Kuala Lumpur. This event, which drew 16,000 participants, including 1,500 from outside Malaysia, generated the highest number of positive COVID-19 cases in Southeast Asia [15]. As of April 2020, 5,251 COVID-19 cases were reported in Malaysia, growing exponentially and peaking in mid-April. The government implemented preventive measures such as the Movement Control Order (MCO) and the Enhanced Movement Controlled Order (EMCO) to control the spread of the virus [16]. Malaysia launched a COVID-19 vaccination program prioritise to high-risk populations, such as frontline healthcare professionals, military and security personnel, and essential service providers [17]. People with disabilities or those with special needs and several underlying medical conditions that increased their risk of developing severe COVID-related illnesses were included in the priority categories. Regardless of citizenship status, a free and voluntary immunisation program was available to all Malaysians. To lower the rate of infections, hospital admissions, and deaths, the government aimed to vaccinate at least 80% of the population by February 2022 [17].

National COVID-19 Immunisation Programme (PICK), launched in February 2021 in Malaysia, aimed to vaccinate eighty percent of the country's population. The vaccinations were provided at no cost to Malaysians and foreigners residing in Malaysia who had willingly enrolled for them [18]. The COVID-19 Immunization Task Force-Adolescent (CITF-A), formed in September 2021, planned to achieve full immunisation coverage for 80% of Malaysians aged 12 to 17 when schools reopened. This included students in private schools, adolescents in protection and rehabilitation programs, those in refugee communities, homeless people, and non-citizens staying in Malaysia. Malaysia, a Southeast Asian nation, has had challenges with the pandemic and as of July 14, 2022, 4.6 million cases and 35.8 thousand fatalities had been reported [17]. Variations in the sociodemographic backgrounds of Malaysians, particularly those who reside in more distant locations, may be responsible for variations in the vaccine uptake rate. A more profound comprehension of the factors contributing to the disparities in vaccination rates among different demographic subgroups may have substantial consequences for the policy and practice of public health. Consequently, this research aims to investigate the prevalence of vaccine uptake and associated factors among remote communities in Malaysia.

Methodology

Study Type, Design, Tools and Data Collection

This study is a cross-sectional study conducted among remote communities in Malaysia in
2 phases: Phase 1: September 2021, Phase 2: April 2023. Remote communities refer to communities that live in an area with a population of 1,000 to a maximum of 10,000 people with access to the nearest town within 10 km to 50 km and limited access to all services. The study used a two-stage stratified sampling method to collect data from head of households (HHs) in the remote area in Malaysia. The Ministry of Education (MOE) and the Department of Statistics Malaysia (DOSM) framework determined the sample framework. The sample size was calculated using the sample size calculator, which can be accessed from the Creative Research Systems survey software, using a 95% confidence level and a confidence interval of 5% were used in the calculation. The minimum sample size calculated was 1005, with 504 respondents in Peninsular Malaysia, 240 in Sarawak, and 261 in Sabah after considering the 30% non-response rate. Inclusion criteria were the head of households (HHs) based on the Department of Statistics Malaysia (DOSM) framework. The exclusion criteria were empty homes at the time of the survey and those who refused to participate in the study.

This study utilised validated questionnaires through the interview process with the selected head of household (HH) as respondents. The enumerators conducted the fieldwork in their native language. The respondents are allowed to withdraw voluntarily whenever they want to do so or when notified by the principal investigator. The withdrawn respondents will be replaced by the participant who fulfils the inclusion criteria.

The precaution on communicable disease transmission was carried out during Phase 1, in which all the team members were required to complete COVID-19 vaccination and allowed to join field work after 14 days of receiving a second dose. Health declarations and testing for COVID-19 were done following the National Security Council's requirements before fieldwork activity and were repeated every two weeks. The COVID-19 rapid test results were uploaded to the online My Sejahtera application. All team members were equipped with hand sanitiser, face masks, face shields, disposable gowns and gloves to be worn throughout the interview session. The respondent's health status, including temperature screening, was also checked before the interviews. The Medical Research & Ethics Committee, Ministry of Health Malaysia, registered and approved the study. (NMRR-20-3303-54950)

Statistical Analysis

Data was entered in a proforma sheet using Microsoft Excel and then analysed using the Statistical Package for Social Sciences (SPSS) version 28.0. Descriptive data on socio-demographics, age, race, occupation, education level, monthly household income, and vaccine uptake were tabulated in number (n) and percentage (%). Comparisons between vaccine uptake and non-vaccine uptake were performed. Variables with a p-value of less than 0.05 in the univariate analysis were included and were further analysed in the multivariate logistic regression. This was to retain important confounding variables for a potentially slightly richer model.

The factors for vaccine and non-vaccine uptake were modelled using multivariate logistic regression. The statistical significance was set at $p < 0.05$. To assess the goodness of fit, the Hosmer-Lemeshow test, classification table and area under receiver operating characteristic (ROC) curve were tested.

Results

Sociodemographic variables

The study showed that the remote communities (N=1005) in both East Malaysia (n=504); consist of Johor, Kelantan, Pahang, Perak, and Terengganu, and West Malaysia (n=501), which include Sabah and Sarawak. Most participants were within the age range of 31 to 70 years, accounting for 77.7% of the sample. Most of the population were indigenous people in East and West Malaysia. Most participants (50.6%) were graduating from the secondary level, although a significant portion (30.4%) had completed primary. Of the participants, 59.6% were employed in the private and agricultural sectors. Monthly Gross Income (RM) from each household in remote areas is generally below RM 2000, which is about 84.9% (Table 1).

Variables		Total N (%)	2nd dose		p-value
			Received	Not received	
Age	11-30	152 (15.1)	135 (88.8)	17 (11.2)	**<0.001**
	31-50	448 (44.6)	401 (89.5)	47 (10.5)	
	51-70	333 (33.1)	324 (97.3)	9 (2.7)	
	>70	72 (7.2)	69 (95.8)	3 (4.2)	
Race	Malay	395 (39.3)	362 (91.6)	33 (8.4)	**<0.001**
	Indigenous	496 (49.4)	479 (96.6)	17 (3.4)	
	Non-indigenous	114 (11.3)	88 (77.2)	26 (22.8)	
Level of education	No ed/Pre-school	84 (8.4)	79 (94.0)	5 (6.0)	0.380
	Primary	306 (30.4)	288 (94.1)	18 (5.9)	
	Secondary	530 (52.7)	486 (91.7)	44 (8.3)	
	Tertiary	85 (8.5)	76 (89.4)	9 (10.6)	
Occupation	Self-employed	327 (42.1)	301 (92.0)	26 (8.0)	0.416
	Private sector	385 (49.5)	349 (90.6)	36 (9.4)	
	Government sector	65 (8.4)	62 (95.4)	3 (4.6)	
Monthly income (RM)	0-1000	424 (42.2)	397 (93.6)	27 (6.4)	0.248
	1001-2000	429 (42.7)	396 (92.3)	33 (32.4)	
	>2000	152 (15.1)	136 (89.5)	16 (10.5)	
Monthly expenses (RM)	0-1000	790 (78.6)	735 (93.0)	55 (7.0)	0.168
	>1000	215 (21.4)	194 (90.2)	21 (9.8)	

Distance to nearest town (km)	0-10	141 (14.0)	141 (100)	0 (0)	**<0.001**
	11-20	241 (24.0)	220 (91.3)	21 (8.7)	
	21-30	108 (10.7)	98 (90.7)	10 (9.3)	
	31-40	132 (13.1)	132 (100)	0 (0)	
	41-50	138 (13.7)	112 (81.2)	26 (18.8)	
	>50	245 (24.4)	226 (92.2)	19 (7.8)	
Distance to nearest clinic (km)	0-5	642 (63.9)	569 (88.6)	73 (11.4)	**<0.001**
	5-10	156 (15.5)	156 (100)	0 (0)	
	>10	207 (20.6)	204 (98.6)	3 (1.4)	
Having chronic disease	Yes	322 (32.0)	303 (94.1)	19 (5.9)	0.170
	No	683 (68.0)	626 (91.7)	57 (8.3)	
Main water source	Public source	759 (75.5)	699 (92.1)	60 (7.9)	0.470
	Natural source	246 (24.5)	230 (93.5)	16 (6.5)	
Natural disaster that commonly occur	Flood	309 (66.2)	291 (94.2)	18 (5.8)	0.348
	Other than flood	158 (33.8)	152 (96.2)	6 (3.8)	

**RM, Ringgit Malaysia; km, kilometre*

Table 1: Sociodemographic Variables of Participants and Sample Count (N=1005)

Table 1 Sociodemographic Variables of Participants and Sample Count (N=1005) Distribution and Uptake of Vaccines The study showed that most remote communities were willing to receive COVID-19 vaccination and the proportions are almost the same for East Malaysia, with 49.7% (n=499), and West Malaysia, with 49.3% (n=496). Among the participants that completed the first vaccination dose, it is similar for 49.3% (n=495) East Malaysia and 49.7% (n=500) West Malaysia. However, for the second dose of vaccination, 49.7% (n=499) from West Malaysia is higher than 42.8% (n=430) from East Malaysia (Figure 1).

		***n* (%)**
Willingness to receive COVID-19 vaccine		
Malaysia	Yes	995 (99%)
	No	10 (1%)
East Malaysia	Yes	499 (49.7%)
	No	5 (0.5%)
West Malaysia	Yes	496 (49.3%)
	No	5 (0.5%)
Completed Vaccination (Dose 1 + Dose 2)		
Malaysia	Yes	960 (95.5%)
	No	45 (4.5%)
East Malaysia	Yes	463 (46.05%)
	No	41 (4.15%)
West Malaysia	Yes	500 (49.7%)
	No	1 (0.1%)

Dose 1		
Malaysia	Yes	995 (99%)
	No	10 (1%)
East Malaysia	Yes	495 (49.3%)
	No	9 (0.9%)
West Malaysia	Yes	500 (49.7%)
	No	1 (0.1%)
Dose 2		
Malaysia	Yes	929 (92.5%)
	No	76 (7.5%)
East Malaysia	Yes	430 (42.8%)
	No	74 (7.4%)
West Malaysia	Yes	499 (49.7%)
	No	2 (0.1%)

Table 2: Covid-19 Vaccine Willingness and Uptake Among Remote Communities in Malaysia (N=1005)

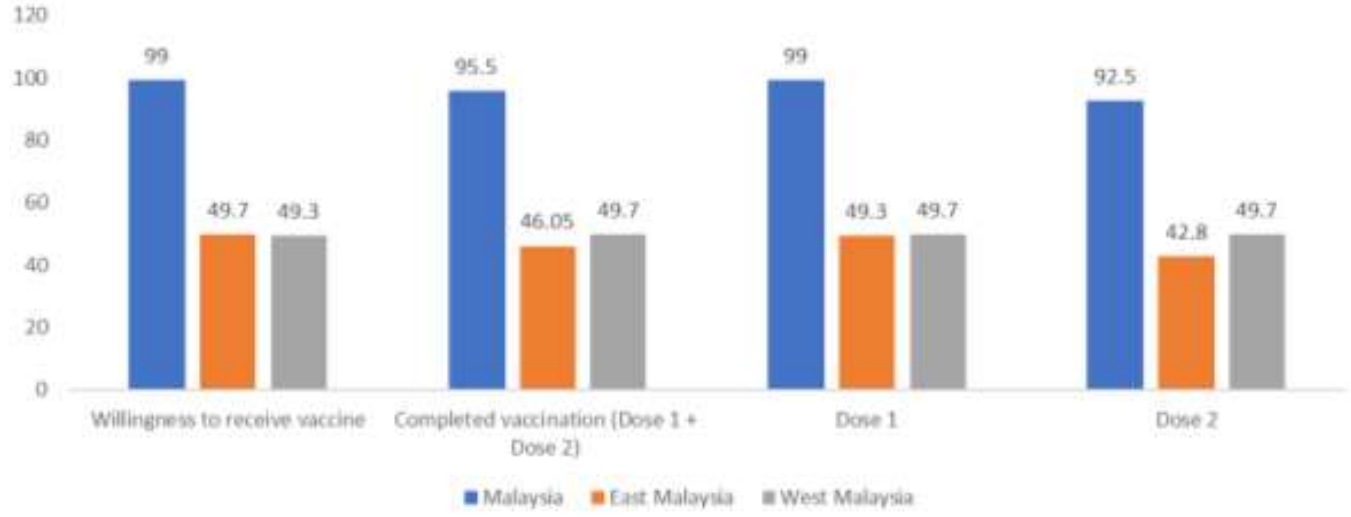

Figure 1: Covid-19 Vaccine Willingness and Uptake Among Remote Communities in Malaysia

Sociodemographic Factors Associated with Covid-19 Vaccine Uptake

A summary of the findings obtained from the logistic regression models (Table 3) showed a significant association between sociodemographic factors and the uptake of COVID-19 vaccination among remote communities were from the Malay (OR 4.272; 95% CI 2.285, 7.987) and Indigenous racial groups (OR 8.939; 95% CI 4.444, 17.981), in comparison with other races. The location of their living quarters was also significant, as those who live less than 40 kilometres from the nearest town were at higher odds to receive vaccination (OR 1.929; 95% CI 1.142, 3.261). Interestingly, there was significantly lower odds in receiving two doses vaccination to the communities living less than 5 kilometres from health clinics (OR 0.061; 95% CI 0.018, 0.201).

The final model fit assessment was tested, with classification table yielded 92.4%, and area under receiver operating characteristics (ROC) curve was 0.796, concluding the final model is a good fit.

Variables	Crude OR (95% CI)	p-value	Adjusted OR (95% CI)	p-value
Age				
11-30	0.345 (0.098, 1.219)	0.098		
31-50	0.371 (0.112, 1.225)	0.104		
51-70	1.565 (0.413, 5.931)	0.510		
>70	1			
Race				
Malay	3.241 (1.843, 5.698)	**<0.001**	4.272 (2.285, 7.987)	**<0.001**
Indigenous	8.325 (4.336, 15.982)	**<0.001**	8.939 (4.444, 17.981)	**<0.001**
Non-indigenous	1		1	
Level of education				
None	1.871 (0.600, 5.837)	0.280		
Primary	1.895 (0.819, 4.385)	0.136		
Secondary	1.308 (0.614, 2.788)	0.487		
Tertiary	1			
Occupation				
Government	1.005 (0.306, 3.298)	0.993		
Private sector	0.487 (0.237, 1.003)	0.051		
Agriculturist	0.582 (0.275, 1.233)	0.157		
Unemployed	1			
Income (RM)				
0-1000	1.730 (0.905, 3.308)	0.098		
1001-2000	1.412 (0.753, 2.646)	0.282		
>2000	1			
Town distance(km)				
0-40 km	2.538 (1.576, 4.088)	**0.03**	1.929 (1.142, 3.261)	0.014
>40 km	1		1	
Clinic distance (km)				
0-5 km	0.065 (0.020, 0.208)	**<0.001**	0.061 (0.018, 0.201)	**<0.001**
>5 km	1			
Chronic disease				
Yes	1.452 (0.849, 2.484)	0.173	1.764 (0.985, 3.159)	0.056
No	1			

**statistically significant at α=0.05

[a] Model fit assessment; Classification table 92.4%, area under ROC curve 0.796

[b] *95% CI, 95% confidence interval; OR, odds ratio*

Table 3: Multivariate Logistic Regression on Factors Associated with Covid-19 Vaccine Uptake Among Remote Communities

Discussion

The results of this study indicated an extremely high level of acceptance of the COVID-19 vaccine among remote communities in Malaysia. Almost all participants (99%) expressed willingness to receive COVID-19 vaccination. This proportion was significantly higher than that reported in several Asian countries, including Indonesia, the Philippines, Thailand, Vietnam and Japan, where willingness to get vaccinated ranged from around 60% to 70%. This was also higher than the rates reported in the United Kingdom and Denmark, which were about 76% to 80% [19,20]. These findings suggest a high level of acceptance of COVID-19 vaccination in the remote communities included in the present study.

Similarly, study participants had high vaccine uptake. Overall, 95.5% of participants had received the recommended series of COVID-19 vaccinations. And 99 per cent had been given at least one dose and 92 per cent a second dose. These findings compare well with published vaccination coverage in remote or rural populations in other countries. Full vaccination coverage was 47% in rural populations in Australia (Damianopoulos et al., 2023) while COVID-19 vaccination completion was 58.58% among village health volunteers in Thailand [22]. In rural South Africa, 41.1% of participants received two doses and 9.3% received one dose [23].

The vaccination coverage seen in the remote communities in this study was also higher than the coverage reported for the overall Malaysian population. As of 22 February 2024, 86.2% of the Malaysian population had received at least one dose of vaccine, and 84.4% had completed the primary vaccination series [24]. This study had higher coverage, which may be attributed to the success of targeted outreach activities specifically conducted for remote communities. However, comparisons between the study population and national data should be interpreted with caution, as the populations, periods for data collection and definitions of vaccination completion may have differed.

International comparisons showed Malaysia was in the intermediate position in terms of overall population coverage of vaccination. The first-dose uptake of 86.2% in Malaysia was lower than Brunei (100%), Denmark (91%), Singapore (90%), Laos (87%) and Spain (87%). However, first-dose coverage was higher in Malaysia (85%), Italy (84%), Sweden (83%), Thailand (83%), the United States of America (82%), Germany (78%), Indonesia (75%), the Philippines (75%), Hungary (65%) and Romania (42%) [25].

A comparable pattern was seen for vaccination completion. The primary vaccination series is only completed by 84.4% of Malaysians, lower than the 100% in Brunei and 90% in Singapore. However, Malaysia had a higher coverage of completed-vaccination compared to Italy (83%), Denmark (82%), France (82%), Spain (79%), Thailand (78%), Laos (78%), Germany (76%), Sweden (72%), Philippines (72%), United States of America (70%), Indonesia (64%), Hungary (63%) and Romania (42%) [25]. These comparisons suggest that Malaysia had relatively high national vaccination coverage compared to many countries in Asia, Europe and North America, but still below that of Brunei and Singapore.

However, direct comparisons between countries should be treated with caution. Differences in vaccination coverage may have been influenced by differences in reporting dates, vaccine eligibility criteria, definitions of complete vaccination, vaccine availability, population characteristics, health-system capacity, and national vaccination policies. The percentages should thus be seen as descriptive international comparisons, not as direct measures of programme effectiveness.

Geographical location, age and the main mode of transportation used to travel to work were associated with Covid-19 vaccine uptake among remote communities in Malaysia [26]. Differences in geographical coverage may be due to distance between communities and vaccination centres, road access, availability of transport, outreach services coverage and implementation of vaccination programmes at the state level. Where public transport is not available or travel is time-consuming and costly, individuals in isolated areas may experience considerable difficulty travelling to fixed vaccination centres.

The mode of transportation to work can also indicate geographical accessibility and mobility. Those with access to private transportation or their own vehicles may have had an easier time attending vaccination appointments. In contrast, those who depended on public transportation, shared vehicles, boats or transportation from others may have experienced more logistical barriers. Thus, mobile vaccination teams, temporary community vaccination centers and outreach programs may have been important in overcoming transportation related barriers and improving access for geographically isolated populations [27].

Age was also associated with vaccinations uptake. Older people were more likely to be vaccinated because they were at greater risk of severe COVID-19, hospitalisation and death. Their greater risk of infection could have raised their perceived need for vaccination [28]. However, older adults can also face practical barriers, including limited mobility, poor access to digital technology, reliance on family and difficulty travelling to vaccination centres. Therefore, vaccination programmes focusing on older people need to incorporate appropriate risk communication, transportation support, mobile vaccination services, and non-digital approaches to registration and the verification of vaccination status.

Similar sociodemographic variations were reported in other Asian countries. Age, income and occupation were associated with the willingness to receive COVID-19 vaccination in Indonesia and Vietnam [19]. Income may influence an individual's capacity to cover indirect costs related to vaccination, such as transportation costs, childcare and time away from work. Although vaccination itself was free, these indirect costs could still be a barrier for lower-income populations.

Occupation may also influence vaccine acceptance and uptake through its effects on workplace exposure, access to reliable health information and opportunities to receive vaccinations through employer-sponsored programs. In Thailand, willingness to get vaccinated against COVID-19 was linked to occupation and educational attainment [19]. More educated people may also have been more exposed to trustworthy health information and more aware of the advantages and possible side effects of vaccination. Overall, these findings suggest that strategies for promoting and delivering vaccines should be adapted to the geographical, socioeconomic, occupational and educational context of the

target population [19,26].

The high vaccine acceptance and uptake among remote communities in Malaysia can be partly explained by the comprehensive implementation of the National COVID-19 Immunisation Programme. Malaysia undertook whole-of-government and whole-of-society approaches including federal ministries, government agencies, state governments, non-governmental organisations, private-sector organisations and community representatives. In this multisectoral approach, resources, personnel, transport and communication channels were coordinated at different levels of society.

In Malaysia, the residents including the non-citizens were given the COVID-19 vaccine free of charge, which helped to eliminate the financial barriers to access to vaccination [17]. The Special Committee for Ensuring Access to COVID-19 Vaccine Supply, also known as JKJAV, was set up to coordinate vaccine procurement, distribution, communication and programme implementation. The government aimed to vaccinate 80% of the total population by February 2022 to decrease COVID-19 transmission, hospitalisation and mortality [17].

Remote populations had to deal particularly with community outreach. Vaccination services were brought closer to communities that might otherwise have had difficulty accessing conventional healthcare facilities through mobile vaccination teams, community-based vaccination centres and working with local leaders. These measures may have reduced geographical and transport barriers, while increasing confidence in the vaccination programme through the participation of trusted community representatives.

High vaccination uptake may also have been facilitated by the digital health infrastructure in Malaysia. MySejahtera application was used for registration for vaccine, appointment, digital vaccine certification and check the vaccination status. It therefore served not only as a health monitoring application, but also as an important component of the national vaccination programme.

Some pandemic responses saw unvaccinated people – those without the requisite doses of vaccine – excluded from some social and public spaces. Such places included shopping complexes, supermarkets, markets, cinemas, educational institutions, workplaces and places of worship. The checking of vaccination status as shown in MySejahtera was often done by security personnel, business operators, employers or event organisers before allowing entry.

For many Malaysians, checking vaccination status became part of everyday activities. For example, people who go to a place of worship for a religious service may be required to show proof of vaccination before being allowed to enter. And customers entering supermarkets or shopping malls were often made to queue while security staff checked their vaccination status on their mobile phones. For many older adults who didn't have a smartphone, like a paper vaccination card was proof of vaccination. It was important to have a non-digital option so that those with limited access to digital technology would not be excluded.

Another practical motivation for people to complete their vaccination series may have been the association between vaccination status and access to public spaces. However, this measure should not be interpreted as the only reason for the high vaccination coverage in Malaysia. Vaccine uptake was likely driven by a combination of factors including free vaccination, risk perception, accessible vaccination services, public-health communication, community engagement, digital monitoring and requirements for participation in selected public activities.

Useful comparisons can also be made with Singapore and Brunei, both of which reported higher overall vaccination coverage than Malaysia. Singapore achieved approximately 90% coverage and Brunei achieved approximately 100% coverage. Both countries had used digital resources to support their COVID-19 responses. Singapore used TraceTogether and Brunei used BruHealth for contact tracing, health monitoring and vaccination-status verification [29,30]. Vaccination was free for eligible residents and penalties or enforcement measures were taken to address breaches of COVID-19 regulations similar to Malaysia [24,31,33,34].

However, differences in population size and geographical area should be taken into account when comparing vaccination coverage. Singapore has a population of about 5.92 million and a land area of 734.3 km2. Brunei has a population of about 445,400 and land area of 5,765 km2. Conversely, Malaysia has a population of approximately 34.49 million and a land area of 330,803 km² [35-39].

Singapore and Brunei may have found it easier to distribute vaccines, communicate about public health, monitor their populations and enforce rules because of their smaller populations and geographic size. In contrast, Malaysia had to roll out vaccination in a much larger and geographically diverse area that included urban centres, rural districts, islands, indigenous settlements and geographically isolated communities. It is notable that Malaysia has achieved a high level of vaccination coverage, given its relatively larger population, bigger land mass and more complex logistics.

The findings of the present study have some practical implications. High vaccination coverage at national level does not mean absence of geographical and socio-economical inequalities in access. Mobile vaccination services, community-based delivery, transportation assistance and collaboration with local leaders should be sustained in future vaccination

and emergency immunisation programmes. These strategies are particularly important for people who live far from health care facilities or in areas with limited public transport.

Risk-communication materials should also be culturally appropriate, in languages that local communities understand, and delivered through both digital and non-digital channels. Older adults, low-income workers, people without smartphones, and populations with low digital proficiency should be given particular attention. Physical vaccination cards or other non-digital alternatives should remain available so that access to vaccination services and public facilities is not entirely dependent on smartphone ownership.

Several limitations of this study exist. Data collection took place during the ongoing national COVID-19 vaccination programme. Hence, some participants who had received their first dose were not yet due for their second dose at the time of the interview. Therefore, the proportion classified as not having completed vaccination may include persons who intended to complete vaccination but were not yet eligible for their next dose.

But international comparisons should be made with caution because the percentages came from different populations, reporting periods and vaccination-programme settings. Some studies measured willingness to be vaccinated, others measured actual uptake. Also, definitions of first-dose uptake and completed vaccination may have varied between countries and over time.

Findings were also based on selected remote communities and may not be generalisable to all remote or urban populations in Malaysia. Future research should compare vaccine acceptance and uptake in remote and urban communities, including the effect of geographical accessibility, transportation, trust, risk perception, digital literacy level, socioeconomic circumstances, and exposure to misinformation.

Despite these limitations, there were a number of important strengths to the study. Data collection in Phase 1 was conducted through direct interviews during the Movement Control Order and Enhanced Movement Control Order periods of the COVID-19 pandemic. We included people who may have been excluded from online surveys due to limited internet connectivity, low digital proficiency, or lack of access to electronic devices using this method. In contrast, several studies in other countries during the pandemic adopted online data collection as the main method.

Another strong point was the opportunity to gauge the acceptance and uptake of vaccination in Malaysia's unique National COVID-19 Immunisation Programme. The free vaccination and targeted outreach services together with the joint efforts of government agencies, healthcare providers, non-governmental organisations, private organisations and community leaders created an enabling environment for vaccine delivery.

The Malaysian programme was unique in that it incorporated MySejahtera and physical vaccination cards into the vaccination-status verification process. The system allowed for recognition of vaccination status in both digital and non-digital settings. Also vaccination completion linked to participation in selected public, economic, educational, social and religious activities.

Overall, remote communities in Malaysia showed very high willingness to receive COVID-19 vaccination and high completion of the primary vaccination series. The percentages found in this study were higher than some of the rural or remote populations in the world and also higher than the overall national vaccination percentages in Malaysia. At the national level, Malaysia had vaccination coverage that was lower than Brunei and Singapore but higher than what was reported in many countries in Asia, Europe and North America.

The high uptake of vaccination in remote communities was likely attributable to a combination of factors including free vaccination, multisectoral implementation, community outreach, mobile vaccination services, risk communication, and digital verification of vaccination status and access requirements in select public settings. Geographic location, age and transport, however, remained important determinants of uptake. Future vaccination programmes should retain successful elements of Malaysia's approach while enhancing equitable access for geographically isolated, digitally excluded and socioeconomically disadvantaged populations.

Conclusion

Malaysia demonstrated high willingness to receive COVID-19 vaccination and high vaccine uptake among remote communities compared with several Asian, European and other rural populations. Among Malaysian remote communities, approximately 99% of respondents were willing to be vaccinated, 99% had received a first dose and more than 90% had completed the recommended vaccination series [26]. This achievement may be attributed to Malaysia's National COVID-19 Immunisation Programme, which combined free vaccination, targeted outreach services and whole-of-government and whole-of-society collaboration. Health education and risk communication were delivered through mass media, social media, messaging applications, electronic platforms and printed materials, allowing vaccination information to reach both urban and geographically isolated communities.

Nevertheless, high national vaccination coverage did not completely eliminate inequalities in access. Geographical location, transportation limitations and distance from healthcare facilities remained important considerations for remote populations. Future pandemic and routine immunisation programmes should therefore maintain mobile vaccination teams, community-based vaccination centres and collaboration with local leaders. Communication should also be culturally appropriate, delivered in languages understood by local communities and adapted to specific concerns rather than relying exclusively on general national messages.

MySejahtera may also have contributed to Malaysia's vaccination coverage by functioning as an integrated platform for vaccine registration, appointment scheduling, reminders and digital vaccination certification. The application allowed individuals to manage appointments and access vaccination records through a single digital system, thereby reducing some administrative barriers (Ministry of Health Malaysia, n.d.). More importantly, vaccination status in MySejahtera became connected with participation in selected public, religious, commercial and recreational activities during particular phases of the National Recovery Plan.

For example, certain standard operating procedures permitted only fully vaccinated, healthy and asymptomatic individuals to attend congregational prayers at mosques and surau. Attendance was recorded using MySejahtera or manual registration systems. These requirements applied to the five daily obligatory prayers and Friday prayers during specified periods (National Security Council, 2021). Consequently, individuals who regularly attended congregational prayers could be required to verify their vaccination or health status repeatedly, creating a practical link between vaccination and participation in communal religious life.

Similar procedures were implemented at supermarkets, shopping centres and other commercial premises. Customers commonly scanned MySejahtera QR codes, while staff or security personnel monitored health-risk status, vaccination evidence, temperature screening and premise capacity. Proof of vaccination could be presented through a digital certificate, a screenshot or a physical vaccination card (MySejahtera, n.d.). Physical documentation and manual registration were particularly important for older adults and individuals without smartphones or adequate digital literacy.

The repeated requirement to demonstrate vaccination status may have reinforced vaccine uptake by linking vaccination with the restoration of everyday activities, including purchasing essential goods, attending religious services, working and participating in social activities. However, the present study did not directly establish that MySejahtera requirements caused higher vaccination uptake. It is therefore more appropriate to conclude that MySejahtera and vaccination-related access policies may have reinforced uptake alongside free vaccination, outreach services, community engagement, effective communication and perceived COVID-19 risk. Further research is needed to determine which digital, communication and outreach strategies had the greatest influence among different remote-community groups.

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