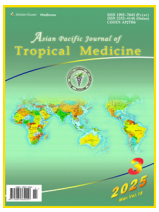

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Evaluating the vaccination coverage and timeliness of childhood vaccination among Indigenous children in Peninsular Malaysia: Findings from the 2022 Orang Asli Health Survey

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ABSTRACT

Objective: To assess the complete vaccination coverage and timeliness of childhood vaccinations among Indigenous children in Peninsular Malaysia.

Methods: The study utilized data from the 2022 Orang Asli Health Survey, a cross-sectional survey conducted among a representative sample of Orang Asli in Peninsular Malaysia. A total of 68 villages were randomly selected from a pool of 853 villages, encompassing diverse geographic and sociodemographic contexts with a total of 15950 respondents Orang Asli successfully interviewed. However, this study only utilized data from surveyed children aged 12 to 59 months with a total of 1551 children included. Validated structured questionnaires were used to collect sociodemographic data and health status, with nurses verifying vaccination records. Children who received all nine primary vaccinations were defined as having complete vaccination while those who received vaccine within the recommended time were defined as having timely vaccination. Data analysis was conducted using IBM SPSS version 25.0, focusing on descriptive analyses of children's vaccination status.

Results: The prevalence of overall complete vaccination among Indigenous children was 87.7%, while timely vaccination was only 40.3%. The prevalence of complete vaccination for Bacillus Calmette-Guérin (BCG), the first dose of hepatitis B, three doses of DTaP-IPV-Hib, and measles, mumps, and rubella (MMR) was above 95.0%, except for the second and third doses of hepatitis B. The prevalence of timely vaccination ranged from above 95.0% for vaccines given at birth, gradually decreasing with increasing age to 57.5% for the first dose of MMR. Moreover, the completion rates for three doses of DtaP-IPV-Hib and the initial dose of MMR surpassed 90% among Indigenous children aged 12-23 months, yet the timeliness remained at a moderate level.

Conclusions: While the overall complete vaccination coverage among Indigenous children in Malaysia is relatively high, there are concerning disparities in the timeliness of vaccination, particularly as children age.

KEYWORDS: Childhood vaccination coverage; Orang Asli; Indigenous; Timeliness; Age-appropriate vaccinations; Peninsular Malaysia

Summary

Question: What is the completeness and timeliness of primary vaccination among indigenous children aged 12–59 months in Peninsular Malaysia?

Findings: In this cross-sectional study using data from the 2022 Orang Asli Health Survey, the prevalence of complete vaccination was 87.7%, while timely vaccination was only 40.3%.

Meaning: While overall vaccination coverage is high, delays in vaccination remain a concern, highlighting the need for targeted interventions to improve timely immunization among Indigenous children.

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1. Introduction

Orang Asli (later referred to as Indigenous people) are among the minority ethnic groups in Malaysia, and the estimated Indigenous population stood at approximately 215215 individuals, constituting merely 0.6% of the total Malaysian population[1]. Under the definition of Section 3 of the *Aboriginal Peoples Act* 1954, any person whose male parent is, or was a member of an aboriginal ethnic group, who speaks an aboriginal language and habitually follows an aboriginal way of life and aboriginal customs and beliefs and includes a descendant through males of such persons were covered under this act[2]. In 2019, 15 deaths of Indigenous people in Kampung Kuala Koh in Kelantan, Peninsular Malaysia attracted attention from many stakeholders to investigate the root cause and it was confirmed to be a measles outbreak[3-5]. Measles is one of the vaccine-preventable diseases that has been included in the scheduled childhood primary vaccination program[6].

Childhood vaccination programs are crucial for public health, playing a pivotal role in preventing the transmission of vaccine-preventable infectious diseases and reducing mortality rates globally[7,8]. Unfortunately, Indigenous people are often of lower socioeconomic status, and tend to struggle with numerous health issues that are exacerbated by limited modern health awareness and a strong adherence to ancestral cultural beliefs[9-11]. Indigenous populations who reside in rural and remote areas were found to have lower vaccination coverage at 76.8% for basic vaccines[12]. On the other hand, certain diseases, such as measles, are highly infectious and can cause outbreaks in non-endemic country like Australia[13]. The Indigenous populations are more susceptible than the general population due to the lower vaccination coverage[14]. In recent measles outbreak among Indigenous people in Kuala Koh, the disease was suspected to have been transmitted by outsiders to the immunologically naive community[15].

Various studies found that Indigenous children's vaccination coverage and timeliness were inadequate compared to non-Indigenous children even before the COVID-19 pandemic[16,17]. The recent COVID-19 pandemic has disrupted routine childhood vaccination coverage worldwide in 2020[18]. In Malaysia, the Department of Orang Asli Development, abbreviated as JAKOA, and the Ministry of Health oversee the Indigenous children's health status including vaccination coverage. The national vaccination coverage among Malaysian children were noted at 86.4% in 2016; however, it was unable to report for the Indigenous population in Malaysia[19,20]. In view of the above point and measles outbreak among Indigenous people in 2019[3], a national survey on vaccination coverage among Indigenous children is timely. This study aims to assess the vaccination coverage and timeliness of childhood vaccination among Indigenous children in Peninsular Malaysia.

2. Methods

This study utilized data from the first nationwide Orang Asli Health Survey, a cross-sectional study conducted among Indigenous populations residing across urban, fringe, and remote regions of Peninsular Malaysia. The primary tribes within this population are traditionally classified into three main groups: the Negrito, Senoi, and Proto-Malays. Indigenous communities are characterized by their adherence to traditional livelihoods deeply entrenched in ancestral lands, predominantly situated in rural and remote areas. Notably, Indigenous populations often experience health disparities marked by elevated rates of chronic illnesses, restricted access to healthcare services, and diminished life expectancies relative to their non-Indigenous counterparts.

2.1. Sampling procedure

The sampling frame, consisting of 853 Indigenous villages in Peninsular Malaysia, was provided by JAKOA, a government institution dedicated to supporting education, health, and socioeconomic development initiatives within Indigenous communities. The survey employed a single proportion formula to calculate the sample size, adjusting for the design effect and a non-response rate of 35%. The sampling process stratified villages based on the tribe locality, with urban, fringe, and remote areas constituting the primary stratum and the primary tribe serving as the secondary stratum. Subsequently, 68 villages were randomly selected in proportion to the tribal locality. All households within the selected villages' living quarters were eligible for participation in the survey. This study focused on the children population under five years old and the sample size was calculated using a precision of 0.05 and a confidence level of 95%, resulting in a required sample size of 384 children for each tribe.

2.2. Data collection

Data was collected between 20th July 2022 and 13th September 2022. Multiple approaches were conducted including a community event approach where the villagers gathered at a community hall to join the health outreach events and participate in the survey. The conventional approach of home visits was conducted for any villagers who were unable to join the community event. The data collection team utilized a structured questionnaire to gather information on sociodemographic profiles. Additionally, verification of primary vaccination data was conducted using children's immunization records books by the registered nurses.

2.3. Variables and measures

The definition of complete primary vaccination refers to a child who has received all the primary vaccinations consisting of Bacillus Calmette-Guérin (BCG), three doses of hepatitis B, three doses of diphtheria, tetanus, acellular pertussis, inactivated poliovirus, and haemophilus influenzae type b (DtaP-IPV-Hib), and Measles, Mumps, and Rubella (MMR), regardless the time of vaccination according to the recommended schedule. A second definition for complete vaccination was also calculated due to the national immunization program schedule transition from pentavalent to the hexavalent vaccine by excluding the second and third doses of the hepatitis B vaccine for children born starting from 1st December 2020 and onwards. The hexavalent vaccine consisted of six types of vaccines, a combination of the previous pentavalent vaccine and hepatitis B[21]. The definition of timely vaccination in this study is when all vaccines were received within the recommended time interval, while delayed primary vaccination refers to a circumstance, in which any of the primary vaccines were received after the recommended time interval. Timely vaccination was defined for each vaccine as well as the overall set of primary vaccines including BCG, hepatitis B at birth, three doses of DtaP-IPV-Hib, and one dose of MMR. The second and third doses of hepatitis B were not considered in the overall timeliness calculation due to the national immunization program schedule transition from the pentavalent to the hexavalent vaccine. In this study, a child was deemed to have had timely vaccination if the vaccine was administered within four days before the due date or one month after the due date as mentioned in previous literature[22-25]. For the scheduled vaccines at birth, the vaccine must be administered within one month after birth.

2.4. Data analysis

Data were extracted in Microsoft Excel format, with a focus on ensuring the validity of the recorded vaccination dates for each vaccine. To determine the children's ages at specific vaccination types and doses, the vaccination date was subtracted from the date of birth, resulting in age calculations in days. The median and interquartile range were used in this study due to the non-normal distribution of the data. The timeliness of vaccination was assessed for each vaccine type. The prevalence of primary vaccination coverage and timeliness was computed using a complex sampling plan (cs-plan) in IBM SPSS version 25.0, to account for population weighting and ensure representativeness. Bivariate analysis comparing the pattern of vaccination across the tribe and age groups was conducted *via* complex sampling cross-tabulation, with statistical significance set at a *P*-value of less than 0.05 based on the second-order Rao-Scott adjusted *Chi*-square statistic.

2.5. Ethical considerations

The research received ethical approval from the Medical Research and Ethics Committee of the Ministry of Health Malaysia and was registered with the National Medical Research Registry (NMRR-19-3108-50999) on 18 December 2019. Additionally, approval was obtained from the Department of Orang Asli Development and the heads of the respective villages prior to the survey. Written informed consent was collected from the parents or guardians of the participating children before data collection. All study procedures adhered to the ethical principles outlined in the Declaration of Helsinki.

3. Results

The community-based survey achieved an overall response rate of 89.8%, with 4 141 out of 4 378 eligible living quarters successfully interviewed. The living quarters' response rate was 94.6%, and 15 950 out of 16 811 eligible participants were interviewed, reflecting an individual response rate of 94.9%. Regarding the target population in this study, a total of 1 551 Indigenous children aged 12 to 59 months participated in the survey. Among them, 1 260 had vaccination records and were included in the analysis, representing 43.3%, 29.4%, and 27.3% from the Senoi, Negrito, and Proto-Malays tribes, respectively, while 291 children without vaccination records were excluded from the analysis (Table 1).

Table 1. Sociodemographic of the Indigenous children aged 12-59 months in Orang Asli Health Survey 2022 (n=1 260).

Variables	Overall	%
Median age (IQR), months	33 (22)	-
Age, months		
12-23*	324	25.7
24-35	382	30.3
36-47	292	23.2
48-59	262	20.8
Sex		
Male	642	51.0
Female	618	49.0
Main tribe		
Senoi	546	43.3
Negrito	370	29.4
Proto-Malay	344	27.3
Strata		
Urban	92	7.3
Fringe	566	44.9
Remote	602	47.8

*The date of birth of the children were in between August 2020 to August 2021.

Table 2 shows the median age of vaccination by the type of vaccine and within the main tribes. The overall median ages (interquartile range, IQR) for BCG, 1st dose of hepatitis B, 1st dose of DtaP-IPV-Hib, 2nd dose of DtaP-IPV-Hib, 3rd dose of DtaP-IPV-Hib, and

MMR vaccinations were 1 (1), 0 (0), 64 (15), 96 (23), 157 (22), and 292 (92) days, respectively. In terms of tribes, Indigenous children from the Negrito tribe consistently shows a higher median age for each vaccine than the Senoi or Proto-Malays tribes.

The prevalence of overall complete vaccination among Indigenous children was 87.7% (95% *CI* 84.2, 90.5) and it was not statistically different among the three main tribes. If the hepatitis B 2nd and 3rd doses were not considered in the calculation, the prevalence of complete vaccination among Indigenous children was 94.6% (95% *CI* 91.6, 96.6). For specific vaccines, the BCG vaccination coverage was high across all ethnic groups, where children from the Senoi tribe showed the highest coverage (99.7%, *P*=0.011). The completion rates for other vaccines, such as hepatitis B and DtaP-IPV-HiB, varied among ethnic groups, although the differences were not statistically significant (*P*>0.05) (Table 3). The completeness for the three doses of DtaP-IPV-HiB and the first dose of MMR was above 95% in all three main tribes.

The prevalence of overall timely vaccination among Indigenous children was 40.3% (95% *CI* 33.5, 47.5) as shown in Table 4. A notable trend emerged, indicating a gradual decrease in timely vaccination rates with increasing child age, ranging from 95.8% (1170/1260) for BCG to 57.5% (632/1260) for MMR. Overall, there were no statistically significant differences observed in the timeliness of each type of vaccine among Indigenous tribes (*P*>0.05).

Table 5 illustrates the primary vaccination completeness patterns among Indigenous children aged 12-59 months, categorized by age groups. Among Indigenous children aged 12-23 months, the overall prevalence of primary vaccination completeness stood at 60.7% (95% *CI* 52.1, 68.7), but steadily above 90% for older children. Notably, the completeness rates for three doses of DtaP-IPV-Hib and the first dose of MMR exceeded 90% among Indigenous children aged 12-23 months. The completeness rates for three doses of DTaP-IPV-Hib were 100% for children aged 48-59 months and 99.3% for the first dose of MMR.

Table 6 presents the pattern of primary vaccination timeliness status categorized by age groups. Notably, good vaccine timeliness was observed for vaccines administered at birth. Among Indigenous children aged 12-23 months, the timeliness for the 3rd dose of DtaP-IPV-Hib was 71.0% (95% *CI* 62.3, 78.4), while for the 1st dose of MMR, it was 57.6% (95% *CI* 48.4, 66.2). Similar patterns of vaccine timeliness were observed for older children as well.

Table 2. Age of vaccination by the type of vaccine and the main tribes [Median (IQR)].

Type of primary childhood vaccination	The recommended age range of vaccination according to Malaysian NIP[#]	Overall, day	Age at vaccination, day			[*]*P*-value
			Negrito	Malay Proto	Senoi	
BCG (*n*=1 242)	24 hours after birth or within 30 days	1 (1)	1 (2)	1 (1)	1 (1)	0.001
Hepatitis B 1st dose; monovalent (*n*=1 241)	24 hours after birth or within 30 days	0 (0)	0 (0)	0 (0)	0 (0)	0.002
Hepatitis B 2nd dose (*n*=1 131)	4 weeks after the first dose (30-120 days)†	34 (25)	37 (28)	33 (29)	33 (17)	<0.001
Hepatitis B 3rd dose (*n*=1 106)	6 months (150-210 days)†	187 (20)	195 (34)	186 (18)	186 (14)	<0.001
DtaP 1st dose (*n*=1 241)	2 months (60-90 days)	64 (15)	70 (25)	63 (9)	64 (11)	<0.001
DtaP 2nd dose (*n*=1 237)	3 months (90-120 days)	96 (23)	107 (39)	95 (16)	94 (11)	<0.001
DtaP 3rd dose (*n*=1 214)	5 months (150-180 days)	157 (22)	164 (43)	156 (17)	155 (16)	<0.001
MMR 1st dose (*n*=1 227)	9 months (270-300 days)	292 (92)	298 (93)	293 (91)	287 (91)	0.017

BCG: Bacillus Calmette-Guérin; MMR: Measles, Mumps, and Rubella; [*]*P*-value based on the independent samples Kruskal-Wallis test. †A wide recommended interval was given due to the transition of a single dose of hepatitis B vaccine for dose-2 and dose-3 with the hexavalent vaccine in the Malaysia NIP scheduled dated December 1st, 2020, onwards. [#]NIP: national immunization program. A timely vaccination was considered if the vaccine was administered within four days before the due date or one month after the due date.

Table 3. Primary vaccination completion status for Indigenous children aged 12-59 months by the main tribe in Orang Asli Health Survey 2022.

Vaccines	Overall (*n*=1 260)		Tribes						*P*-value
			Negrito (*n*=370)		Malay Proto (*n*=344)		Senoi (*n*=546)		
	n	% (95% *CI*)	*n*	% (95% *CI*)	*n*	% (95% *CI*)	*n*	% (95% *CI*)	
BCG	1 242	98.9 (97.0, 99.6)	365	98.6 (96.3, 99.5)	333	97.8 (91.1, 99.4)	544	99.7 (98.9, 99.9)	0.011
Hepatitis B 1st dose	1 241	99.1 (97.1, 99.7)	362	98.2 (95.6, 99.2)	333	97.8 (91.9, 99.4)	546	100.0 (100.0, 100.0)	0.099
DTaP 1st dose	1 241	98.0 (94.6, 99.3)	365	99.0 (96.8, 99.7)	334	96.2 (86.7, 99.0)	542	99.1 (96.5, 99.8)	0.108
Hepatitis B 2nd dose	1 131	92.6 (90.0, 94.5)	308	84.6 (79.4, 88.6)	316	91.8 (86.6, 95.1)	507	93.5 (90.6, 95.5)	0.184
DTaP 2nd dose	1 237	98.0 (94.3, 99.3)	363	98.4 (96.4, 99.3)	335	96.9 (83.8, 99.5)	539	98.7 (97.3, 99.4)	0.346
DTaP 3rd dose	1 214	96.9 (93.9, 98.4)	356	96.6 (92.5, 98.5)	327	95.7 (86.7, 98.7)	531	97.7 (95.8, 98.8)	0.385
Hepatitis B 3rd dose	1 107	91.9 (89.7, 93.7)	303	81.7 (76.4, 86.0)	301	92.0 (88.2, 94.6)	503	92.4 (89.2, 94.6)	0.099
MMR 1st dose	1228	97.2 (94.5, 98.6)	361	97.9 (96.2, 98.9)	334	96.9 (88.4, 99.2)	533	97.4 (94.9, 98.7)	0.839
Completed all vaccines	1 039	87.7 (84.2, 90.5)	275	74.1 (67.1, 80.0)	287	88.6 (82.7, 92.7)	477	87.7 (82.8, 91.4)	0.160
[*]Completed vaccines	1 188	94.6 (91.6, 96.6)	349	94.2 (89.9, 96.8)	319	94.0 (87.4, 97.2)	520	95.1 (91.1, 97.3)	0.720

[*]Completed vaccines but hepatitis B 2nd and 3rd doses were not considered in the calculation due to the NIP schedule transition from pentavalent to hexavalent vaccine.

Table 4. Primary vaccination timeliness status for Indigenous children aged 12-59 months by the main tribe in Orang Asli Health Survey 2022.

Vaccines	Overall (*n*=1 260)		Tribes						*P*-value
			Negrito (*n*=370)		Malay Proto (*n*=344)		Senoi (*n*=546)		
	n	% (95% *CI*)	*n*	% (95% *CI*)	*n*	% (95% *CI*)	*n*	% (95% *CI*)	
BCG	1 170	95.8 (93.2, 97.4)	332	91.3 (81.5, 96.1)	318	95.9 (88.2, 98.7)	520	95.9 (93.8, 97.2)	0.599
Hepatitis B 1st dose	1 169	96.0 (93.7, 97.5)	329	91.0 (82.1, 95.7)	318	96.3 (89.5, 98.8)	522	96.0 (94.2, 97.3)	0.495
DTaP 1st dose	1 011	86.0 (81.4, 89.7)	274	76.0 (68.7, 82.1)	283	88.3 (78.5, 94.0)	454	85.0 (79.9, 89.0)	0.464
Hepatitis B 2nd dose	931	83.8 (79.1, 87.6)	243	79.0 (70.8, 85.3)	260	81.8 (70.9, 89.2)	428	85.3 (80.3, 89.2)	0.306
DTaP 2nd dose	930	81.9 (76.1, 86.5)	230	64.1 (54.4, 72.9)	270	84.0 (72.7, 91.2)	430	81.4 (74.5, 86.7)	0.335
DTaP 3rd dose	876	76.7 (71.1, 81.5)	219	62.5 (53.9, 70.3)	250	75.6 (65.0, 83.7)	407	78.2 (71.6, 83.6)	0.261
Hepatitis B 3rd dose	842	79.9 (76.1, 83.2)	205	68.4 (61.0, 75.0)	236	80.0 (75.0, 84.1)	401	80.4 (74.8, 85.0)	0.339
MMR 1st dose	632	57.5 (50.5, 64.2)	180	50.9 (42.6, 59.2)	163	61.4 (46.9, 74.1)	289	55.3 (50.0, 60.4)	0.417
[*]All vaccines timely vaccinated	407	40.3 (33.5, 47.5)	104	29.1 (22.3, 36.9)	110	45.1 (32.9, 57.9)	193	37.7 (30.3, 45.8)	0.278

[*]All vaccines timely vaccinated, however hepatitis B 2nd and 3rd doses were not considered in the calculation due to the NIP schedule transition from pentavalent to hexavalent vaccine.

Table 5. Patterns of primary vaccination completion status for Indigenous children aged 12-59 months by the age groups in Orang Asli Health Survey 2022.

Vaccines	12-23 months		24-35 months		36-47 months		48-59 months		*P*-value
	n	% (95% *CI*)	*n*	% (95% *CI*)	*n*	% (95% *CI*)	*n*	% (95% *CI*)	
BCG	316	98.0 (94.4, 99.3)	374	98.6 (94.5, 99.7)	291	97.7 (97.5, 100.0)	261	99.8 (98.5, 100.0)	0.080
Hepatitis B 1st dose	315	98.2 (94.6, 99.4)	373	98.6 (94.5, 99.7)	291	100.0 (99.6, 100.0)	262	100.0 (100.0, 100.0)	0.156
DTaP 1st dose	314	93.7 (85.1, 97.5)	373	98.6 (94.5, 99.7)	292	100.0 (100.0, 100.0)	262	100.0 (100.0, 100.0)	0.007
Hepatitis B 2nd dose	211	72.3 (64.9, 78.6)	370	98.5 (94.6, 99.6)	290	99.8 (98.8, 100.0)	260	99.9 (99.6, 100.0)	<0.001
DTaP 2nd dose	312	93.9 (84.7, 97.7)	372	98.6 (94.5, 99.7)	292	100.0 (100.0, 100.0)	261	100.0 (100.0, 100.0)	0.012
DTaP 3rd dose	300	90.6 (83.6, 94.8)	364	98.0 (94.4, 99.3)	289	99.6 (97.7, 99.9)	261	100.0 (99.7, 100.0)	<0.001
Hepatitis B 3rd dose	213	73.0 (65.6, 79.3)	349	96.1 (92.3, 98.1)	286	99.6 (98.8, 99.9)	259	99.9 (99.4, 100.0)	<0.001
MMR 1st dose	307	93.4 (87.8, 96.6)	369	96.9 (92.7, 98.7)	292	100.0 (100.0, 100.0)	260	99.3 (95.6, 99.9)	0.008
Completed all vaccines	165	60.7 (52.1, 68.7)	340	94.2 (90.1, 96.7)	280	98.6 (97.0, 99.4)	254	98.6 (95.7, 99.5)	<0.001
[*]Completed vaccines	284	85.5 (78.9, 90.3)	359	95.9 (92.0, 97.9)	287	99.2 (97.4, 99.7)	258	98.7 (95.7, 99.6)	<0.001

[*]Completed vaccines but hepatitis B 2nd and 3rd doses were not considered in the calculation due to the NIP schedule transition from pentavalent to hexavalent vaccine.

Table 6. Patterns of primary vaccination timeliness status for Indigenous children aged 12-59 months by the age groups in Orang Asli Health Survey 2022.

Vaccines	12-23 months		24-35 months		36-47 months		48-59 months		*P*-value
	n	% (95% *CI*)	*n*	% (95% *CI*)	*n*	% (95% *CI*)	*n*	% (95% *CI*)	
BCG	304	97.8 (94.3, 99.2)	352	95.2 (88.7, 98.0)	272	95.1 (90.0, 97.7)	242	94.9 (90.2, 97.4)	0.478
Hepatitis B 1st dose	297	95.8 (92.2, 97.8)	354	95.6 (89.1, 98.3)	273	97.2 (94.5, 98.6)	245	95.5 (90.9, 97.9)	0.799
DTaP 1st dose	251	82.8 (76.0, 88.1)	318	88.1 (82.1, 92.3)	231	85.0 (79.8, 89.1)	211	87.6 (82.1, 91.6)	0.167
Hepatitis B 2nd dose	155	76.6 (65.0, 85.2)	318	85.7 (79.9, 90.0)	241	85.8 (80.2, 89.9)	217	85.1 (78.8, 89.7)	0.100
DTaP 2nd dose	229	77.5 (69.9, 83.7)	293	82.9 (75.3, 88.6)	224	85.8 (78.5, 91.0)	184	80.8 (72.5, 87.1)	0.159
DTaP 3rd dose	201	71.0 (62.3, 78.4)	276	76.7 (68.0, 83.7)	222	83.4 (76.8, 88.5)	177	75.7 (70.1, 80.5)	0.027
Hepatitis B 3rd dose	129	64.3 (56.3, 71.6)	293	83.1 (76.4, 88.2)	220	84.5 (77.3, 89.7)	200	83.8 (74.6, 90.1)	0.001
MMR 1st dose	155	57.6 (48.4, 66.2)	198	55.5 (48.6, 62.1)	158	58.8 (47.5, 69.2)	121	59.0 (43.0, 73.4)	0.879
[*]All vaccines timely vaccinated	218	63.7 (53.3, 72.9)	230	57.4 (48.4, 65.9)	190	59.2 (47.5, 69.9)	186	59.3 (45.4, 71.8)	0.720

[*]All vaccines timely vaccinated, however, hepatitis B 2nd and 3rd doses were not considered in the calculation due to the NIP schedule transition from pentavalent to hexavalent vaccine.

4. Discussion

The findings of this study provide valuable insights into the vaccination coverage status and timeliness among Indigenous children in Peninsular Malaysia, shedding light on both successes and challenges within the vaccination program. The high overall response rate of 89.8% indicates a robust data collection process, ensuring a representative sample of the Indigenous population post-COVID-19 pandemic. The study was instigated in response to the 2019 measles outbreaks in Kuala Koh, affecting the Bateq sub-tribe, a part of the main Negrito tribe residing in Northern Peninsular Malaysia[3,5,14]. Measles is a highly contagious disease, and the outbreak was recorded even in very high vaccination coverage countries[26,27]. Measles, diphtheria, pertussis, tetanus, and several other vaccine-preventable diseases were included in the global primary vaccination program to reduce children's mortality and morbidity since the establishment of an expanded program in 1974[8]. The vaccination program has been instrumental in averting 3.5 to 5 million deaths annually, underscoring its critical role in public health. Monitoring trends in vaccination coverage, especially for childhood primary vaccinations, is imperative to address disparities arising from minority populations[28].

A study examining childhood vaccination coverage in five South Asian countries revealed notable disparities: Afghanistan reported

the lowest coverage at 42.6%, followed by Pakistan (62.2%), India (77.1%), Nepal (79.2%), and Bangladesh achieving the highest rate at 88.2%[29]. Vaccination coverage is often lower among populations in rural and remote areas, as experienced by Indigenous populations, due to geographic isolation that limits access to healthcare services and infrastructure[30,31]. A previous study reported that only 52% of children from tribal populations in India were fully vaccinated by the age of 12 months, highlighting significant disparities in immunization coverage within these communities[32]. A comparison between Indigenous and non-Indigenous groups in Australia highlighted vaccine coverage inequalities, although vaccination rates among Aboriginal and Torres Strait Islander children were reported to be above 90%[17,23,33]. This study reported a high overall vaccination coverage of 87.7% among Indigenous children aged 12 to 59 months, which is comparable to the national vaccination coverage of 86.4% among Malaysian children[20]. A high vaccination coverage was observed for three doses of DTaP-IPV-Hib and the first dose of MMR among Indigenous children aged 12 to 23 months, despite an overall vaccination coverage of only 60.7% for this age group. This lower overall rate is attributed to the inclusion of the second and third doses of hepatitis B in the calculation of total primary vaccination coverage, which may have impacted the total rate. This group of children was born in 2021 when Malaysia implemented the hexavalent vaccine which combines the previous pentavalent vaccine (Pentaxim®) plus hepatitis B[21]. The vaccination coverage was steadily above 90% for the older children during the surveyed time. This could potentially be attributed to the effectiveness of the outreach programs conducted by the Ministry of Health for primary childhood immunization which was also seen during the COVID-19 immunization program[4]. Outreach programs are one of the most effective interventions to increase vaccine uptake among children in low and middle-income countries[34,35].

A high vaccination coverage may overestimate the protection as the vaccine effectiveness also depend on the timely vaccination within the recommended schedule[36]. However, the observed decrease in timely vaccination rates with increasing child age in this study raises concerns regarding the effectiveness of vaccination programs as children grow older. This decline in timeliness, particularly evident in vaccines such as MMR, highlights the need for targeted interventions to improve vaccination adherence among children at their appropriate age for the MMR vaccine. A similar trend was observed in previous studies where the timeliness rate is half or much lower from the vaccination coverage rate[17,23,37,38]. This pattern was noted before the COVID-19 pandemic with the evidence of measle outbreaks in many areas[26,27].

Furthermore, disparities in vaccination completeness and timeliness across different tribe groups, although not statistically significant, warrant attention and further investigation. Indigenous populations have unique ancestral beliefs and cultures and have wide variation among the tribes[39]. Some of the Negrito and Senoi populations resided in very remote areas, were nomadic, and nearly have no connection with the outer communities[40]. The disparities observed in timeliness rates among Indigenous tribes underscore the importance of culturally sensitive approaches to vaccination programs, tailored to address specific community needs and challenges. The recent COVID-19 pandemic shows that Indigenous people were not left behind[4] but have a strong resilience in facing the COVID-19 pandemic[41].

Overall, this study underscores the importance of ongoing monitoring and evaluation of vaccination programs, with a focus on addressing disparities in vaccination coverage and timeliness among Indigenous populations. Collaborative efforts between healthcare providers, policymakers, and community stakeholders are essential to strengthen vaccination programs, enhance public health outcomes, and reduce the burden of vaccine-preventable diseases among marginalized populations.

This was the first nationwide survey conducted among Indigenous people in Peninsular Malaysia covering the main three tribes of Negrito, Proto-Malays and Senoi. The study was conducted with adequate support from the Department of Orang Asli Development and the Ministry of Health Malaysia following the 2019 measles outbreak among the Indigenous population residing in northern Peninsular Malaysia. Adequate sample size for children's immunization coverage objective to ensure valid, reliable, and representative findings. The study limitation is the study focuses on children with valid data in their immunization cards. Self-reported vaccination was not considered due to the language barrier.

In conclusion, this study sheds light on complete vaccination coverage and timeliness among Indigenous children aged 12 to 59 months in Peninsular Malaysia, as evidenced by the participation of 1 260 children from diverse tribal backgrounds. While the overall prevalence of complete vaccination is relatively high at 87.7%, notable disparities exist in timeliness across different vaccine types, with decreasing rates observed as children age. Despite achieving completeness rates exceeding 90% for certain vaccines among children aged 12 to 23 months, the timeliness of vaccinations remains a concern, particularly for vaccines administered later in the childhood schedule. These findings underscore the importance of targeted interventions to enhance the timely administration of vaccines among Indigenous communities, thereby bolstering overall public health outcomes and reducing the risk of vaccine-preventable diseases in this population.

Conflict of interest statement

Authors declare no conflict of interest.

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Availability of data and materials

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.

Authors' contributions

SMA: Conceptualization, writing the original draft, review and editing; methodology, and formal analysis. NAW: Conceptualization, project administration, data collection supervision, writing the original draft, review and editing, methodology, formal analysis. NS: project administration, data collection supervision, writing the original draft, review and editing. MAAA: Conceptualization, project administration, data collection supervision, review and editing. NHR: Conceptualization, project administration, data collection supervision, review and editing. NA: Conceptualization, project administration, data collection supervision, review and editing, resources. All authors reviewed and approved the final version of the manuscript for publication.

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