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Influence of maternal risk perception and vaccination knowledge on childhood vaccination intentions

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Abstract

Background Vaccine hesitancy remains a significant barrier to effective public health strategies aimed at overcoming the resurgence of vaccine-preventable diseases globally. This study aims to explore the roles of maternal knowledge, risk perception, health self-efficacy, and demographic characteristics in influencing the intention of antenatal mothers to accept childhood vaccination for their newborns.

Methods A descriptive and analytic cross sectional study design was conducted from March to September 2021, among antenatal mothers attending routine antenatal follow-ups at 17 public health clinics in Selangor, Malaysia. A validated and reliable self administered questionnaire was used to collect data on demographic characteristics, knowledge, risk perceptions, health self-efficacy, and vaccination intentions among antenatal mothers. Multiple linear regression analysis was used to identify determinants of vaccination intention among antenatal mothers.

Results The study included 796 antenatal mothers, predominantly Malay mothers (87.5%). The respondents presented a high mean vaccination intention score of 26.02 ± 2.77. Significant determinants of vaccination intention among antenatal mothers included the number of children ($\beta = 0.156$, 95% CI [0.013, 0.299], $p = 0.032$), knowledge score ($\beta = 0.397$, 95% CI [0.288, 0.506], $p < 0.001$), and risk perception score ($\beta = 0.047$, 95% CI [0.036, 0.058], $p < 0.001$). However, health self-efficacy was not significantly associated with vaccination intention.

Conclusion Psychological and cognitive factors play important roles in influencing maternal vaccination intention. Intervention that aimed at increasing level of maternal knowledge and addressing maternal risk perception, focusing on less experienced mothers would be an effective strategies to improve maternal vaccination intention.

Keywords Immunization, Vaccine hesitancy, Knowledge, Perception, Self-efficacy, Parent

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Introduction

Vaccination is one of the most effective public health interventions for preventing infectious disease, saving millions of lives annually. The importance of vaccines has been well recognized since 1974 when the World Health Organization (WHO) initiated a vaccination program known as the Expanded Program on Immunization (EPI) [1]. Since then, there has been a notable decline in the prevalence of vaccine-preventable diseases, resulting in the prevention of over 2 million child deaths annually [2]. Additionally, the role of vaccination is pivotal in advancing the Sustainable Development Goals (SDGs), notably SDG 3, which aims to ensure healthy lives and well-being for all ages, and focuses on immunization as one the strategies to reduce under-5 mortality [3]. Despite their proven efficacy, vaccine hesitancy remains a significant global health challenge. Vaccine hesitancy can be defined as delay in acceptance or refusal of vaccination despite the availability of vaccination services [4]. The World Health Organization (WHO) has identified vaccine hesitancy as one of the top ten threats to global health, highlighting the urgent need to address the underlying factors contributing to this issue [5].

In Malaysia, the Malaysian National Immunisation Programme (NIP) was established in the early 1950s and effectively protects against thirteen vaccine-preventable diseases. However, despite the long establishment of the NIP, Malaysia recently faced a new challenge, whereby the prevalence of primary vaccination completion among children aged 12–23 months recently decreased from 95.3% in 2016 to 87.1% in 2022 [6]. There was a tenfold increase in the prevalence of unvaccinated children, increasing from 0.1% in 2016 to 1.0% in 2022,with 5% Malaysia parents being vaccine-hesitant [6]. Despite this small percentage, the growing trend of vaccine hesitancy among the Malaysian population warrants closer examination.

Understanding vaccine acceptance and hesitancy necessitates a holistic approach that transcends sociodemographic and socioeconomic traits. Psychological and cognitive factors, such as knowledge, risk perception, and health self-efficacy, are equally vital in shaping individuals's vaccination intentions as they have received considerable attention in the literature as key determinants of vaccine related behaviors. Knowledge and risk perception enable individuals to recognize immunization's broader societal benefits and understand the risks associated with being unvaccinated, hence pivotal in influencing vaccine related behavior. Health self-efficacy may influence vaccination intention by empowering individuals to make informed immunization decisions. Numerous studies worldwide have suggested that possessing adequate knowledge about vaccine, higher risk perception of not vaccinating, and higher health self-efficacy are associated with increased vaccination intention and reduced vaccine hesitancy [7–16].

Previous studies in Malaysia have examined vaccine attitudes among antenatal mothers. However, only a few have explored how demographic characteristics, maternal knowledge, health self-efficacy, and risk perception influence one another in shaping the vaccination intention. Recognizing the important roles of these factors, this study aims to further explore their roles in shaping the intention to accept childhood vaccination among antenatal mothers in Selangor, a state in Malaysia that is known for its diverse, multi ethnicity population. By choosing public health clinics in Selangor as study setting, this study seeks to further understand the influence of sociocultural factors within a more socioeconomically diverse population, whose vaccination attitudes may differ from those observed in previous studies [17–19].

Methodology

Study design and setting

A descriptive and analytical cross sectional study design was conducted from March to September 2021, among antenatal mothers attending routine antenatal follow-ups at 17 public health clinics in Selangor, Malaysia. Selangor is a state in West Malaysia, consisting of nine districts, that is known for its diverse, multi ethnicity population. The combination of urban and sub-rural districts in Selangor provides a suitable landscape for exploring the predictors of vaccination intention from a diverse population background. A validated and reliable self administered questionnaire was used to collect data on demographic characteristics, knowledge, risk perceptions, health self-efficacy, and vaccination intentions among antenatal mothers. The sociodemographic and socioeconomic background of study participants was described in the descriptive study, along with the scores of each factor. The cross sectional analysis enabled further exploration of associations between factors and the antenatal mothers' vaccination intention.

Study methods and participants

A multistage random sampling method was used to identify potential respondents. In the first stage, 17 public health clinics were selected from a list of 78 public health clinics in Selangor via a computer-generated simple random sampling method. In the second stage, proportionate random sampling was used to determine the number of participants required from each selected clinic. Within each clinic, systematic random sampling was applied to identify antenatal mothers attending for follow-ups as potential respondents.

Antenatal mothers meeting the following criteria were invited to participate in the study: (a) Malaysian citizens, (b) over 20 years old, and (c) had completed a primary

school certificate. Potential respondents were excluded if they: (a) were known sexual assault victims, or (b) had been diagnosed with or suspected of having mental illness. These exclusions were made because these individuals are considered vulnerable populations that might face emotional distress, negative effects on pregnancy or the baby, or trauma from participating in research [20]. Antenatal mothers who met the criteria and agreed to participate were asked to complete a written consent form and fill out a hardcopy questionnaire. Only those who provided informed consent were included in the study.

With the use of OpenEpi program software [21] version 3.01, the t-test was employed for a priori sample size calculation to achieve a power of 90%, minimizing the risk of Type II errors and ensuring reliable results for this critical public health study. A power of 90% was chosen to enhance the study's ability to detect meaningful associations, particularly in addressing vaccine hesitancy, a complex public health issue where small effect sizes can have significant implications. The confidence interval was set at 95%, requiring a total of 534 participants. Considering a 20% non-response rate [22, 23] and 10% missing data, the final sample size required was 695 respondents.

Study instruments

A validated questionnaire comprising five sections was used in this study, with all sections adopted from validated instruments established in prior local studies [24–27]. These instruments had undergone rigorous assessment for construct validity and reliability in their original studies, ensuring their suitability for measuring the intended constructs in the current context. Details for each section and questionnaires used are described in subsequent section.

The first section of questionnaire covers the sociodemographic and socioeconomic background of antenatal mothers. The remaining sections measure the four main constructs; (a) vaccination knowledge, (b) risk perception, (c) health self-efficacy, and d) vaccination intention. The variables measured in the study are as follows.

Sociodemographic and socioeconomic characteristics

a) **Age** (years): The participants' chronological age at the time of the study, measured as a continuous variable.
b) **Number of Children**: Total number of living children the participants have before the current pregnancy, measured as a continuous variable.
c) **Ethnicity**: The ethnic background of the participants, categorized as Malay, Chinese, Indian, or Indigenous.
d) **Education Level**: Categorized into two groups, "Primary/Secondary" and "College/University", which capture the highest level of formal education completed by the participants [28].
e) **Mother's income and household income**: Economic status of the participants and the household, respectively. The categories include B40 (< 6,000 *Ringgit Malaysia*), M40 (6,000–12,000 *Ringgit Malaysia*), and T20 (> 12,000 *Ringgit Malaysia*).

Vaccination knowledge

Vaccination knowledge was assessed via the Immunization Knowledge Questionnaire developed by Awadh et al. (2014) [24]. This questionnaire evaluates knowledge related to vaccines, the vaccination process, and its outcomes. It consists of ten items with response options of yes, no, or do not know, administered in Malay. Each correct response is awarded one point, whereas incorrect or no responses receive zero points. The Cronbach's alpha for the vaccination knowledge items was 0.75, indicating acceptable reliability. Scores range from 0 to 10, with higher scores reflecting greater knowledge of vaccination [24].

Vaccination risk perception

Risk perception is defined through two subdimensions of risk perception, (i) perceived severity and (ii) perceived likelihood. Perceived severity measures antenatal mothers' views on the seriousness of the consequences of vaccine-preventable diseases (VPDs), whereas perceived likelihood assesses the probability of their children being infected with VPDs if left unvaccinated. It was assessed via the risk perception scale developed by Nazori et al. (2022), which includes 15 items on a 7-point Likert scale in Malay [25]. The scale which includes seven items assessing perceived likelihood and eight items assessing perceived severity. Construct validity and reliability was established from previous study, with Cronbach's alpha for the scale was 0.94, indicating high internal consistency. The response options range from 1 "strongly disagree" to 7 "strongly agree," with total scores ranging from 15 to 105. Higher scores reflect a heightened perception of risk among expectant mothers.

Health self-efficacy

Health self-efficacy refers to an individual's confidence in his or her ability to manage health-related situations. In this study, health self-efficacy was assessed using the Health Efficacy and Assertiveness Scale developed by Stadtlander et al. (2015) [29], translated into Malay language and validated for its construct validity and reliability by Nazori et al. (2022) [26]. The scale consists of 5 items on a 7-point Likert scale that measures the antenatal mothers' perceived ability to handle health-related challenges. The total scores range from 5 to 35, with

response options ranging from 1 "I will certainly never do", to 7 "I will certainly do." The items measuring health self-efficacy have a Cronbach's alpha of 0.76, indicating acceptable reliability in assessing the health self-efficacy construct.

Vaccination intention

Vaccination intention, which represents maternal intention to vaccinate newborns according to Malaysia's National Immunization Program, was assessed via 4 items adapted from studies by Dubé et al. (2012) and Paek et al. (2015) and translated into the Malay language by Mohd Nazori et al. [27, 30, 31]. Construct validity and reliability was established from previous study, with Cronbach's alpha reliability for the items was 0.96, indicating high internal consistency [27]. The responses were on a 7-point scale from 1 "totally disagree" to7 "totally agree", with scores ranging from 4 to 28;- higher scores indicate stronger vaccination intention.

Statistical analysis

All the statistical analyses were conducted using SPSS for Windows, Version 26. Descriptive statistics included frequencies and percentages for categorical sociodemographic and socioeconomic variables, where as mean and standard deviations were used for continuous variables:

Table 1 Characteristics of antenatal mothers, scores of knowledge, risk perception, health self-efficacy, and vaccination intention

Variables	Frequency, *n* (%)	Mean (SD)
Age (years) (*n* = 796)	-	31.07 (4.64)
No of Children (*n* = 796)	-	1.37 (1.24)
Education Level (*n* = 792)		
Primary/Secondary	231 (29.2%)	
Colleges/University	561 (70.8%)	
Ethnicity (*n* = 784)		
Malay	686 (87.5%)	
Chinese	42 (5.4%)	
Indian	34 (4.3%)	
Indigenous	22 (2.8%)	
Mothers Income (*n* = 784)		
B40	738 (94.1%)	
M40	45 (5.8%)	
T20	1 (0.1%)	
Household Income (*n* = 770)		
B40	667 (86.7%)	
M40	95 (12.3%)	
T20	8 (1.0%)	
Knowledge score (*n* = 796)	-	6.64 (1.68)
Risk Perception score (*n* = 796)	-	79.69 (16.61)
Health Self-Efficacy score (*n* = 796)	-	23.63 (5.84)
Vaccination Intention score (*n* = 796)	-	26.02 (2.77)

B40 = Bottom 40% income group, M40 = Middle 40% income group, T20 = Top 20% income group

age, number of children, knowledge score, risk perception score, health self-efficacy score, and vaccination intention score. The continuous data were found to be normally distributed, justify the use of parametric test in further analyses. Normality of data was checked through both graphical methods, and skewness and kurtosis indices.

Associations and correlations between variables were assessed via independent t-test, one-way ANOVA, and Pearson correlation tests. Simple Linear Regression (SLR) was then employed to evaluate variable relationships and variables with $p < 0.25$ in SLR underwent further analysis using Multiple Linear Regression (MLR), adjusting for confounding factors to identify determinants of vaccination intention among antenatal mothers. The significance level was set at $p < 0.05$ with a 95% confidence interval.

Initially, our study included 850 respondents. However, incomplete responses in sections assessing knowledge, risk perception, health self-efficacy, and vaccination intention, were excluded from the final analysis, resulting in a sample size of 796 respondents. For any missing data within the sociodemographic section, we analysed the available data without imputing or computing missing values. This ensures that the analyses reflect the actual responses provided by the participants without introducing potential biases from data imputation techniques. In our study, data on ethnicity were initially collected in four groups (Malay, Chinese, Indian, and Indigenous). However, during analysis, it became apparent that the sample sizes for some groups were too small to yield reliable statistical results. To address this, we consolidated these into two broader groups (Malay and Non-Malay). This strategy reduces the possibility of bias from small group representation while ensuring a large enough sample size for thorough analysis.

Ethical approval was granted by the Medical Research Ethics Committee [NMRR-20-3030-55793(IIR)] and Universiti Sains Malaysia Ethics Review Board [USM/JEPeM/19100566].

Results

Descriptive analysis

This study investigated the level and determinants of childhood vaccination intentions among antenatal mothers, with a sample size of 796 participants. Table 1 below describes the characteristics of the antenatal mothers and the mean scores of the continuous variables.

The demographic background revealed that the mean age of the antenatal mothers was 31.07 (SD = 4.64) years. This relatively young cohort corresponded with a lower average number of children, with a mean of 1.37 children (SD = 1.24). The education level among antenatal mothers varied, with a significant majority having attended tertiary education. Specifically, 70.8% ($n = 561$) of the

Table 2 Factors associated with vaccination intentions among antenatal mothers (independent t-test and one-way ANOVA)

Variables (*n*)	Vaccination Intention Score Mean (SD)	Mean difference (95% CI)	t-statistic (df)	*p*-value
Education Level (*n* = 792)		-0.513 (-0.972, -0.055)	-2.203 (790)	0.028 [a]
Primary/Secondary (231)	25.65 (3.12)			
Colleges/University (561)	26.16 (2.61)			
Ethnicity (*n* = 784)		0.607 (-0.059, 1.273)	1.805 (782)	0.074 [a]
Malay (686)	26.10 (2.69)			
Non-Malay (98)	25.49 (3.17)			
Mother's Income (*n* = 784)		-	0.874 (2,781)[b]	0.418 [c]
B40 (738)	26.00 (2.76)			
M40 (45)	26.32 (2.55)			
T20 (1)	23.00 (NA)			
Household's Income (*n* = 770)		-	0.856 (2,767)[b]	0.425 [c]
B40 (667)	25.96 (2.81)			
M40 (95)	26.34 (2.45)			
T20 (8)	26.38 (2.62)			

[a] Independent T-test [b] F-Statistic (df) [c] One-way ANOVA. Non-Malay includes Chinese, Indian, and Indigenous

respondents reported having completed college/university education, indicating a relatively educated cohort. The ethnic composition of the study population was predominantly Malay, with only 12.5% belonging to the non-Malay group. The majority, 94.1% ($n = 738$) of antenatal mothers, belong to the B40 income category, representing the lowest economic tier. This aligns with data showing that approximately 24.9% ($n = 198$) of these mothers are unemployed and without personal income. Similarly, household income was predominantly classified within the B40 category, at 86.6% ($n = 667$), although this percentage is slightly lower than that of the antenatal mothers' income.

The antenatal mothers demonstrated relatively high levels of knowledge, risk perceptions, health self-efficacy, and intentions to vaccinate, as evidenced by their mean scores, which all exceeded the midpoint of the scoring range. The means (SD) for each measure were as follows: knowledge 6.64 (1.68), risk perception 79.69 (16.61), health self-efficacy 23.63 (5.84), and vaccination intention 26.02 (2.77).

Bivariate analysis

Bivariate analyses were conducted via an independent t-test and one-way ANOVA test, to explore the relationships between maternal demographic factors and vaccination intention. Table 2 summarizes the results from the bivariate analysis. The analysis revealed a significant association between education level and vaccination intention scores, whereby antenatal mothers who had completed college/university education had a higher mean score of vaccination intention [mean 26.16 (SD = 2.61)] compared to those who had completed primary/secondary education [mean 25.65 (SD = 3.12)] with a *p*-value of 0.028 and 95% CI: -0.972, -0.055. There was no significant association between ethnicity, mother's income, and household income with vaccination intention score, with *p*-values of 0.074, 0.418, and 0.425, respectively.

B40 = Bottom 40% income group, M40 = Middle 40% income group, T20 = Top 20% income group.

Table 3 Factors associated with vaccination intentions among antenatal mothers (Pearson correlation analysis)

Variable	*r*	*p*-value
Age	0.126	< 0.001
Number of Children	0.118	0.001
Knowledge score	0.325	< 0.001
Risk Perception score	0.350	< 0.001
Health Self-Efficacy score	0.074	0.037

Table 3 shows the results of the correlation between the continuous variables and the vaccination intention score. Pearson correlation indicated a fair positive correlation between the vaccination intention score and the risk perception score ($r = 0.350$, p-value < 0.001), as well as the knowledge score ($r = 0.325$, p-value < 0.001). However, for the other continuous variables, there were poor correlations between the vaccination intention score and age ($r = 0.126$, p-value < 0.013), number of children ($r = 0.118$, p-value = 0.001), and health self-efficacy score ($r = 0.074$, p-value = 0.037).

Multiple linear regression analysis

Table 4 presents the Multiple Linear Regression (MLR) analysis results, identifying the determinants of vaccination intentions among antenatal mothers. Initially, Simple Linear Regression (SLR) analysis identified potential factors associated with vaccination intention, including age, number of children, education level, ethnicity, and scores for knowledge, risk perception, and health self-efficacy, with p-values < 0.25. Subsequent MLR analysis, considering those factors with p-values < 0.25 from the SLR, revealed three significant determinants of vaccination

Table 4 Determinants of vaccination intention among antenatal mothers

Factors	Unstandardized Beta	Standardized Beta	95% CI	t	*p*-values	DW	F (df)	*P*-Value
Number of children	0.156	0.070	(0.013,0.299)	2.145	0.032	2.168	60.139 (3)	< 0.001
Knowledge score	0.397	0.243	(0.288,0.506)	7.149	< 0.001			
Risk Perception score	0.047	0.286	(0.036,0.058)	8.530	< 0.001			

Dependent Variable: Vaccination Intention. Backward multiple linear regression was applied. $R^2 = 0.188$

Corrected $R^2 = 0.185$. All model assumptions were checked and fulfilled. No multicollinearity (VIF < 10)

DW: Durbin-Watson. CI: Confidence Interval

intention among antenatal mothers: number of children (β = 0.156, 95% CI [0.013, 0.299], $p = 0.032$), knowledge score (β = 0.397, 95% CI [0.288, 0.506], $p < 0.001$), and risk perception score (β = 0.047, 95% CI [0.036, 0.058], $p < 0.001$).

These results indicate that an increase in the number of children by one child increases the vaccination intention score by 0.16. For the knowledge and risk perception scores, increasing the knowledge score by 1 and the risk perception score by 10, increased the vaccination intention score by 0.40 and 0.47, respectively. The knowledge score appears to be the strongest predictor of vaccination intention among antenatal mothers. Overall, these factors were able to explain about 18.8% variability of the vaccination intention among antenatal mothers ($R^2 = 0.188$, Corrrected $R^2 = 0.185$).

All assumptions for the multiple linear regression analysis were checked and fulfilled. The linearity assumption was met whereby the linear model fit well. The assumption for independence was met and checked using Durbin Watson test, the residuals were normally distributed and homoscedasticity was observed. No significant outliers were detected and no multicollinearity was detected, as all the Variance Inflation Factor (VIF) for independent variables were below the value of 10. No serious autocorrelation of the residual was detected with Durbin Watson value of 2.186.

Discussion

This study offers insight into potential determinants of vaccination intentions among antenatal mothers. In our sample, antenatal mothers attending follow-up care in public health clinics in Selangor had a high intention to vaccinate their newborns with childhood vaccines according to the Malaysia National Immunization Programme (NIP). This finding is consistent with previous studies in Malaysia that reported that only 6.8% of parents were vaccine-hesitant toward childhood vaccines [32]. This could be because the Malaysia National Immunization Programme (NIP) has long been established in the Malaysian population since the early 1950s and parents may have fostered trust and confidence in the programme. Despite this small percentage, the rising prevalence of unvaccinated children has increased from 0.1% in 2016 to 1.0% in 2022, which may pose a challenge as this pocket of unvaccinated individuals could grow further. Recognizing the urgency of examining the associated factors, our study was able to reveal that maternal knowledge, risk perception, and the number of children are significant determinants of vaccination intention among our study population.

Maternal knowledge

Our study revealed that mothers with higher knowledge scores had greater intentions to vaccinate their children. This finding corroborates the findings of previous studies which also demonstrated that higher knowledge score predicts greater vaccination intentions among parents [7, 8, 32–34]. This could be attributed to a better understanding of the benefits of vaccination on their children which in turn leads to an inclination to do so [35, 36]. The majority of antenatal mothers, 67.6% ($n = 534$), in our study correctly answered that '*more than one dose of vaccine may be required for complete protection*', indicating their understanding of how vaccines can provide complete protection to their children. This finding resonates with the theory from Health Belief Model (HBM), which emphasizes the role of perceived benefits as one of the key motivators for adopting health promoting behaviors [37]. Antenatal mothers who understand the benefits of vaccination are more likely to express higher vaccination intention. This supports the Health Belief Model (HBM) framework, which posits that individuals are motivated to engage in specific actions, such as vaccination, when they are able to perceive the benefits that they may gain from the action [37].

Additionally, knowledge could play a significant role in enhancing mother's perceptions of the susceptibility of their children to infection or the severity if they are left unvaccinated, subsequently increasing their intention to vaccinate their children [27]. This concept is aligned with the Health Belief Model (HBM), which recognizes perceived threat as one of factors influencing the adoption of health promoting behaviors [37]. Mothers who perceived a greater susceptibility of their newborns to become infected had a significantly greater intention to vaccinate [35]. In addition, well-educated parents tend to process the available evidence regarding vaccination

more effectively and comprehend the information better [38]. The overall understanding of the benefits of vaccines may be better among our antenatal mothers, as the majority, 70.8%, had a higher level of education (completed college/university). Our finding therefore underscore the importance of enhancing maternal knowledge as a means increasing vaccination intention, particularly by highlighting the protective benefits of vaccination and potential threat of not vaccinating their newborn.

However, our study findings contradict those of several other studies conducted in Malawi and the United States where no significant association was reported between the level of knowledge about the vaccine and the vaccination intention itself [9, 39]. These conflicting findings could be due to differences in the study populations and the influence of other confounding factors. The study population in Malawi generally has a low educational background, and knowledge levels are confounded by education in this population [39]. However, in the United States, their study population is relatively homogeneous among lower socioeconomic groups, potentially leading to different results and limiting their generalizability [9].

Risk perception

Our findings highlight the role of risk perception as a determinant of vaccination intention among antenatal mothers, specifically the perceived likelihood of being infected and the perceived severity of infection if not vaccinated. The association between risk perception and vaccination intention has also been identified in previous studies. A study in Italy and the United States revealed that increased disease risk perception led to a greater willingness to be vaccinated [10, 11]. This result aligns with the Health Belief Model (HBM), which suggests that individuals are more likely to engage in health-promoting behaviors if they perceive a higher risk of disease and believe that a particular health action would be beneficial in reducing that risk [37].

The influence of risk perception on vaccination intention emphasizes the psychological mechanisms that may further shape parental attitudes toward vaccination. Our study population had a relatively high score of risk perception, which may reflect the aftermath of the COVID-19 pandemic in the country. Risk perception regarding other diseases may increase following a pandemic as a study in Italy revealed that risk perception of flu disease and acceptance of the flu vaccine increased after the reopening phase of the COVID-19 lockdown, likely due to an enhanced general sensitivity to disease hazards [11]. Antenatal mothers may have an increased risk perception of the likelihood and severity of disease after witnessing how unvaccinated individuals during the pandemic are at greater risk of infection and develop more severe complications. This heightened risk perception, in turn, makes them more likely to prioritize vaccinating their newborns as a preventive measure owing to increased awareness of vaccine-preventable disease hazards. Therefore, to increase parents' intention to vaccinate their children, increasing parents' risk perceptions, particularly the likelihood and severity of VPDs related to unvaccinated newborns, is essential.

However, when comparing our results to those of older studies, it should be highlighted that some studies report conflicting findings, whereby they found that perceived severity did not have a significant effect on vaccination intention [40, 41]. This could be due to differences in the methodologies used in these studies. Studies in China and the United States used online platforms for their surveys, meaning that only people with internet access could participate. This could lead to selection bias and undercoverage of the sample frame, making the results less generally representative and potentially leading to insignificant findings [40, 41].

Health self-efficacy

Self-efficacy is a concept of health behavior that refers to an individual's perception of their capacity and ability to learn or behave in a particular way [42]. This concept is a cornerstone of Bandura's Social Cognitive Theory, which underscores the central role of self-efficacy in shaping the health related behaviors [42] including vaccination decisions. In the context of antenatal vaccinations, health self-efficacy may empower expectant mothers to actively seek information, acquire knowledge, overcome barriers and ultimately make an informed decisions about vaccination.

Even though the theoretical frameworks suggest that health self-efficacy is an important predictor for vaccination decision, empirical evidence presents mixed findings regarding the influence of health self-efficacy on vaccination intentions. Some studies have shown that health self-efficacy is related to vaccination intention [15, 16, 43],, whereas others have shown no association between the two [44]. However, our study did not find a significant association between health self-efficacy and maternal vaccination intention. Although both variables showed a significant association in the bivariate analysis, this association was nullified when other factors were considered in the multiple linear regression. This finding could be explained by the possibility that health self-efficacy may influence vaccination intention indirectly by acting as a mediator between the relationship between vaccination intention and other factors studied in our research as suggested by its relatively weak association from the beginning. This hypothetical suggestion is supported by previous studies that found that self-efficacy may act as a mediator rather than a direct determinant of vaccination intention [27, 45]. To further elucidate

these relationships, future research could investigate the mediating roles of self-efficacy among other influencing factors.

Number of children

The finding that the number of children is a determinant of vaccination intention aligns with previous research conducted in Rome, Australia, and Malaysia, which revealed that vaccination intention increased with multiparity [18, 33, 46]. However, this result contradicts other studies that reported that vaccine hesitancy was either negatively correlated with or not associated with the number of children [47, 48].

Mothers with more children are generally older than first-time mothers. Our study population consisted of antenatal mothers in the middle-aged group with a mean age of 31.07 (4.64) years. Mothers in this age group might be more knowledgeable about vaccination than younger parents because of their experience with vaccinating previous children, established relationships with healthcare providers, and better cognitive capacity and sources of knowledge [49]. Consequently, mothers with more children may have greater awareness of vaccination benefits, having experienced more antenatal care visits and frequent health education regarding the immunization program. This increased information and awareness of vaccination benefits are associated with a higher level of vaccination intention [35, 36]. Furthermore, these mothers may have received more information and repeated recommendations from healthcare workers during previous pregnancies, which could enhance their intention to vaccinate their newborns. Adequate vaccine information and recommendations from healthcare professionals have been identified as key factors influencing vaccination intention [50, 51].

Strengths, limitations, and future directions

The strength of this study lies in its large sample size, which significantly enhances the reliability of our findings. However, several limitations are inherent to operational research studies. First, the findings of this study may not be generalizable to the entire Selangor or Malaysian population. Selangor was chosen as study setting in this study because of its diverse population background, which was hoped to reflect Malaysia's demographic makeup. However, a limitation arose as the majority of respondents turned out to be Malay. The predominance of Malay ethnicity in our study population limits generalizability, as other ethnic groups were underrepresented, possibly due to lower attendance at public health clinics. Expanding the study to include private health clinics could improve the representation of various ethnic groups. Therefore, caution is needed when these findings are applied to populations with different ethnic compositions.

Besides, the use of self-administered questionnaire in this study may have introduced potential biases. Despite efforts to ensure the clarity of the questionnaire, some respondents might not fully understood certain questions, and their answers could have been influenced by social desirability bias, where they provide responses they believe are more socially acceptable rather than their true feelings and intentions. To address these biases in the future research, providing on-site support to clarify any questions and emphasizing the anonymity and confidentiality of the responses might help mitigate these biases while retaining the advantages of the self administered questionnaire method.

The use of different scale or instruments to measure vaccination intention may also presents as another limitation in this study. Various approaches, including categorical and continuous scales, are employed in global research. This may lead to differences in the granularity of the measurement and may affect the comparability and generalizability of the findings. Future research could benefit from standardizing measurement tools to improve consistency and facilitate cross sectional comparisons.

The findings from this study provide valuable insights to steer the future direction of maternal and child health program in Malaysia. Future educational and health promotional activities design by health managers should not only aim to increase maternal knowledge on the benefits of vaccination but also enhance their risk perception regarding the severity and likelihood of newborns getting infected. Additionally, health promotion activities must effectively reach young mothers with fewer children who are not yet regular visitors to public health clinics. Utilizing various social media channels and conducting more outreach programs including in workplace area, may serve as an innovative strategies to ensure the vaccination message reach the target audience.

Vaccination education should be regularly delivered to antenatal mothers by primary healthcare workers during routine antenatal care follow ups. This education should be personalized and targeted by exploring the knowledge gaps among antenatal mothers and exploring the risk perceptions towards vaccination. Additionally, clinicians especially pediatricians who primarily treat sick children, can also play a role by delivering vaccine education each time they encounter patients with vaccine preventable diseases. They may educate parents on the benefits of vaccination, further highlighting the risk of severe morbidity and mortality if children are left unvaccinated.

Finally, future research should further explore how to ensure the effectiveness of health promotion and educational interventions, specifically examining the factors

influencing the level of knowledge gained and risk perception built through the programs. Overall, these collective actions from various stakeholders would contribute to more comprehensive strategies that help to build supportive environment that enhance vaccination intention and ultimately improving maternal and child health outcomes in Malaysia.

Conclusion

In conclusion, enhancing maternal vaccination intention is a crucial step in achieving nationwide childhood vaccination coverage and herd immunity. This study has shed light on the vital interplay between factors associated with vaccination intention, which include psychological and cognitive factors. Tailored interventions that emphasize less experienced antenatal mothers, aimed at increasing maternal knowledge about childhood vaccination and addressing risk perceptions related to the likelihood and severity of being unvaccinated are crucial for effectively increasing vaccination intention and improving immunization coverage.

Abbreviations

WHO	World Health Organization
EPI	Expanded Program on Immunization
SDGs	Sustainable Development Goals
NIP	National Immunization Programme
VPDs	Vaccine-Preventable Diseases
MLR	Multiple Linear Regression
SLR	Simple Linear Regression
HBM	Health Belief Model

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Author contributions

TMMS was involved in conceptualization, investigation, formal analysis, and writing (original draft, review, and editing). AI was involved in conceptualization and writing (review and editing). RI was involved in the conceptualization, initial design of the study, and funding acquisition. MNMN and NSR, NMN, ZS and AJ were involved in the conceptualization, initial design of the study, and data collection. All the authors read and approved the final manuscript.

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Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki and received ethical approval from the Medical Research Ethics Committee NMRR-20-3030-55793(IIR) and Universiti Sains Malaysia Ethics Review Board USM/JEPeM/19100566. Prior to participation, all participants received detailed information about the study and voluntarily provided their informed consent. Confidentiality and anonymity were maintained throughout the study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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