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ORIGINAL ARTICLE

The Prevalence of Complete, Timely and Delayed Primary Childhood Vaccination in Malaysia: Insights from the 2022 National Maternal and Child Health Survey

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ABSTRAK

Program immunisasi kanak-kanak yang berkesan akan memastikan liputan vaksin yang tinggi dan pemberian vaksin dalam tempoh yang disarankan. Namun, terdapat kekurangan maklumat mengenai ketepatan masa pemberian vaksin. Kajian ini bertujuan untuk menilai liputan vaksin dan ketepatan masa pemberian vaksin bagi kanak-kanak di Malaysia. Data telah dianalisa daripada tinjauan keratan rentas peringkat nasional. Vaksin lengkap merujuk kepada kanak-kanak yang menerima semua vaksin utama tanpa mengira tempoh yang disarankan. Vaksinasi tepat masa didefinisikan sebagai vaksin yang diberikan dalam tempoh masa yang disarankan, manakala vaksinasi lewat merujuk kepada vaksin yang diberikan selepas tempoh tersebut. Rekod imunisasi semasa pengumpulan data telah disemak oleh jururawat terlatih. Seramai 3,523 kanak-kanak berusia 12 hingga 23 bulan telah menyertai kajian ini. Prevalens keseluruhan liputan vaksin ialah 87.1% (95% CI: 84.9, 89.1). Dalam kohort ini, prevalens vaksin tepat pada masanya ialah 51.2% (95% CI: 47.2, 55.2), manakala prevalens vaksin lewat ialah 35.6% (95% CI: 31.7, 39.7). Pemberian vaksin lewat ketara pada dos kedua vaksin pneumokokal dan measles-mumps-rubella, masing-masing pada kadar 15.0% (95% CI: 12.8, 17.5) dan 11.2% (95% CI: 8.1, 15.3). Perbezaan turut dikesan antara kawasan bandar dan luar bandar, dengan kawasan bandar menunjukkan prevalens vaksin lewat yang lebih tinggi (39.0%) berbanding kawasan luar bandar (27.6%). Negeri Johor, Selangor, dan Kuala Lumpur & Putrajaya mencatatkan prevalens vaksin tidak tepat masa tertinggi (45.5%, 43.0%, dan 42.5%). Malaysia mencatatkan kadar liputan vaksin keseluruhan yang memberangsangkan pada 87.1%; namun, ketepatan masa pemberian vaksin masih menjadi kebimbangan, dengan hanya 51.2% kanak-kanak menerima vaksin dalam waktu yang disarankan. Terdapat perbezaan ketara antara kawasan bandar dan luar bandar serta beberapa negeri bagi dapatan pemberian vaksin tidak mengikut waktu yang disarankan, berkemungkinan disebabkan oleh kewujudan kumpulan miskin bandar yang kurang terdedah kepada kepentingan vaksin serta masalah keraguan vaksin yang tinggi dalam kalangan ibu bapa di bandar. Ini menunjukkan bahawa intervensi kesihatan awam perlu memberi tumpuan kepada kanak-kanak di kawasan bandar, bagi meningkatkan kadar pemberian vaksin dalam tempoh yang dijadualkan dan memaksimumkan keberkesanan program imunisasi.

Kata kunci: *Kelewatan imunisasi; ketepatan masa; lengkap; Malaysia; vaksinasi kanak-kanak*

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ABSTRACT

An effective primary childhood vaccination programme ensures high vaccine coverage, with vaccinations administered within the recommended timeframe. However, there is a lack of information on the timeliness of these vaccinations. This study aimed to assess the completeness and timeliness of primary childhood vaccinations in Malaysia. Data from a nationwide cross-sectional survey were analysed. Complete vaccination refers to children who received all primary vaccines regardless of the recommended timeframe. Timely vaccination is defined as vaccines administered within the recommended timeframe, while delayed vaccination refers to those given after this period. Immunisation records were verified by trained nurses. A total of 3,523 children aged 12 to 23 months participated in this survey. The prevalence of overall vaccination coverage was 87.1% (95% CI: 84.9, 89.1). Within this cohort, the prevalence of timely vaccination was 51.2% (95% CI: 47.2, 55.2), while the prevalence of delayed vaccination was 35.6% (95% CI: 31.7, 39.7). The prevalence of delayed vaccination particularly evident in the second dose of pneumococcal and measles-mumps-rubella vaccines at 15.0% (95% CI: 12.8, 17.5) and 11.2% (95% CI: 8.1, 15.3), respectively. Urban-rural disparities were evident, with urban areas demonstrating higher delayed vaccination prevalence (39.0%) than rural areas (27.6%). Johor, Selangor, and Kuala Lumpur & Putrajaya had the highest overall delayed vaccination prevalence (45.5%, 43.0%, and 42.5%, respectively). Malaysia demonstrates commendable overall vaccination coverage at 87.1%; however, the timeliness of vaccination remains a concern, with only 51.2% of children receiving vaccinations within the recommended timeframe. Significant disparities exist between urban and rural areas as well as among states in delayed vaccination rates, likely attributed to the presence of urban poor populations who are less exposed to the importance of vaccination and higher levels of vaccine hesitancy among urban parents. This highlights the need for public health interventions to focus on children in urban areas to improve timely vaccination rates and maximise the effectiveness of immunisation programs.

Keywords: Childhood vaccination; completeness; delayed immunisation; Malaysia; timeliness

INTRODUCTION

The primary childhood vaccination or the expanded programme on immunisation (EPI) has successfully decreased the incidence of and mortality from childhood vaccine-preventable diseases (Bustreo et al. 2015). The initial childhood vaccines recommended by the EPI included Bacillus Calmette-Guérin (BCG), oral polio, diphtheria-tetanus-pertussis, and measles. However, the list has grown to encompass hepatitis B, *Haemophilus influenzae* type b (Hib), rubella, pneumococcal conjugate vaccine (PCV) and rotavirus vaccine (World Health Organisation 2024). The conventional metric for assessing vaccination coverage is the percentage of children who have received the necessary vaccine doses, irrespective of the timing of these vaccinations (World Health Organisation 2023). Nevertheless, the effectiveness of vaccines is intricately linked to the adherence to vaccinations within recommended timeframes, offering maximum protection to children during their formative years as recommended by the World Health Organisation (WHO) (World Health Organisation 2024). Deviation from the recommended vaccination schedule increases the vulnerability of the child to vaccine-preventable diseases such as pertussis, diphtheria and measles which may lead to severe complications including brain damage or mortality (Donadel et al. 2021; Gampa et al. 2021). Furthermore, delayed vaccinations contribute to uncontrolled disease transmission, compromising herd immunity within the community (Brewer et al. 2017; Thompson & Duintjer Tebbens 2017).

The meticulous examination of vaccination timeliness becomes crucial in identifying potential gaps in the immunisation process and optimising public health outcomes. However, previous studies on primary childhood vaccination have

a wide range of definitions for vaccination timeliness. Delayed, early and untimely interval vaccination were the most common domains studied (Masters et al. 2019; Wariri et al. 2022). Timely vaccination is widely defined as all vaccine doses administered within four days prior and within four weeks after the minimum recommended age interval according to the specific vaccine in the national immunisation schedule (Mekonnen et al. 2020; Wariri et al. 2022). As vaccination practices vary across different populations and regions, understanding the nuances of timeliness becomes essential for crafting targeted interventions tailored to the specific needs of diverse communities. For example, timeliness vaccination may associated with sociodemographic characteristics of the children, such as income status and place of residence (Adetifa et al. 2018; Banjari et al. 2018).

Although data on childhood immunisation coverage in Malaysia reported very high coverage for each type of vaccine (WHO & UNICEF 2023), there were outbreaks of vaccine-preventable diseases such as polio (Avoi et al. 2020), diphteria (Tok et al. 2022) and measles (Mat Daud et al. 2022), and a higher burden of pertussis was recently reported (Mohamed et al. 2022). Consequently, a national survey was conducted among children aged 12 to 23 months in 2016, revealing an overall vaccination coverage of 95.3% (Institute for Public Health 2016). Focussing on vaccination coverage only without considering the timeliness of vaccination may contribute to overestimating the expected protection among vaccinated children (Adetifa et al. 2018). The timeliness of vaccination among children who completed their primary vaccination in Malaysia was lacking in terms of a nationwide survey. The first Maternal and Child Health Survey in 2016 focused on national level vaccination coverage and incomplete vaccination (Ahmad et al. 2017; Lim et al. 2017). A small study was conducted in Seremban District, Negeri Sembilan, assessing the adherence to vaccination in terms of completeness and timeliness. However, a different definition was used to define timeliness (Abidin et al. 2017), while another study focussed on vaccination defaulters among children under five in the Petaling District in Selangor State and its predictors (Krishna et al. 2019).

Ensuring timely and complete childhood vaccinations is imperative for preventing vaccine-preventable diseases and promoting public health. The WHO emphasises the significance of adhering to recommended vaccination schedules for optimal protection. While Malaysia has made substantial progress in its vaccination programme, comprehensive insights into the timeliness of primary childhood vaccinations still need to be made. This study addressed this gap by presenting findings from the 2022 nationwide maternal and child health survey, shedding light on the timeliness of primary childhood vaccinations in the Malaysian context.

MATERIALS AND METHODS

Population, Sampling Procedure and Sample Size Calculation

Data were obtained from the National Health and Morbidity Survey (NHMS) 2022, a cross-sectional nationwide household survey on maternal-child health in Malaysia. The target population was mothers (15 to 49 years) with their last child below two years old. The household sampling frame was obtained from the Department of Statistics Malaysia (DOSM) and consisted of enumeration blocks (EBs), an artificial land area with specific boundaries about 80 to 120 living quarters in one EB, which contained approximately 500 to 600 people. A two-stage stratified random sampling was utilised to select the EBs as primary sampling units and the living quarters (LQs) as secondary sampling units. A listing procedure was conducted by trained local nurses to ensure that the selected household consisted of mothers (15 to 49 years) with their youngest child below two years old. This process was conducted to ensure adequate sample size. The sample size for NHMS was calculated based on a single proportion formula for childhood vaccination for 14 strata using EPI INFO Statcalc. Malaysia consists of 13 states and three federal

territories (FT); however, respondents from FT Kuala Lumpur were combined with those who resided in FT Putrajaya. As for FT Labuan, it was combined with Sabah State. This step was taken because the respondents shared nearly similar sociodemographic characteristics and due to logistic issues. This survey was the second national survey for maternal-child health, as the first study was conducted in 2016. The prevalence of complete primary childhood vaccination in 2016 was 95.3%. However, the research team expected a lower prevalence in 2022 due to the COVID-19 pandemic and lockdown measures. The sample size was calculated using a single-proportion formula based on an expected prevalence of complete vaccination of 86.4% (verified by cards), a 95% confidence level, and a precision of 5%, yielding a minimum sample size of 196 per stratum, which was rounded up to 200 respondents (Lim et al. 2017). With 16 strata (13 states and 3 Federal Territories), the total minimum required national sample size was therefore 3,200 children aged 12-23 months. In this survey, 3,523 children in this age group were invited to participate, and data from 3,463 respondents were available for analysis of the primary childhood vaccination coverage module. The detailed methodology of this survey was publicly accessible through the Institute for Public Health's official website. The overall response rate for the NHMS survey was 74.9% (Institute for Public Health 2023).

Data Collection

Data collection was conducted from August to October 2022, by trained data collectors. The team comprised of temporary research assistants, drivers and registered nurses from the surveyed locality. A structured validated questionnaire NHMS 2016 was used to collect data related to maternal-child health. The questionnaire was adapted from the Multiple Indicator Cluster Survey (MICS) from The United Nations Children's Fund (UNICEF). Childhood vaccination topics used a face-to-face interview and validated with the child's vaccination book. The interview was conducted with the parents or guardians of the children. The child's birth date and the date for each received vaccination were recorded.

Variable Definitions

In this study, the team considered the sociodemographic variables and primary vaccination status of children aged 12 to 23 months, adopting the recommended vaccination ages from the latest Malaysian National Immunisation Programme (NIP) as of October 2023 (Bahagian Pembangunan Kesihatan Keluarga 2023). The definitions of early and delayed immunisation were derived from the literature, with a broad recommended interval provided for the second and third doses of the hepatitis B vaccine due to the transition from a single monovalent hepatitis B vaccine to the hexavalent vaccine (DtaP-IPV-HepB-Hib), which officially began on December 1, 2020 (Immunise4Life) 2023; World Health Organisation 2024). In the latest vaccination schedule, the second and third doses of the hepatitis B vaccine are not administered as a single monovalent vaccine. Complete vaccination was defined as a child receiving all primary vaccinations by 23 months of age, including BCG, three doses of hepatitis B, three doses of DtaP-IPV-Hib, two doses of pneumococcal vaccine, and two doses of measles-mumps-rubella (MMR), irrespective of the timing of vaccination according to the recommended schedule. In this study, timely vaccination was defined as each vaccine was administered within the recommended time interval, while delayed primary vaccination referred to any primary vaccine given after the recommended time interval for the cohort who had completed the primary vaccine series. The timeliness of vaccination was detailed in Table 1, which categorised vaccinations into early, timely and delayed, based on previous studies (Mekonnen et al. 2020; Wariri et al. 2022). The study further defined timely vaccination as occurring within four days prior and up to one month after the recommended date for all vaccines, and within one month for vaccinations

TABLE 1: Type of primary childhood vaccination according to the recommended vaccination age according to NIP and the definition of delay used in this study

Type of primary childhood vaccination	Recommended time and the interval of vaccination according to NIP	Definition of early from the recommended time (age of a child in days)	Definition of delay from the recommended time (age of a child in days)
BCG single dose	during the 24 hours after birth (0-30 days)	-	> 30 days
Hepatitis B 1st dose; monovalent	during the 24 hours after birth (0-30 days)	-	> 30 days
*Hepatitis B 2nd dose	4 weeks after the first dose (30-90 days)	-	> 90 days
*Hepatitis B 3rd dose	6 months (150-210 days)	-	> 210 days
DtaP-IPV-Hib 1st dose	2 months (60-90 days)	before 4 days from the minimum recommended interval of vaccination or <56 days	after 30 days from the minimum recommended interval of vaccination or >90 days
DtaP-IPV-Hib 2nd dose	3 months (90-120 days)	before 4 days from the minimum recommended interval vaccination or <86 days	after 30 days from the minimum recommended age of vaccination or >121 days
DtaP-IPV-Hib 3rd dose	5 months (150-180 days)	before 4 days from the minimum recommended interval of vaccination or <146 days	after 30 days from the minimum recommended interval of vaccination or >181 days
PCV 1st dose	4 months (120-150 days)	before 4 days from the minimum recommended interval of vaccination or <116 days	after 30 days from the minimum recommended interval of vaccination or >150 days
PCV 2nd dose	6 months (180-210 days)	before 4 days from the minimum recommended interval of vaccination or <176 days	after 30 days from the minimum recommended interval of vaccination or >210 days
MMR 1st dose	9 months (270-300 days)	before 4 days from the minimum recommended interval of vaccination or <266 days	after 30 days from the minimum recommended interval of vaccination or >300 days
MMR 2nd dose	12 months (360-390 days)	before 4 days from the minimum recommended interval of vaccination or <356 days	after 30 days from the minimum recommended interval of vaccination or >390 days

*A wide recommended interval was given due to the transition of a single dose of Hepatitis B vaccine for dose-1 and dose-2 with the hexavalent vaccine in the Malaysia NIP scheduled dated December 1 2020, onwards. NIP: National immunisation program; BCG: Bacillus calmette-guérin; DtaP-IPV-Hib: Diphtheria, tetanus, acellular pertussis-inactivated poliovirus-Haemophilus influenza type B; PCV: Pneumococcal; MMR: Measles-mumps-rubella
Source: Bahagian Pembangunan Kesihatan Keluarga (2023)

scheduled at birth, as mentioned in previous literature (Jackson et al. 2023; Mekonnen et al. 2020; Stein-Zamir & Israeli 2019; Veerasingam et al. 2017). Overall timely vaccination was defined as a child receiving BCG, hepatitis B dose 1, three doses of DTaP-IPV-Hib, two doses of pneumococcal vaccine and two doses of MMR within the recommended intervals stated in Table 1. Hepatitis B doses 2 and 3 were not considered separately because they were included in vaccine combinations due to the NIP schedule transition from pentavalent to hexavalent vaccines.

Data analysis

Data were extracted in Microsoft Excel (Microsoft Corporation, Redmond, WA, USA) format and subsequently analysed using IBM SPSS Statistics for Windows, Version 29.0 (IBM Corp., Armonk, NY, USA). It is essential to ensure the validity of the recorded date of vaccination for each vaccine, however, a few outliers remained in the dataset. To obtain the children's age at the specific vaccination types and doses, the date of birth was subtracted from the vaccination date. Age was calculated in days. A normality check was conducted to choose the appropriate statistical analysis. Median and interquartile were used because the data were not normally distributed. Timeliness of the vaccination was measured using three categories: early, timely and after the recommended time. The timeliness was measured for each type of vaccine and limited to the child with a vaccination record. The prevalence of primary vaccination status and timeliness of vaccination were calculated via a complex sampling plan (cs-plan) to add on population weight to ensure representativeness. A bivariate analysis of delayed and timely vaccination was calculated via complex sampling cross-tabulation, and a p-value of less than 0.05 from the second-order Rao-Scott adjusted Chi-square statistic was taken as a statistically significant result.

Ethical Consideration

The ethical approval was obtained from the Medical Research and Ethics Committee of the of the Ministry of Health Malaysia and this study was registered under the National Medical Research Registration bearing registration number of NMRR-20-959-53329. A written consent was obtained from the respondents prior to the survey. Data were treated as anonymous with a newly created identification number to prevent identification of the respondent identity during data analysis and presentation of the findings. The data was handled privately, and only the core team could access it.

RESULTS

Out of the 3,523 children aged 12 to 23 months invited to participate in the survey, 3,463 responded to the primary childhood vaccination coverage module. Table 2 provided a detailed sociodemographic profile of the children. Notably, 79.0% were children from Malay ethnicity and 10.3% from Bumiputera Sabah and Sarawak. However, there was a limited representation of Chinese (4.7%) and Indian (3.5%) ethnicities. Urban residency was predominant, with 70.2%, compared to 29.8% in rural areas.

Table 3 outlined the vaccination status for each type of vaccine, including full-dose vaccination. The prevalence of complete primary vaccination, verified through vaccination book examination, was 83.5% (95% CI: 80.9, 85.8). When the prevalence of complete vaccination via self-reported data is included (3.6%; 95% CI: 2.4, 5.3), the overall prevalence of complete primary vaccination in Malaysia increases to 87.1%; (95% CI: 84.9, 89.1).

The analysis of timeliness, as presented in Table 4, indicated that the median age for BCG vaccination was at Day 1 (IQR: 1), and for hepatitis B first dose vaccination, it was at birth. These median ages aligned with the recommended vaccination schedule. The prevalence of delayed vaccination for BCG and Hepatitis B first dose

TABLE 2: Sociodemographic of the children aged 12 to 23 months in NHMS 2022, n = 3523

Variable	n	%
Sex		
Boy	1797	51.0
Girl	1726	49.0
Ethnicity		
Malay	2782	79.0
Chinese	167	4.7
Indian	124	3.5
Other Bumiputera	362	10.3
Others	85	2.4
Strata		
Urban	2474	70.2
Rural	1049	29.8
Citizenship		
Malaysian	3436	97.6
Permanent resident or non-citizen	86	2.4
Household income group		
Below 40%	1242	42.0
Medium 40%	1291	43.7
Top 20%	424	14.3
Strata state & federal territory (FT)		
Johor	214	6.1
Kedah	296	8.4
Kelantan	277	7.9
Melaka	253	7.2
Negeri Sembilan	227	6.4
Pahang	239	6.8
Pulau Pinang	274	7.8
Perak	253	7.2
Perlis	258	7.3
Selangor	217	6.2
Terengganu	257	7.3
Sabah & FT Labuan	233	6.6
Sarawak	276	7.8
FT Kuala Lumpur & FT Putrajaya	249	7.1

TABLE 3: Primary vaccination status for children aged 12-23 months in NHMS 2022; n = 3,463

Vaccines	Complete (verified with book)				Complete (self-reported)				Incomplete				Unvaccinated			
	n	%	95% CI		n	%	95% CI		n	%	95% CI		n	%	95% CI	
			Lower	Upper			Lower	Upper			Lower	Upper			Lower	Upper
BCG	3338	94.9	93.1	96.3	107	4.1	2.9	5.8	-	-	-	-	18	1.0	0.5	2.0
Hepatitis B 3 doses	3055	94.6	92.6	96.1	98	4.2	2.9	6.1	-	-	-	-	20	1.2	0.6	2.2
DtaP-IPV-Hib 3 doses	3219	90.7	88.5	92.5	143	5.1	3.8	6.9	25	1.1	0.6	2.1	76	3.1	2.2	4.4
Pneumococcal 2 doses	3277	92.8	90.8	94.4	140	5.1	3.7	6.9	29	1.1	0.6	1.8	17	1.0	0.5	2.0
MMR 2 doses	3154	88.1	85.8	90.0	139	5.1	3.7	6.9	91	2.7	2.0	3.8	79	4.1	3.0	5.7
Primary full vaccination	2957	83.5	80.9	85.8	90	3.6	2.4	5.3	399	11.9	10.1	14.0	17	1.0	0.5	2.0

BCG: Bacillus calmette-guérin; DtaP-IPV-Hib: Diphtheria, tetanus, acellular pertussis-inactivated poliovirus-Haemophilus influenza type B; MMR: Measles-mumps-rubella

TABLE 4: Analysis of timeliness of primary childhood vaccination among children who completed full vaccination in NHMS 2022; n = 2,943

Type of primary childhood vaccination	*Recommended age of vaccination according to NIP	Age at vaccination in days (Median; IQR)	Interval from the previous doses for multidose vaccine	Timeliness of vaccination		
				Early, n = 400 %; 95% CI, (n)	Timely, n = 1,640 %; 95% CI, (n)	Delay, n = 903 %; 95% CI, (n)
BCG (n = 2,957)	during 24 hours after birth or within 30 days	1 (1)	-	-	98.0%; 96.8, 98.7, (2909)	2.0; 95%CI: 1.3, 3.2, (48)
Hepatitis B 1st dose; monovalent (n=2957)	during 24 hours after birth or within 30 days	0	-	-	97.6%; 96.8, 98.7, (2899)	2.4; 95%CI: 1.6, 3.6, (58)
Hepatitis B 2nd dose; (n=1733)	30-90 days (4 weeks after the first dose)	62 (5)	62 (6)	3.0; 95%CI: 2.0, 4.5, (46)	88.9; 95%CI: 85.9, 91.3, (1553)	8.0; 95%CI: 5.9, 10.8, (134)
Hepatitis B 3rd dose; (n=1574)	180-210 days (6 months)	153 (61)	90 (64)	37.9; 95%CI: 33.0, 43.2, (595)	59.0; 95%CI: 53.9, 63.9, (935)	3.1; 95%CI: 2.0, 4.7, (44)
DtaP-IPV-Hib 1st dose (n=2957)	60-90 days (2 months)	63 (4)	-	4.2; 95%CI: 2.6, 6.6, (96)	91.2; 95%CI: 88.6, 93.2, (2751)	4.7; 95%CI: 3.5, 6.1, (110)
DtaP-IPV-Hib 2nd dose (n=2957)	90-120 days (3 months)	94 (7)	30 (7)	3.1; 95%CI: 2.3, 4.3, (101)	90.8; 95%CI: 89.0, 92.3, (2711)	6.0; 95%CI: 4.8, 7.6, (145)
DtaP-IPV-Hib 3rd dose (n=2957)	150-180 days (5 months)	155 (9)	62 (8)	4.9; 95%CI: 3.5, 6.9,(147)	83.5; 95%CI: 80.3, 86.3, (2578)	11.6; 95%CI: 9.2, 14.5, (232)
PCV 1st dose (n = 2,927)	120-150 days (4 months)	125 (8)	-	7.0; 95%CI: 4.8, 10.1, (172)	83.0; 95%CI: 79.5, 85.9, (2532)	10.0; 95%CI: 7.9, 12.6, (233)
PCV 2nd dose (n = 2,927)	180-190 days (6 months)	187 (13)	63 (10)	9.4; 95%CI: 6.1, 14.3, (179)	75.5; 95%CI: 71.2, 79.4, (2373)	15.0; 95%CI: 12.8, 17.5, (375)
MMR 1st dose (n = 2.957)	270-300 days (9 months)	270 (9)	-	3.6; 95%CI: 2.7, 4.8, (120)	86.5; 95%CI: 84.2, 88.6, (2590)	9.9; 95%CI: 8.1, 12.0, (247)
MMR 2nd dose (n = 2,957)	360-390 days (12 months)	368 (8)	91 (10)	3.4; 95%CI: 2.5, 4.6, (102)	85.4; 95%CI: 81.5, 88.7, (2613)	11.2; 95%CI: 8.1, 15.3, (242)

*Recommended time for DtaP-IPV-Hib dose, Pneumococcal, MMR was before four days from the starting of the recommended age of vaccination and within 30 days of recommended age); n=unweighted count.
BCG: Bacillus calmette-guérin; DtaP-IPV-Hib: Diphtheria, tetanus, acellular pertussis-inactivated poliovirus-Haemophilus influenza type B; PCV: Pneumococcal; MMR: Measles-mumps-rubella

was 2.0% (95% CI: 1.3, 3.2) and 2.4% (95% CI: 1.6, 3.6), respectively. For DtaP-IPV-Hib, the prevalence of delayed vaccination for the first dose was 4.7% (95% CI: 3.5, 6.1), for the second dose was 6.0% (95% CI: 4.8, 7.6) and for the third dose was 11.6% (95% CI: 9.2, 14.5). The prevalence of delayed vaccination particularly evident in the second dose of Pneumococcal and MMR vaccines at 15.0% (95% CI: 12.8, 17.5) and 11.2% (95% CI: 8.1, 15.3), respectively.

The overall prevalence of timely vaccination among children who completed primary vaccination was 51.2% (95% CI: 47.2, 55.2), while the overall delay was 35.6% (95% CI: 31.70, 39.70). Urban areas exhibited a significantly higher prevalence of overall delay (39.0%; 95% CI: 33.9, 44.4) than rural areas (27.6%; 95% CI: 23.5, 32.1) with p = 0.002. The study identified Johor, Selangor and FT Kuala Lumpur & FT Putrajaya as the top three states with the highest prevalence of overall delay at 45.5% (95% CI: 36.6, 54.8), 43.0% (95% CI: 29.5, 57.7) and 42.5% (95% CI: 32.1, 53.6), respectively (p = 0.028) (Table 5).

DISCUSSION

This study delves into the landscape of childhood vaccinations among Malaysian children aged 12 to 23 months. The data was taken from the second nationwide maternal health survey. It was conducted after the COVID-19 pandemic slowdown. The apparent success of the immunisation coverage reflected in the overall prevalence of complete primary vaccination at 87.1% and should be viewed in the context of recent challenges of COVID-19 pandemic. A global distruption ot routine immunisation was noted in 2020 but it was recovered progressively to prevent the resurgence of vaccine preventable diseases (O'Brien & Lemango 2023).

This study found that each vaccine's median age of vaccination was aligned with the recommended vaccination schedule. However, the timely vaccination among children aged 12 to 23 months who completed their primary vaccination in Malaysia was only 51.2%. Based on previous studies that used a similar definition for timely definition, the prevalence was 31.9 % in Northwest Ethiopia (Mekonnen et al. 2020) and 60.7 % in the Philippines (Raguindin et al. 2021). A higher timeliness for the BCG vaccine at 98.0% and hepatitis B dose-1 at 97.6%; however, the percentage decreased with increasing age. The study in Negeri Sembilan showed a similar pattern of vaccine timeliness, with higher timeliness for vaccines administered at younger ages (Abidin et al. 2017).

The prevalence of delayed vaccination in this study, by using definition after the maximum EPI interval or 30 days from the recommended age, was 35.6%. The prevalence observed in this study was higher compared to the finding of a study conducted in Jeddah, Saudi Arabia, where the prevalence was 24.2% (Banjari et al. 2018). Delay vaccination occurs even in high-income countries such as in Australia (Thomas et al. 2022) and the United Kingdom (Suffel et al. 2023). This study also found that vaccine administered at a later age of the child has a higher prevalence of delay, particularly the second dose of pneumococcal and MMR vaccines (15.0% and 11.2%, respectively). This finding is similar to other studies conducted in the United Kingdom (Suffel et al. 2023; Walton et al. 2017) and elsewhere such as Kingdom of Saudi Arabia, Ghana, Senegal and India (Banjari et al. 2018; Laryea et al. 2014; Mbengue et al. 2017; Yadav et al. 2012).

The results illuminate a significant urban-rural disparity in vaccination timeliness, with urban areas exhibiting a higher overall delay prevalence (39.0%) than rural areas (27.6%). In addition to urban-rural disparities, a state-level variation was also noted where Johor, Selangor and FT Kuala Lumpur & FT Putrajaya were states with the highest overall delay prevalence (45.5%, 43.0% and 42.5%, respectively). Both discrepancies necessitate an exploration of the underlying factors contributing to vaccination delays, such as access to healthcare services, community awareness and potential socioeconomic influences (Choudhary et al. 2019; Hu et al. 2014; Mbengue et al. 2017; Mekonnen et al. 2020; Ramaswamy et al. 2014). In Malaysia, vaccination

TABLE 5: Analysis of the overall timely and delayed primary childhood vaccination among children who completed full vaccination in NHMS 2022 based on children's sociodemographic factors; n = 2,543.

Variables	Timely vaccination				Delay vaccination				p-value
	n	%	95% CI		n	%	95% CI		
			Lower	Upper			Lower	Upper	
Overall, (n = 2,543)	1640	51.2	47.2	55.2	903	35.6	31.7	39.7	
Strata									
Urban	1088	47.5	42.5	52.6	672	39.0	33.9	44.4	0.002*
Rural	552	59.8	54.1	65.2	231	27.6	23.5	32.1	
Strata state & federal territory (FT)									
Johor	74	40.8	32.6	49.6	72	45.5	36.6	54.8	0.028*
Kedah	147	55.3	49.8	60.7	81	29.7	24.1	36.1	
Kelantan	111	60.3	52.0	68.1	53	27.8	20.6	36.3	
Melaka	133	53.9	47.1	60.6	70	29.3	22.3	37.5	
Negeri Sembilan	124	64.8	56.1	72.6	48	23.4	17.1	31.3	
Pahang	141	66.5	59.1	73.2	51	22.1	17.1	28.0	
Perak	129	58.2	50.6	65.5	67	31.0	24.3	38.6	
Perlis	135	60.0	51.4	68.0	53	21.9	15.6	29.8	
Pulau Pinang	115	59.1	45.1	71.8	48	26.4	18.0	37.0	
Sabah & FT Labuan	92	46.4	39.0	53.9	72	41.7	34.8	48.9	
Sarawak	152	56.3	49.8	62.6	83	32.2	26.5	38.5	
Selangor	91	45.1	31.1	60.0	83	43.0	29.5	57.7	
Terengganu	119	55.1	47.2	62.8	55	25.1	19.0	32.3	
FT Kuala Lumpur & FT Putrajaya	77	38.9	29.1	49.6	67	42.5	32.1	53.6	
Sex									
Boy	831	50.7	44.5	56.8	464	36.3	30.4	42.6	0.907
Girl	809	51.8	47.3	56.2	439	34.8	30.8	39.1	
Ethnicity									
Malay	1311	52.8	50.1	55.6	707	34.1	31.5	36.8	0.768
Chinese	67	42.4	29.6	56.3	43	40.3	28.9	52.9	
Indian	52	47.6	33.9	61.6	29	39.3	25.8	54.7	
Other Bumiputera	194	56.5	50.6	62.3	107	31.8	26.5	37.6	
Others	15	45.8	16.4	78.4	17	43.8	15.4	77.0	
Citizenship									
Malaysian	1625	51.4	48.4	54.3	886	34.5	31.8	37.3	0.317
Permanent resident or non-citizen	14	48.6	15.7	82.7	17	50.1	16.7	83.5	
Household income group									
Below 40%	720	52.9	48.5	57.2	359	32.7	28.5	37.2	0.422
Medium 40%	705	52.2	44.9	59.4	400	36.0	29.0	43.6	
Top 20 %	215	45	36.4	53.9	144	40.9	33.8	48.3	

*p-value <0.05

coverage and timeliness may not be an issue for those who reside in rural areas as health services are generally easily accessible except for those in very remote areas such as indigenous population (Mat Daud et al. 2022). While those who reside in urban areas may be attributed to parental knowledge, vaccine hesitancy, false beliefs, trust issues in the healthcare provider and urban poverty (Ahmad et al. 2017; Musa et al. 2019; Voo et al. 2021). Collaborative efforts between healthcare authorities and communities in these regions can enhance targeted interventions, ensuring timely vaccinations and mitigating disparities.

The observed trends emphasise the importance of ongoing surveillance and targeted interventions in the vaccination programme. Strengthening public health policies, especially in urban areas and states with higher delay prevalence is crucial. Investigating the specific factors contributing to delays and assessing the impact of interventions can guide evidence-based policy adjustments. Further research is warranted to explore parental perceptions, healthcare system challenges and community engagement strategies to enhance vaccination timeliness across diverse populations.

Strengths and Limitations

This study is a nationwide survey with an adequate sample for national surveys; however, there is inadequate response from Chinese and Indian ethnicities and limits the ethnicity exploration. Future studies should adopt proportionate sampling based on ethnicity to ensure adequate representation and variation across different ethnic groups. The study on timeliness used immunisation card verification, which reduced the potential recall bias among the respondents. This study is a cross-sectional survey which limits causal relationships. The survey encompasses many topics covering maternal and child health issues in which a specific indepth exploration of parents characteristic, attitudes and knowledge is lacking.

CONCLUSION

In conclusion, while Malaysia demonstrates a commendable overall prevalence of complete primary vaccination but the timeliness of vaccination needs to be improved. The delayed immunisation warrants targeted interventions, particularly for the second doses of Pneumococcal and MMR vaccines. The observed urban-rural disparities and state-level variations underscore the need for tailored strategies to address specific challenges in vaccination timeliness. Strengthening public health policies, community engagement and ongoing research are essential to ensure equitable and timely vaccination coverage, safeguarding children's health nationwide.

Data availability statement: The dataset for this study is available upon request to the corresponding author. The principal author kept the dataset according to the National Institutes of Health Malaysia research data repository guidelines.

Author contributions: Study design, supervision for the field data collection: NH, MAAA, MAAR; Data analysis, findings interpretation: SMA, WSAJ, NAW; Manuscript-original draft SMA, NH, WSAJ; Manuscript-review and editing: MAAA, MAAR. All authors have diligently reviewed and approved the final draft and collectively assume responsibility for the manuscript's content and its similarity index.

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Ethical approval: The study obtained ethical approval from the Medical and Research Ethics Committee (MREC), Ministry of Health, Malaysia (NMRR-20-959-53329). The study was conducted in accordance with the relevant guidelines and regulations or in accordance with the Declaration of Helsinki. Informed consent was obtained from the parents/ guardians prior to the survey.

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