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Postvaccination breakthrough SARS–CoV–2 infections among adults in Malaysia and attitudes towards future vaccination

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ABSTRACT

Objective: To determine the frequency and severity of the breakthrough infections and the associated factors in Malaysia.

Methods: This cross-sectional study was conducted among the adult general population in Malaysia who completed at least one dose of vaccination. The validated online questionnaires were used for data collection between December 2022 to February 2023. The participants were recruited by a convenient sampling method. The data were analysed by descriptive statistics, and logistic regression by using SPSS (Version 27). Qualitative data from open-ended questions were analysed as thematic analysis by using RQDA software.

Results: A total of 524 participants' data were analyzed and 77.5% of them completed three doses of COVID-19 vaccination. Breakthrough infections after vaccination were reported in 57.3% of the participants. Age group of 18 and 30 years (aOR 2.32, 95% CI 1.01-5.32) and other ethnicities (aOR 2.00, 95% CI 1.02-3.93) significantly associated with the occurrence of breakthrough infections. A total of 35.5% of the participants were not willing to take another booster dose in the future because of their attitudes towards fear of long-term side effects, lack of trust to the vaccine, less susceptibility to severe infection, belief in natural immunity, and myths.

Conclusions: Future public health policies and interventions should be focused on disseminating the information about safety of booster doses of vaccine, management and re-assurance of side effects, and targeted vaccination to the working (younger age group) and ethnic minorities.

KEYWORDS: COVID-19; SARS CoV-2; Breakthrough infection; Vaccine; Malaysia

1. Introduction

The COVID-19 pandemic is documented as the fifth pandemic since the flu pandemic in 1918[1]. According to the World Health Organization (WHO) report on March 11, 2022, tens of millions of individuals had been affected globally by the COVID-19. The report also found that the most vulnerable groups to COVID-19 and its problems included older adults, those who suffered from comorbid diseases, and front-line workers[2]. In view of this, many renowned pharmaceutical companies started to develop vaccines against COVID-19 and were approved for emergency use[3].

In Malaysia, Pfizer's mRNA-based vaccine was one of the first vaccines that received conditional registration approval from the

Significance

COVID-19 breakthrough infections were common among the Malaysian population with approximately half of the vaccinated people having contracted it. 30–40 years age group and other ethnicities are more likely to get breakthrough infection. Interestingly, 35.5% of the participants were not willing to take the booster dose in the future due to fear of long-term side effects, lack of trust, beliefs in natural immunity, and myths about vaccines.

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Ministry of Health[4]. It was estimated that about 88.3% of the Malaysian population would have received their primary vaccination series by January 2022[4]. Various data reported that vaccination provided significant protection from all main variants, including the most fatal Delta variant. Despite that, there were growing concerns over the protection provided by the vaccines as the breakthrough infections were reported globally among fully vaccinated individuals[5].

Breakthrough infection is defined as, an infection in which a vaccinated individual gets infected due to the failure to provide proper immunity against the infection[6]. Vaccines were designed to prevent transmission of SARS-CoV-2 through two main approaches *i.e.* through prevention of primary infection and secondly by fewer cases of breakthrough infections[7]. Breakthrough SARS-CoV-2 infections among fully vaccinated individuals were reported mainly among the Delta variants and Omicron variants[8]. One of the causes of breakthrough SARS-CoV-2 infection was caused by the fast waning of immunity among fully vaccinated individuals (within a few months). Most of the vaccines for COVID-19 were reported to be effective against serious forms of COVID-19 but not fully effective in preventing breakthrough infections[9].

In Asia, the prevalence of breakthrough infections after COVID-19 vaccination has been reported in India as 23.36%[10], Bangladesh as 38.5%[11], and Nepal as 12.63%[12]. In Malaysia, a prospective cohort of 551 healthcare professionals reported that the prevalence of breakthrough infections among healthcare workers was 10% in 2021[4].

A plethora of studies on breakthrough infections of SARS-CoV-2 among fully vaccinated individuals were conducted in many countries[13–16]. Although a study was conducted to investigate the prevalence of breakthrough SARS-CoV-2 infections among healthcare workers in Malaysia, prevalence data in large-scale communities is still limited in Malaysia. Therefore, this study was undertaken to find the frequency and severity of these breakthrough infections and their associated factors in Malaysia. Furthermore, this study explored the willingness to take booster COVID-19 vaccination as well as reasons for unwillingness to take the vaccination in the future.

2. Subjects and methods

2.1. Study design and setting

This cross-sectional study was conducted among the Malaysian adults with age 18 years and above, between December 2022 and February 2023.

2.2. Sample size and sampling

The sample size was estimated by using Epi info software, with an estimated prevalence of 10%[4], a confidence interval of 95%, and a margin of error of 3%. It was estimated that this survey needs a minimum sample size of 384 adults.

Study participants were recruited by using convenience sampling from the general population in Malaysia. The inclusion criteria were adults above 18 years living in Malaysia who had received at least one dose of COVID-19 vaccination. The exclusion criteria include those who did not provide informed consent and those who were never vaccinated. Participants recruitment and data analysis process are presented in Figure 1.

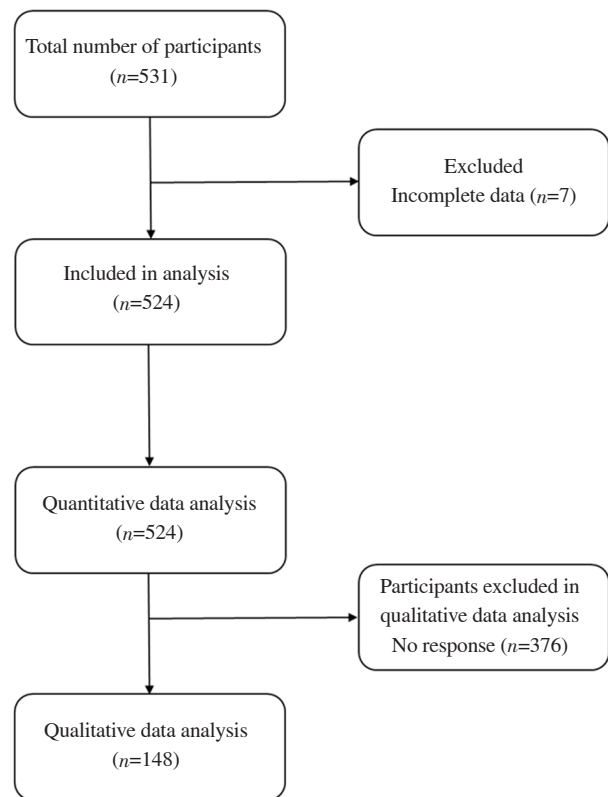


Figure 1. Flow diagram of the participant recruitment in the study.

2.3. Data collection

The questionnaires were developed in Google form format and administered through social media and other platforms for example, through WhatsApp, Instagram, Twitter, and emails. This survey was conducted using self-administered questionnaires incorporating the five different components, namely (1) demographic, comorbidities, and personal habits/ lifestyle, (2) COVID-19 vaccination status, (3) breakthrough SARS-CoV-2 infection after vaccination, (4) willingness to take COVID-19 booster dose in the future, and (5) the reason for not willing to take the booster dose in the future.

The questionnaires were content validated by requesting six

experts' opinions and relevancy ratings. The items with an item-content validity index (I-CVI) of 0.83 and above were included in the questionnaire. The content-validated questionnaires used in the data collection were translated into Bahasa Malaysia for those who were less proficient in English. The translation process followed the WHO recommended guidelines on the translation of study instrument[17].

2.4. Data analysis

The data was analyzed as frequency counts, percentage, mean, median, and standard deviation. Inferences and associations between post-vaccination and breakthrough SARS-CoV-2 infections were assessed by multivariate binary logistic regression. The data was analyzed using IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp. Qualitative data from the open-ended questionnaire was analyzed by using RQDA: R-based Qualitative Data Analysis; R package version 0.3-1.

2.5. Ethical consideration

The participation was voluntary participation and informed consent was obtained. The study protocol has been registered at National Medical Research Register (NMRR) Malaysia (NMRR ID-23-01501-9WI). Ethical approval was granted from the Research Ethics Committee, Manipal University College Malaysia (MUCM), Malaysia (Ref no: 004/2023).

3. Results

Table 1 shows the socio-demographic characteristics of the participants. A total of 524 participants' data were analyzed in this study. The median age of the participants was 24 years, consisting of 59.5% males and 40.5% females (Table 1).

Figure 2 shows the types of COVID-19 vaccination taken for each dose among the participants. Pfizer is the common vaccine taken for all doses, which is followed by AstraZeneca (Figure 2). Among the participants, 8.8% took 4 doses, 77.5% took 3 doses, 13.4% took 2 doses, and 0.4% took only 1 dose of COVID-19 vaccinations. Table 2 shows the breakthrough SARS-CoV-2 infections among the participants. A total of 57.3% participants in this study reported having breakthrough SARS-CoV-2 infection at least one time (Table 2).

As for the duration and severity of breakthrough SARS-CoV-2 infection among the participants, the mean duration of illness was 6.87 days. Approximately half of the participants who had breakthrough infections after the first dose of vaccination had Category 1 COVID-19 while in the repeated breakthrough infections, most of them were in Category 2A (Figure 3).

Table 1. Demographic characteristics of participants (n=524).

Variable	n (%)
Age, years, median (IQR)	24 (22-42)
Sex	
Male	212 (40.5)
Female	312 (59.5)
Ethnicity	
Malay	66 (12.6)
Chinese	217 (41.4)
Indian	146 (27.9)
Others*	95 (18.1)
Living area	
Rural	21 (4.0)
Suburban	105 (20.0)
Urban	398 (76.0)
Occupation	
Healthcare professionals	62 (11.8)
Non-healthcare professionals	189 (36.1)
University students	242 (46.2)
Unemployed	31 (5.9)
Income	
<RM 4850 / month	217 (41.4)
RM 4850-RM10970 / month	175 (33.4)
>RM 10970 / month	132 (25.2)
Blood group	
A	107 (20.6)
B	146 (28.1)
AB	46 (8.8)
O	221 (42.5)
BMI (kg/m ²)	
Underweight (<18.5)	66 (12.6)
Normal weight (18.5-22.9)	183 (35.1)
Overweight and obesity (≥23)	273 (52.3)
Comorbidities [†]	
Yes	110 (21.0)
No	414 (79.0)
Smoking [‡]	
Yes	38 (7.3)
No	486 (92.7)
Regular physical activity	
Yes	377 (71.9)
No	147 (28.1)
Diet	
Vegetarian	22 (4.2)
Non-vegetarian	502 (95.8)
Fruits intake	
Yes	151 (28.8)
No	373 (71.2)
Vitamin supplement	
Yes	269 (51.3)
No	255 (48.7)

Missing information: Blood group (n=4), BMI (n=2).

*Other ethnicities including other Bumiputra populations; [†]Comorbidities including diabetes, hypertension, heart disease, liver diseases, kidney disease, asthma, chronic obstructive pulmonary disease; [‡]Smoking (Yes) means current smoker regardless of the number of cigarettes and (No) means do not smoke at the time of data collection including never smoker or ex-smoker.

Table 3 shows the binary logistic regression analysis of factors associated with the occurrence of breakthrough infections among the participants. Participants between the age of 30 and 40 years were more likely to contract breakthrough infections compared to the younger age group between 18 and 30 years (aOR 2.32, 95% CI

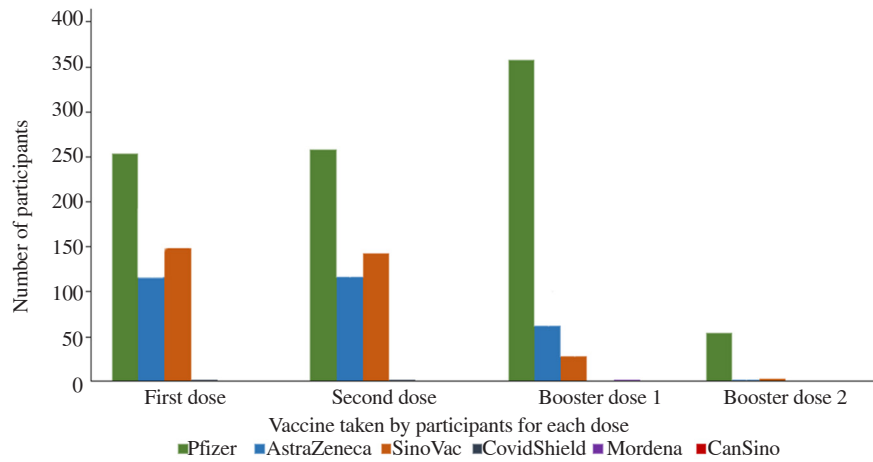


Figure 2. COVID-19 vaccines taken by participants for each dose (n=524).

1.01-5.32). Other ethnicities were more likely to be contracted with breakthrough infections compared to Malay ethnicity (aOR 2.00, 95% CI 1.02-3.93) (Table 3). One-third (35.5%) of the participants reported that they were not willing to take another COVID-19 vaccine booster dose in the future.

Table 2. COVID-19 breakthrough infection among the vaccinated participants (n=524).

Total number of breakthrough infection	COVID-19 breakthrough infection, n (%)	
	Yes	No
No breakthrough infection	-	224 (42.7)
One time	229 (43.7)	-
Two times	40 (7.6)	-
Three times	17 (3.2)	-
Four times	14 (2.7)	-
Total	300 (57.3)	224 (42.7)

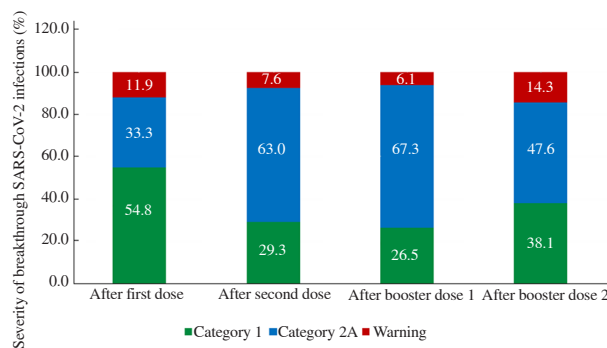


Figure 3. Severity of breakthrough infections. The risk categories are classified into 3 categories according to the MySejahtera mobile application applied for COVID-19 pandemic in Malaysia. “Category 1: Asymptomatic COVID-19 positive patients. Category 2A: Symptomatic COVID-19 positive patients. Symptoms include fever, cough, loss of taste, loss of smell, and sore throat. Warning: Symptomatic COVID-19 positive patients with worsening symptoms, namely, difficulty in breathing, chest pain/discomfort, lethargy, diarrhoea, nausea and/or vomiting, cyanosis (face; and/or lips turning blue), drowsiness; and/or light headedness, and hypoxia (oxygen saturation <95%)”.

Among the 524 participants, 148 participants shared their attitudes and experiences regarding COVID-19 vaccination. To ascertain the anonymity of the participants, the coding of P (ID number)

was provided for each qualitative data and included in the thematic analysis. Four salient themes developed from the answers of qualitative data, *i.e.* (I) attitudes towards COVID-19 vaccine, (II) attitudes towards SARS-CoV-2 infection, (III) personal factors, and (IV) beliefs in alternative prevention methods.

I . Attitudes towards COVID-19 vaccine

(1) Lack of confidence and trust

Participants in this study revealed a lack of confidence and trust on COVID-19 vaccination after getting the breakthrough infections.

The participants revealed their thoughts as follows:

“Because I did not trust the vaccine (P 16)”

“Totally avoiding COVID-19 is impossible even with vaccination (P 19)”

(2) Received adequate doses

In addition, the participants considered that they have already received adequate doses of COVID-19 vaccination and therefore, they do not need to take further booster doses in the future.

“The reason that I won't take another dose of vaccine is because the first two dose which is the first and the second is already enough for the immunization of the whole body. (P 123)”

(3) Fear of side effects and long-term sequel

The main concern raised by most of the participants was due to the fear of the side effects of the vaccine. Participants' concern about the future negative consequences of the COVID-19 vaccination are as follows:

“Seems like there is no end. And worried that what could be the long-term effects on our bodies due to the vaccines. At some point, it just feels like they try to get profit through this. I know as a future medical officer, I shouldn't be saying this. But as a human being, I think we should be open to all kinds of issues. As I know some doctors also strictly advised to avoid getting anymore vaccines. (P 108)”

“The long-term underlying risk of the vaccine is still unknown. (P 122)”

Table 3. Factors associated with COVID-19 breakthrough infection among the vaccinated participants (n=524).

Variable	Univariate analysis			Multivariate analysis		
	Unadjusted OR	95%CI	P	Adjusted OR	95%CI	P
Sex						
Female	Reference					
Male	1.13	0.79-1.60	0.514			
Age						
18-≤30	Reference			Reference		
30-≤40	2.85	1.44-5.64	0.003	2.32	1.01-5.32	0.047
40-≤50	1.15	0.65-2.07	0.625	0.88	0.42-1.86	0.736
50-≤60	1.36	0.77-2.42	0.293	0.76	0.34-1.71	0.511
60-≤70	0.69	0.31-1.51	0.348	0.31	0.11-0.90	0.031
70-≤80	1.14	0.25-5.18	0.864	0.38	0.07-2.12	0.269
Ethnicity						
Malay	Reference			Reference		
Chinese	1.19	0.69-2.07	0.533	1.21	0.67-2.20	0.515
Indian	1.56	0.87-2.81	0.136	1.40	0.74-2.67	0.302
Others*	1.71	0.91-3.24	0.098	2.00	1.02-3.93	0.043
Living area						
Urban	Reference			Reference		
Suburban	0.62	0.40-0.96	0.031	0.59	0.24-1.49	0.265
Rural	0.49	0.20-1.20	0.119	0.67	0.42-1.07	0.090
Occupation						
Healthcare professionals	Reference			Reference		
Non-healthcare professionals	0.60	0.33-1.11	0.104	0.57	0.30-1.11	0.098
University students	0.50	0.27-0.90	0.021	0.60	0.28-1.28	0.187
Unemployed	0.80	0.32-2.00	0.638	1.17	0.42-3.25	0.763
Income						
<RM 4850 / month	Reference					
RM 4850-RM 10970/month	1.12	0.75-1.68	0.569			
>RM 10970/month	1.27	0.82-1.97	0.292			
Blood group						
O	Reference			Reference		
A	1.02	0.64-1.63	0.930	0.97	0.59-1.59	0.907
B	0.97	0.63-1.48	0.874	0.87	0.56-1.36	0.544
AB	0.65	0.35-1.24	0.191	0.62	0.31-1.22	0.162
BMI (kg/m ²)						
Underweight (<18.5)	Reference			Reference		
Normal weight (18.5-22.9)	1.43	0.81-2.52	0.214	1.41	0.78-2.56	0.257
Overweight (≥23)	1.53	0.89-2.62	0.124	1.44	0.80-2.61	0.225
Comorbidities [†]						
No	Reference			Reference		
Yes	1.33	0.87-2.05	0.192	1.49	0.84-2.65	0.169
Smoking [‡]						
No	Reference					
Yes	1.16	0.59-2.27	0.672			
Regular physical activity						
No	Reference					
Yes	0.80	0.54-1.18	0.251			
Diet						
Vegetarian	Reference					
Non-vegetarian	1.64	0.70-3.87	0.257			
Fruits intake						
No	Reference					
Yes	0.98	0.67-1.44	0.915			
Vitamin supplement						
No	Reference			Reference		
Yes	1.24	0.88-1.76	0.217	1.40	0.96-2.06	0.082

Significant level 0.25 (univariate analysis); *Other ethnicities including other Bumiputra populations; [†]Comorbidities including diabetes, hypertension, heart disease, liver diseases, kidney disease, asthma, chronic obstructive pulmonary disease; [‡]Smoking (Yes) means current smoker regardless of the number of cigarettes and (No) means do not smoke at the time of data collection including never smoker or ex-smoker.

(4) Previous COVID-19 vaccination experience

Study participants reported that previous experiences of side effects greatly influence their decision to take booster doses in the future.

Participants encountered various side effects including chills and flu-like symptoms, fatigue, dizziness, and skin allergies, which became a barrier to the intention to uptake the vaccine in the future.

Participants reported their experiences on side effects as follows:

“Since I got my vaccine, I realised that my immune system was getting low. I often felt sick with flu or fever few times in a year. Before this, I only got sick once or twice per year. (P 115)”

“I feel after my 3rd dosage, I got some complications such as nerve problems (P 57)”

“After the vaccine shot, unknown skin allergies only on the hands, same with my patients. Memory became really bad (P 70)”

(5) Myths about the COVID-19 vaccine

The COVID-19 pandemic is the first pandemic in history that occurred in the era of technology, leading to an overbalance and the spread of information. The infodemic, mis- and disinformation, spreading of rumours and myths were challenges for healthcare providers during that period. In this study, participants revealed the myths and misinformation they have heard as follows:

“Heard rumours that there are side effects to the health after taking the second booster (P 43)”

“Too many negative and frightening comments (P 129)”

“Got chip inside (P 40)”

II. Attitudes toward SARS-CoV-2 infection

(1) Less severe infection

Participants in this study were optimistic that COVID-19 was less severe when encountering changes of variants. This perspective leads to reducing the importance of taking booster doses.

“New emerging variants, less severe (P 1)”

(2) Natural immunity from infection

While others believed that immunity attained from natural infection was sufficient to protect them from another SARS-CoV-2 infection.

“Being infected with SARS-CoV-2 has provided me the sufficient antibodies to deal with it again (P 24)”

“The infection was a natural booster. (P 121)”

(3) Variant change

Participants were aware of the variant changes and consider that taking the vaccine might not be protective from the new variant. Participants mentioned that

“COVID-19 virus keeps mutating (P 45)”

“(I do not wish to take booster dose in the future) Because variant keep on changing (P 23)”

This perception led to non-adherence to booster dose recommendations to prevent COVID-19.

III. Personal factors

(1) Beliefs in natural immunity

Personal beliefs about their immunity influenced their decision to deny future vaccination. The participants revealed their personal beliefs as follows:

“Because I would prefer that my body build its own immunity instead of constantly depending on drugs for immunity because it may create withdrawal in the future. (P 18)”

(2) Other personal factors

Furthermore, personal feelings on annoying to take the vaccination, relying on faith, and lack of time due to a busy schedule to take vaccinations were barriers to taking booster doses.

“I already accepted the fate... No matter how many doses I take, I will still get infected by the way. (P 45)”

IV. Alternative methods for prevention

(1) Self-care and wellness

Self-protection and wellness were given the attention by the participants to prevent SARS-CoV-2 infection instead of taking the vaccine. Healthy diet, physical fitness, and vitamin supplements were believed to be sufficient to protect against COVID-19 vaccination.

“I prefer to take my precautions instead of a vaccine that has no proven data (P 64)”

“Take a lot of supplements for increasing immunity. (P 118)”

“I am managing my diet and physical fitness well now (P 11)”

(2) Preference on traditional methods of prevention

Some participants believed in traditional medicine for the prevention of SARS-CoV-2 infection and reported as

“I use traditional methods (medicine to prevent SARS-CoV-2 infection) (P 69)”.

4. Discussion

This cross-sectional study was conducted among the Malaysian general population to study the breakthrough SARS-CoV-2 infections among adults in Malaysia. In this study, we found that 57.3% of the adults in Malaysia had breakthrough SARS-CoV-2 infections. Previous studies conducted among healthcare workers in Malaysia reported that 10% of their study participants developed breakthrough infections from 10 to 24 weeks after the vaccination[4]. The prevalence rate was much higher in the current study compared to the study among healthcare workers. It could be contributed to the duration of the study period, as in that study, the observation period was for 24 weeks[4]. In our study, the cumulative occurrence of breakthrough infections were reported after the introduction of the national vaccination drive in February 2021 till the conduct of this study in 2023. Moreover, a previous study reported that humoral responses gradually declined six months after second dose of the vaccine[18]. Weaning of IgG antibody titre over a period might be a contributing factor to the higher prevalence of breakthrough infections. The findings of our study could be related to the spike of Omicron initiated since February 2022 and a surge of infections and re-infections in Malaysia[19]. Our finding was similar to the high prevalence reported in the US, among 79% of the immunized individuals[7].

Re-infection of SARS-CoV-2 has been reported in previous

studies[20,21]. A study conducted in the US reported that 2.5% of the study participants had re-infection with an interval of at least 90 days apart[21]. Another study from London care homes reported a high rate of re-infection of 13.9%[22]. The re-infection could occur in a short period even within the interval of from 20 to 60 days[23]. However, the repeated infections were less severe compared to the first-time SARS-CoV-2 infections[23]. Literature is limited about the frequency of re-infection in the community. In our study, the participants reported breakthrough infections up to four times. In the previous report, it was reported that a person was infected three times with SARS-CoV-2 infection[24]. Therefore, taking personal precautions along with booster vaccination are the recommendation to prevent severe infection.

In our study, a significant association was found between post-vaccination breakthrough infections and the age demographic variable. This study revealed that the younger age group (30–40 years) was more likely to get the breakthrough infections while the older age group (60–70 years) was less likely to get the breakthrough infection. This finding is similar to a study conducted in Texas, where the incidence of breakthrough infections were the highest among 20 to 39 years of age, and lowest among people aged 60 years and above[25]. On the contrary, a study done among Indian citizens showed that the older age group (61 years and above) was found to be at higher risk of getting breakthrough infections[26]. However, the prevalence of COVID-19 is lower among the elderly group (12.6%) aged 65 years and above compared to the prevalence in the 18–50 years age group (43.9%)[27]. Re-opening of the international border and lifting of the movement control order had increased travel, interaction and communication, which might have caused the surge in infections[28]. A modelling study in the US revealed that the younger age group (35–44 years) had the highest contact intensity compared to the older age group (45 years and above)[29]. In addition, the 20–49 years age group mainly sustained the resurgence of the infection in the US[29]. Therefore, it is necessary to focus on the younger age group to prevent breakthrough infections.

Ethnicity was found to be associated with the occurrence of breakthrough SARS-CoV-2 infection in our study. Other ethnicities in Malaysia such as smaller Bumiputra populations in Malaysia reported to have a higher likelihood of contracting breakthrough infection. Other Bumiputra populations included ethnic groups such as Kadazan-Dusun, Iban, Bidayuh, Orang Ulu, *etc.* They are mainly living in East Malaysia, Sabah, and Sarawak. This finding could be related to the fact that vaccine hesitancy was reported to be high among those who lived in the East Coast zone and Sabah[30]. The vaccination progress still needs to be improved in Sabah where only 65.9% of the population received at least two doses of the COVID-19 vaccine and it was considered to be the second lowest vaccine uptake state in Malaysia[31]. Furthermore, the adult (18 to 59 years)

population vaccination rate was the lowest in Sabah compared to the other states in Malaysia by October 2022[31]. Similar findings were reported in Texas where a specific ethnic group, whites, reported the highest incidence of breakthrough infections[25]. Therefore, it should be ascertained that COVID-19 booster vaccination and prevention should be utilized across different ethnic groups across Malaysia.

The qualitative findings from the open-ended question revealed the participant's past experience with COVID-19 vaccination, reasons for hesitancy to take booster doses in the future, and their own preferred way for prevention of SARS-CoV-2 infection. Trust in the vaccine, susceptibility, religious beliefs, and attitudes were found to be the predictors of COVID-19 vaccine uptake in Malaysia[32]. Another qualitative study among the Malaysian population explored and revealed that mistrust of vaccines, beliefs in conspiracy theories, and personal beliefs shaped their vaccine hesitancy and refusal[33]. Concern about unknown long-term side effects was also revealed as a hindering factor to taking the vaccination[34]. Qualitative findings from our study suggested that the attitudes towards the vaccine and attitudes towards SARS-CoV-2 infections have important influence on the intention to take booster doses in the future. Belief in natural immunity and a sense of safety seems to hinder their intention to uptake of the vaccine. Interventions to provide the correct information about the safety of vaccines, improve the perceived susceptibility of re-infection with SARS-CoV-2, combat myths, and re-assurance and management of side-effect of vaccines should be focused on future interventions.

Our study had some limitations. First, the data was collected by using the questionnaire without laboratory findings and clinical data. Therefore, self-reported data might cause an information bias in this study. Second, a non-probability sampling method was used to recruit the participants. Therefore, the finding might limit the generalizability to all Malaysian populations. Third, the participant's attitude towards booster dose vaccination was enquired as an open-ended question. Therefore, in-depth information on their attitudes and perception might not be able to capture completely. Further qualitative studies should be explored to have a better understanding of the prevention of COVID-19 and vaccination.

In conclusion, our finding demonstrated that breakthrough SARS-CoV-2 infection is common among the Malaysian population with approximately half of the vaccinated people having contracted it. However, most of the breakthrough infections were symptomatic positive cases without warning signs (Category 2A). The age group of (30–40 years) and other ethnicities were more likely to get breakthrough infections. Interestingly, 35.5% of the participants were not willing to take the booster dose in the future due to fear of long-term side effects, lack of trust, beliefs in natural immunity, and myths about vaccines. Future public health policies and interventions should be focused on disseminating the information about safety

of booster doses of vaccines, management and re-assurance of side effects, and targeted vaccination to working (younger age group) and ethnic minorities. Further clinical and longitudinal studies should be continued to investigate the breakthrough infections and severity, development of immunity from booster dose and natural infection.

Conflict of interest statement

The authors declare that there are no conflicts of interest.

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Authors' contributions

PKN, KEK, CYB, LARN, and MDM contributed to the study conception and design. PKN, KEK, CYB, LARN, MDM, and KMR were involved in data collection. MLNNH and HHKS contributed for data processing and quantitative data analysis. MLNNH and SM conducted qualitative thematic synthesis. PKN, KEK, CYB, LARN, MDM, KMR, and MLNNH prepared the first draft of the manuscript. Manuscript editing was done by SM, HHKS, and TMK. All authors have reviewed and approved the final manuscript for publishing.

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