SOCIOECONOMIC FACTORS AFFECTING VACCINATION COVERAGE AND TIMELINESS AMONG CHILDREN LIVING ALONG THE THAI-MYANMAR BORDER

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Abstract. Vaccination coverage in children may be inadequate among those living in areas with poor access to health care facilities potentially causing disease outbreaks. We assessed vaccination coverage and timeliness among children living in Thailand along the Thai-Myanmar border and assessed the factors associated with these findings in order to inform efforts to improve vaccination rates. We conducted a cross-sectional study at 11 child development centers run by the Mae Song Sub-district administrative office, Tha Song Yang District, Tak Province, Thailand from January to May 2018. The vaccination records for the first year of life used to obtain data for this study were from child health booklets, other documents and records from the extended program of immunization (EPI) register database for the Mae Song Health Promotion Hospital, a primary health facility in the study area. Anthropometry of the study subjects was measured by the study team. Caregivers of the study subjects were asked to complete a questionnaire asking about socio-demographic factors, household income, subject birth place, vaccination history and birth order. A total of 304 subjects were included in the study; 50.2% male. The mean (±standard deviation; range) age of study subjects was 4.5 (±1.1, 2-6 years). Majority (95.3%) of subjects had received the Bacillus Calmette-Guérin (BCG) vaccine, 87.1% had received the third dose of the diphtheria, tetanus, pertussis (DTP) vaccine; 87.1% had received the third dose of the hepatitis B (HepB) vaccine, 87.1% had received the third dose of the oral poliovirus (OPV) vaccine and 93.6% had received the first dose of the measles, mumps, Rubella (MMR) vaccine. Sixty-two-point-seven (62.7) percent of subjects had received all the above vaccine doses by age 12 months. The median delays in receiving vaccination doses were: 7.7 weeks for the birth dose of the HepB vaccine, 14.8 weeks for the third dose of the DTP vaccine,

14.8 weeks for the third dose of the HepB vaccine, 14.8 weeks for the third dose of the OPV vaccine and 22.6 weeks for the first dose of the MMR vaccine. Fifteen-point-one (15.1) percent of study subjects received timely vaccinations. The factors significantly associated with vaccination coverage and timeliness were: the caregiver being literate in the Thai language (adjusted odds ratio (aOR): 2.1, 95% confidence interval (CI): 1.1-3.9, $p = 0.018$), the study subject being aged 2-4 years (aOR: 2.3, 95% CI: 1.1-4.5, $p = 0.024$), the study subject being the first or second born child (aOR: 1.9, 95% CI: 1.1-3.2, $p = 0.028$) and vaccinations being given at the Health Promotion Hospital (aOR: 2.1, 95% CI: 1.3-3.6, $p = 0.005$). In summary, among study subjects the vaccination coverage was inadequate (<90%) for the BCG, HepB, OPV and DTP vaccines but adequate for the MMR vaccine during the first year but the great majority of vaccines were not given in a timely manner and the factors associated with this were the caregiver being literate, a young study subject, the birth order of the study subject and where the vaccines are given. We conclude, timely reminders need to be given to caregivers, especially to those who are illiterate in the Thai language, those who have at least 3 children, those with older children and those who do not live near a hospital, in order to improve first year vaccination rates in the study population. Further studies are needed to determine if these efforts can improve these vaccination rates.

Keywords: vaccination coverage, vaccination timeliness, Thailand-Myanmar border; migrant, expanded program on immunization; immunization.

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INTRODUCTION

Vaccinations are the most cost-effective method to reduce childhood morbidity and mortality with approximately 2.5 million vaccine-preventable deaths occurring world-wide annually (WHO, 2013). In low- and middle-income countries, vaccine-preventable diseases, such as measles and diphtheria, continue to cause morbidity and mortality, particularly among migrants, urban slum residents and those living in remote areas or with poor access to health facilities (Gauri and Khaleghian, 2002). Vaccination coverage in these at risk groups is usually lower than in the general population (Gauri and Khaleghian, 2002; Oyo-Ita *et al*, 2011).

The major barriers to vaccination include living in a remote area (Antai, 2010), having no or inadequate knowledge about the safety and benefits of vaccination (Munsawaengsub *et al*, 2011, Hu *et al*, 2013; Prakunwisit and Areesantichai, 2015), perceptions regarding immunization and its risks (Munsawaengsub *et al*, 2011), previous experiences with vaccination (McNeil *et al*, 2019), caregiver access to health care services (Hu *et al*, 2013), language barriers (Prakunwisit and Areesantichai, 2015), migration (Antai, 2010; Hu *et al*, 2013; Prakunwisit and Areesantichai, 2015) and the socio-economic status of the caregiver (Hu *et al*, 2013). Studies of vaccine coverage among migrant children living in Tak Province, Thailand near the Thai-Myanmar border reported vaccine coverage to be 56.7% in 2013 (Prakunwisit and Areesantichai, 2015) and 56.3% in 2017 (Pinna *et al*, 2020). Another study reported in this same population, the proportion of subjects who completed three doses of the Diphtheria, Pertussis and Tetanus vaccine (DTP) was 63.8% (Kaji *et al*, 2016) while the national average among Thai children was >90% (WHO SEARO, 2020). Inadequate vaccination coverage can lead to epidemics of vaccine-preventable diseases.

In this study we aimed to determine vaccination coverage and timeliness of those vaccines and the factors associated with that coverage and timeliness among both Thai and migrant children living in Thailand along the Thai-Myanmar border.

MATERIALS AND METHODS

Study design, location and population

We conducted a cross-sectional study at 11 child development centers, which are child care centers for children aged 2-6 years, in the catchment area of Mae Song Health Promotion Hospital, Tak Province, Thailand near the Thai-Myanmar border (Fig 1) from January to May 2018. The study subject sample size was calculated using the formula: $n = \frac{NX}{X+N-1}$, where n= sample size; N= the population size; and X = was derived from the formula $\frac{z^2pq}{d^2}$, where z = the z-score corresponding to the degree of confidence, p = the prevalence of vaccine coverage in this study, q = (1-p) and d = the desired precision (Daniel and Cross, 2013). A pre-study estimated vaccine coverage rate of 51.9% was based on a previous study among migrant children in Tak Province, Thailand (Kaji *et al*, 2016). The minimum number of study subjects determined to be needed for this study was 294, to give a 95% confidence interval, a 5% precision and a total estimated population of migrant children aged 2-6 years in the study area during 2017 of 1242 (Permanent Secretary, Mae Song Sub-district Administrative Office, personal communication).

Data from the Health Register Database, Mae Song Health Promotion Hospital for 2018 showed >88% of the population in the study area were

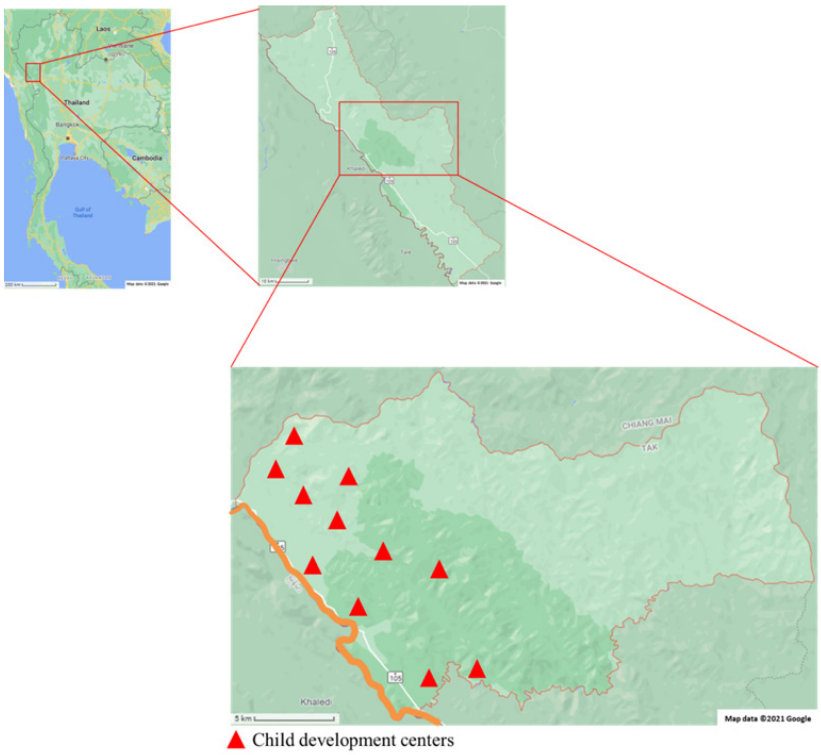

Fig 1 - Study location in Tak Provence, Thailand
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ethnic Karen, 63% were of Thai nationality and the rest were from Myanmar who lived either short-term or long-term in Thailand. Members of the study population often have families and friends living on both sides of the border and they regularly cross the border to visit family, seek health care, seek work and to allow their children to attend school in Thailand (Parker *et al*, 2014).

Most of the terrain in the study area is remote and mountainous with poor road access. The majority of people living in the study area are subsistence farmers (Kunstader, 1983; Parker *et al*, 2014). The child development centers provide pre-school age child care services and early childhood education and are run by the Mae Song Sub-district Administrative Office. Approximately 96% of children aged 2-6 years living in the study area attend these centers (Mae Song Sub-district Administrative Office database, Permanent Secretary, Mae Song Sub-district Administrative Office, personal communication). Mae Song

Health Promotion Hospital is a public health facility in the study area providing primary health care services, including vaccinations, for the population in the study area free of charge regardless of their legal migrant status. A child health booklet is given to the parents/guardians of all the children who attend these public health facilities and it is a record of the child's growth, illnesses, treatments and vaccinations. Many of the children who have recently moved to the study area from Myanmar do not have vaccination records since they were lost or left behind in Myanmar.

Study instrument and data collection

The parents/guardians of each study subject were asked to complete a questionnaire asking about socio-demographic data. This questionnaire was divided into two parts. The first part asked about the house and the household members: number of household members, materials used for the house for the walls, roof and floor, household belongings (car, truck, motorcycle, television, and refrigerator), land ownership, animals (cattle, pigs and goats) and any money sent home to the family by family workers living outside the home. The second part of the questionnaire asked information about the caregiver: age, gender, literacy in the Thai language and occupation of the caregiver and information about the subject: gender, date of birth, place of birth, place(s) of vaccinations, birth order and if living with both parents.

The vaccination data recorded for the study subjects were: types and dates of vaccinations during the first year of life. The minimum vaccinations determined necessary for this study were: the Bacillus Calmette-Guérin (BCG) vaccine, the hepatitis B (HepB) vaccine birth dose, a total of 3 doses of the HepB vaccine; the diphtheria, tetanus, pertussis (DTP) vaccine; the oral poliovirus (OPV) vaccine and the first dose of the measles, mumps, rubella (MMR) vaccine.

All the vaccination data were obtained from child health booklets except where data were missing. Incomplete or missing data were obtained from the Extended Program for Immunization (EPI) database at the Mae Song Health Promotion Hospital.

The weight of each study subject was measured using a Tanita@ weight scale and the height of each subject was measured using a height scale approved by the Ministry of Industry, Thailand.

Timely vaccination was defined as receiving the vaccine within 30 days of the recommended date. An untimely vaccine was defined as a delay in or early vaccination of more than 30 days. In Thailand at the time of the study, the BCG and HepB vaccine were given at birth, the DTP, HepB and OPV vaccines were given at 2, 4 and 6 months of age and the first dose of the MMR vaccine was given at 9 months; this has been changed to 12 months (National Vaccine Institute, 2017).

The family wealth index (FWI) was used to measure the economic status of each study subject household. The FWI is "a composite measure of a household's cumulative living standard" defined by the structure and materials used to make the floor, walls and roof of the house and the household belongings, including ownership of vehicles (Filmer and Pritchett, 2001). The housing materials, transportation vehicles and household belongings are grouped and classified into 5 groups: FWI 1 is classified as the poorest; FWI 2 is classified as poor; FWI 3 is classified as average, FWI 4 is classified as wealthy and FWI 5 is classified as the wealthiest (Liu *et al*, 2015) (Table 1).

Data analysis

Data from the questionnaires, vaccination records and anthropometry were entered into Microsoft Excel, version 16 (available from: URL: https://microsoft-excel-2016.en.softonic.com/). The data were then imported into the Statistical Package for the Social Sciences (SPSS), version 22.0 for analysis (International Business Machines Corporation, Armonk, NY). Percentages were used to summarize categorical variables, including socio-demographics, vaccine coverage and timeliness of vaccinations. Medians were used to measure frequencies of delays and early vaccinations. Multivariate logistic

Table 1

Principal components of study houses by family wealth index level (adapted from Lui *et al*, 2015)

Family wealth index	Housing components	Transportation	Family belongings
1 (Poorest)	Bamboo walls and thatched roof	None	None or chickens or ducks
2 (Poor)	Wooden walls and thatched roof	Bicycles	Pigs or goats
3 (Median)	Wooden walls and terracotta/ tin roof	Motorcycles	Cattle or horses
4 (Wealthy)	Brick walls and terracotta/tin roof	Tractors	Television sets or refrigerators
5 (Wealthiest)	Steel and concrete walls and terracotta roof	Trucks	Elephants

regression analysis was to explore the sociodemographic factors associated with vaccine coverage and timeliness. Factors with a p-value <0.1 on univariate analysis were included in multivariate analysis (Lang and Secic, 2006). Adjusted odds ratios (aOR) (with 95% confidence intervals (95%CI)) were used to measure the strengths of these associations.

Ethical considerations

This study was approved by the Ethics Committee, Faculty of Tropical Medicine, Mahidol University, Thailand (approval number: FTM ECF-019-05). Written informed consent was obtained from each of the parents/guardians of the study subjects prior to inclusion in the study.

RESULTS

Caregiver and study subject characteristics

A total of 295 study subjects were included in the study, 50.2% male (n = 148). The mean (+standard deviation (SD)) age of study subjects was 4.5 (±1.1) years; 145 (49.2%) were aged 5-6 years. About two-third (66.8%) of subjects (n = 197) were either the first or second child (Table 2). Most (97.6%) of study subject caregivers were female, 87.8% were the subject's mother. The mean (+SD) study subject caregiver age was 32.6 (±9.9) years; 71.5% of study subject caregivers (n = 211) were aged <35 years. Sixty-nine-point eight (69.8) percent of study subject caregivers (n = 206) were illiterate in the Thai language. More than one-third (36.9%) of study subject caregivers (n = 109) were farmers. Up to 86.4% of study subject households (n = 255) were classified as poor (FWI = 2); 79.7% of study subject households (n = 235) received money sent home by family members working elsewhere.

Vaccination coverage and timeliness

Most of study subjects (95.3%) had received a BCG vaccine, 67.8% had received a birth dose of the HepB vaccine, 92.5% had received first doses of the DTP, HepB and OPV vaccines, 90.2% had received second doses of the DTP, HepB and OPV vaccines, 87.1% had received third doses of the DTP, HepB and OPV vaccines and 93.6% had received a dose of the MMR vaccine. The proportion of subjects who received the HepB vaccine birth dose was significantly lower (p <0.001) than the proportion who received the BCG vaccine. The proportion of subjects who received the second dose of the DTP, HepB and OPV vaccines was significantly lower (p = 0.016) than the proportion who received the first dose of the DTP, HepB and OPV vaccines and the proportion of subjects who received the third dose of the DTP, HepB and OPV vaccines was significantly lower (p = 002) than the proportion who received the second dose of the DTP, HepB and OPV vaccines (Fig 2).

Some 15.1% of study subjects received all the dosages of the vaccine

Table 2

Characteristics of study subjects and their caregivers

Characteristics	*n* (%) (N = 295)
Gender of caregiver	
Male	7 (2.4)
Female	288 (97.6)
Caregiver relationship	
Mother	259 (87.8)
Others	36 (12.2)
Mean age group of caregiver in years	
<35	211 (71.5)
≥35	84 (28.5)
Literacy of caregiver	
Literate in Thai language	89 (30.2)
Illiterate	206 (69.8)
Occupation of caregiver	
Casually employed	106 (35.9)
Agriculturist	109 (36.9)
Housework	58 (19.7)
Others	22 (7.5)
FWI of household	
1 - Poorest	12 (4.1)
2 - Poor	255 (86.4)
2 - Median	23 (7.8)
4 - Wealthy	5 (1.7)
Money sent home by family members not living at home	
Yes	60 (20.3)
No	235 (79.7)

Table 2 (cont)

Characteristics	*n* (%) (N = 295)
Gender of study subject	
Male	148 (50.2)
Female	147 (49.8)
Mean age group of study subject in years	
2-4 years	150 (50.9)
5-6 years	145 (49.2)
Birth order of study subject	
First or second	197 (66.8)
Others	98 (33.2)

FWI: Family wealth index

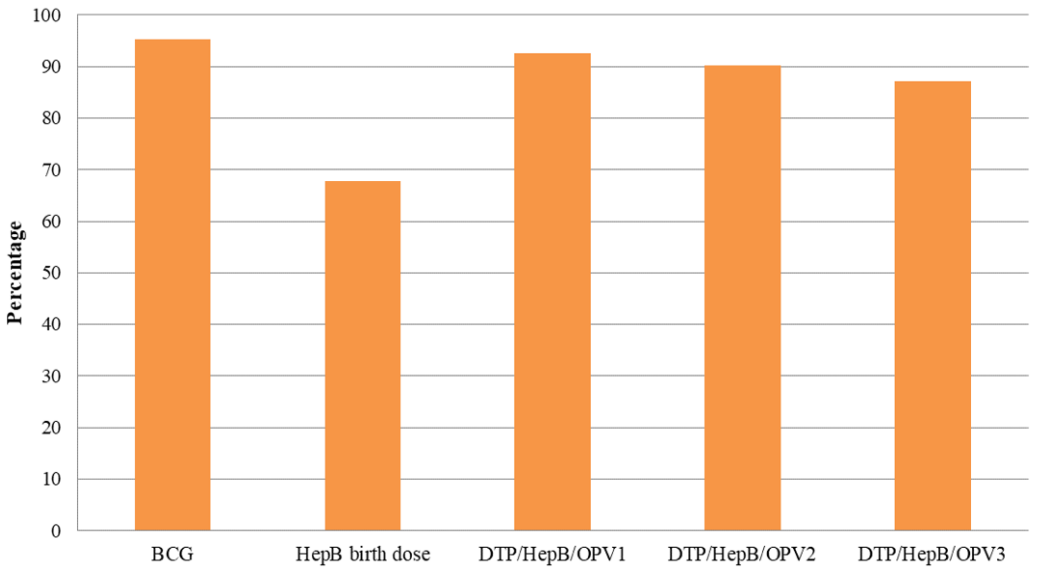

Fig 2 - Percentages of vaccination coverage among study subjects

BCG: Bacillus Calmette-Guérin vaccine; HepB: hepatitis B vaccine; DTP: diphtheria-tetanus-pertussis vaccine; OPV: oral poliovirus vaccine

in a timely manner: within 30 days of the recommended age for the vaccine (Table 3). Almost half (46.6%) of study subjects received a timely BCG vaccine and 61.5% received a timely HepB vaccine birth dose. Fifty-six-point eight (56.8) percent of subjects received a timely first dose of the DTP, HepB and OPV vaccines, 41.0% received a timely second dose of the DTP, HepB and OPV vaccines and 24.1% received a timely third dose of the DTP, HepB and OPV vaccines. Thirty-seven-point three (37.3) percent of study subjects received a timely dose of the MMR vaccine.

Among study subjects the BCG vaccine was delayed by a median of 11.5 weeks, the HepB vaccine birth dose was delayed by a median of 7.7 weeks, the first, second and third doses of the DTP, HepB and OPV vaccines were delayed by medians of 9.3, 10.9 and 14.8 weeks, respectively, and the MMR was delayed by a median of 22.6 weeks. Among study subjects who received vaccines earlier than the schedule dates, the first, second and third doses of the DTP, HepB and OPV vaccines were given early at median times of 1.2 weeks, 2.1 weeks, and 3.6 weeks, respectively and the MMR vaccine was given early at a median time of 6.3 weeks (Fig 3).

Factors influencing vaccination coverage

On univariate analysis, full vaccination coverage was significantly positively associated with the caregiver being literate in the Thai language (crude odds ratio (cOR): 2.9, 95% confidence interval (CI): 1.6-5.2, p = <0.001), study subject being aged 2-4 years (cOR: 2.2, 95% CI: 1.2-4.2, p = 0.018), study subject being the first or second born child (cOR 2.4, 95% CI: 1.4-3.9, p = 0.001), <3 children in the study subject household (cOR: 1.7, 95% CI: 1.0-2.7, p = 0.042), study subject having a normal height for age (cOR: 1.6, 95% CI: 1.0-2.7, p = 0.049), study subject being born at a healthcare facility (cOR: 2.2, 95% CI: 1.3-3.6, p = 0.002) and study subject being vaccinated at the Health Promotion Hospital (cOR: 2.6, 95% CI: 1.6-4.2, p<0.001). On multivariate analysis the factors significantly positively associated with vaccination coverage were: the caregiver being literate in the Thai language (adjusted odds ratio (aOR): 2.1, 95% CI: 1.1-3.9, p = 0.018), the subject being aged 2-4 years) (aOR: 2.3, 95% CI: 1.1-4.5, p = 0.024), the study subject being the first or second born child (aOR: 1.9, 95% CI: 1.1-3.2, p = 0.028) and study subject being vaccinated the Health Promotion Hospital (aOR: 2.1, 95% CI: 1.3-3.6, p = 0.005) (Table 4).

Factors associated with vaccination timeliness

On univariate analysis, factors significantly associated with vaccination timeliness (p ≤0.05) were: the caregiver working in the home (cOR: 2.5, 95% CI: 1.0-5.9, p = 0.044), having money sent home by family members living outside the home (cOR: 3.0, 95% CI: 1.3-7.1, p = 0.013), having <3 children in the

Table 3

Vaccination coverage and timeliness among 295 study subjects

Vaccine	Coverage *n* (%)	Never *n* (%)	Timely *n* (%)	Untimely	
				Delay *n* (%)	Early *n* (%)
BCG	281 (95.3)	14 (4.7)	131 (46.6)	150 (53.4)	-
HepB birth dose	200 (67.8)	95 32.2)	123 (61.5)	77 (38.5)	-
HepB/DTP/OPV first dose	273 (92.5)	22 (7.5)	155 (56.8)	106 (38.8)	12 (4.4)
HepB/DTP/OPV second dose	266 (90.2)	29 (9.8)	109 (41.0)	149 (56.0)	8 (3.0)
HepB/DTP/OPV third dose	257 (87.1)	38 12.9)	62 (24.1)	190 (73.9)	5 (1.9)
MMR	276 (93.6)	19 (6.4)	103 (37.3)	164 (59.4)	9 (3.3)
Overall immunization up to one year of age	185 (62.7)	110 (37.3)	28 (15.1)		

BCG: Bacillus Calmette-Guérin vaccine; DTP: diphtheria-tetanus-pertussis vaccine; HepB: hepatitis B vaccine; MMR: measles-mumps-rubella vaccine; OPV: oral poliovirus vaccine

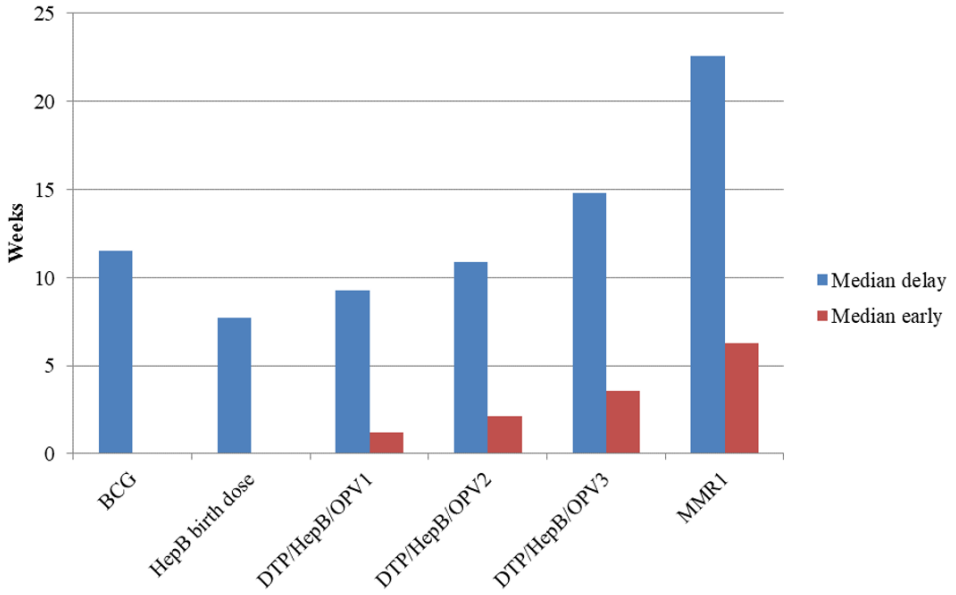

Fig 3 - Median length of time between when a vaccination was and when it should have been given among study subjects

BCG: Bacillus Calmette-Guérin vaccine; HepB: hepatitis B vaccine; DTP/HepB/OPV1: first dose of diphtheria-tetanus-pertussis, hepatitis B and oral poliovirus vaccines; DTP/HepB/OPV2: second dose of diphtheria-tetanus-pertussis, hepatitis B and oral poliovirus vaccines; DTP/HepB/OPV3: third dose of diphtheria-tetanus-pertussis, hepatitis B and oral poliovirus vaccines; MMR: measles-mumps-rubella vaccine

study subject household (cOR: 3.5, 95% CI: 1.2-10.6, $p = 0.026$), the study subject having a normal height for age (cOR: 3.2, 95% CI: 1.0-9.5, $p = 0.043$) and the study subject being born in a healthcare facility (cOR: 3.2, 95% CI: 1.3-7.7, $p = 0.010$). On multivariable analysis, the factors significantly associated with vaccination timeliness were: the caregiver being literate in the Thai language (aOR: 2.5, 95% CI: 1.0-6.3, $p = 0.046$), having money sent home by family members living outside the home (aOR: 4.0, 95% CI: 1.2-14.9, $p = 0.037$), having <3 children in the study subject household (aOR: 3.9, 95% CI: 1.2-13.1, $p = 0.028$) and the study subject being born in a healthcare facility (aOR: 3.1, 95% CI: 1.2-8.2, $p = 0.022$) (Table 4).

DISCUSSION

In this study we determined the coverage and timeliness of selected

Table 4

Factors significantly associated with full vaccinations among study subjects

Variables	Full vaccination coverage					Timely vaccinations				
	n (%)	cOR (95%CI)	*p*-value	aOR (95%CI)	*p*-value	*n* (%)	cOR (95%CI)	*p*-value	aOR (95%CI)	*p*-value
Caregiver status										
Others	24 (66.7)	1.2 (0.6-2.5)	0.601			6 (25.0)	2.1 (0.8-5.9)	0.155		
Mother (Ref)	161 (62.2)					22 (13.7)				
Age of caregiver in years										
<35	137 (64.9)	1.4 (0.8-2.3)	0.213			19 (13.9)	0.7 (0.3-1.7)	0.418		
≥35 (Ref)	48 (57.1)					9 (18.8)				
Occupation of caregiver										
Housework	39 (67.2)	1.3 (0.7-2.4)	0.427			10 (25.6)	2.5 (1.0-5.9)	0.044	2.4 (0.9-6.3)	0.082
Others (Ref)	146 (61.6)					18 (12.3)				
Caregiver literacy in the Thai language										
Literate	70 (78.7)	2.9 (1.6-5.2)	<0.001	2.1 (1.1-3.9)	0.018	15 (21.4)	2.1 (1.0-4.8)	0.066	2.5 (1.0-6.3)	0.046
Illiterate (Ref)	115 (55.8)					13 (11.3)				
FWI of the household										
Others	178 (62.9)	1.2 (0.4-3.9)	0.749			26 (14.6)	0.4 (0.1-2.3)	0.325		
Poorest (Ref)	7 (58.3)					2 (28.6)				

Table 4 (cont)

Variables	Full vaccination coverage					Timely vaccinations				
	n (%)	cOR (95%CI)	*p*-value	aOR (95%CI)	*p*-value	*n* (%)	cOR (95%CI)	*p*-value	aOR (95%CI)	*p*-value
Money sent to family										
Yes	39 (65.0)	1.1 (0.6-2.1)	0.681			11 (28.2)	3.0 (1.3-7.1)	0.013	4.0 (1.1-14.9)	0.037
No (Ref)	146 (62.1)					17 (11.6)				
Gender of study subject										
Female	88 (59.9)	0.8 (0.5-1.3)	0.314			15 (17.1)	1.3 (0.6-3.0)	0.491		
Male (Ref)	97 (65.5)					13 (13.4)				
Age of study subject in years										
2-3	45 (76.3)	2.2 (1.2-4.2)	0.018	2.3 (1.1-4.5)	0.024	8 (17.78)	1.3 (0.5-3.2)	0.570		
4-6 (Ref)	140 (59.3)					20 (14.3)				
Birth order of study subject										
First or second	137 (69.5)	2.4 (1.4-3.9)	0.001	1.9 (1.1-3.2)	0.028	22 (16.1)	1.3 (0.5-3.5)	0.555		
Others (Ref)	48 (49.0)					6 (12.5)				
Number of children in household										
<3	123 (67.2)	1.7 (1.0-2.7)	0.042	1.4 (0.8-2.3)	0.276	24 (19.5)	3.5 (1.2-10.6)	0.026	3.9 (1.2-13.1)	0.028
≥3 (Ref)	62 (55.4)					4 (6.5)				

Table 4 (cont)

Variables	Full vaccination coverage					Timely vaccinations				
	n (%)	cOR (95%CI)	*p*-value	aOR (95%CI)	*p*-value	*n* (%)	cOR (95%CI)	*p*-value	aOR (95%CI)	*p*-value
Weight for age of study subject										
Normal	141 (65.3)	1.5 (0.9-2.5)	0.133			24 (17.0)	2.1 (0.7-6.3)	0.208		
Abnormal (Ref)	44 (55.7)					4 (9.1)				
Height for age of study subject										
Normal	127 (66.8)	1.6 (1.0-2.7)	0.049	1.3 (0.8-2.3)	0.287	24 (18.9)	3.2 (1.0-9.5)	0.043		
Abnormal (Ref)	58 (55.2)					4 (6.9)				
Height to weight for study subject										
Normal	161(64.7)	1.7 (0.9-3.2)	0.110			25 (15.5)	1.3 (0.4-4.7)	0.700		
Abnormal (Ref)	24 (52.2)					3 (12.5)				
Parents in home										
No or only one	47 (68.1)	1.4 (0.8-2.4)	0.290			11 (23.4)	2.2 (0.9-5.1)	0.071	0.9 (0.3-3.1)	0.847
Both (Ref)	138 (61.1)					17 (12.3)				
Season of study subject birth										
Dry season	106 (65.0)	1.3 (0.8-2.0)	0.360			17 (16.0)	1.2 (0.5-2.7)	0.692		
Rainy season (Ref)	79 (59.9)					11 (13.9)				

Table 4 (cont)

Variables	Full vaccination coverage					Timely vaccinations				
	n (%)	cOR (95%CI)	*p*-value	aOR (95%CI)	*p*-value	*n* (%)	cOR (95%CI)	*p*-value	aOR (95%CI)	*p*-value
Place of study subject birth										
Healthcare setting	89 (73.0)	2.2 (1.3-3.6)	0.002	1.7 (1.0-2.9)	0.064	20 (22.5)	3.2 (1.3-7.7)	0.010	3.1 (1.2-8.2)	0.022
Home (Ref)	96 (55.5)					8 (8.3)				
Place of study subject vaccination										
Health Promotion Hospital	122 (72.2)	2.6 (1.6-4.2)	<0.001	2.1 (1.3-3.6)	0.005	18 (14.8)	0.9 (0.4-2.1)	0.841		
Health center (Ref)	63 (50.0)					10 (15.9)				

aOR: adjusted odds ratio; cOR: crude odds ratio; CI: confidence interval; FWI: family wealth index; Ref: reference

first year of life vaccines among study subjects. The World Health Organization recommends a goal of at least 90% coverage for the studied vaccines (WHO SEARO, 2017). Study subjects in our study reached this goal for the BCG vaccine (95.3%), the first 2 doses of the DTP, HepB and OPV vaccines (92.5% and 90.2%), and the MMR vaccine (93.6%) but did not reach the goal for the third dose of the DTP, HepB and OPV vaccines (87.2%) and HepB vaccine birth dose (67.8%). The World Health Organization (2020) has estimated the overall vaccine coverage during the first year of life for Southeast Asia is 93% for the BCG vaccine, 49% for the HepB vaccine birth dose, 93% for a measles-containing vaccine (MCV) and 90% coverage for the third dose of the DTP, HepB and OPV vaccines (WHO, 2020). The coverage in our study was lower than the coverage reported by another study among Thai children (Ministry of Public Health, 2018) which reported a coverage of 99.8% for the BCG vaccine, 99.6% for the HepB vaccine birth dose, 96.5% for the third dose of the DTP, HepB and OPV vaccines and 96.1% for the first dose of the MMR vaccine.

The population living in Thailand along the Thai-Myanmar border is more mobile than the general Thai population (Parker *et al*, 2014). Previous studies have shown mobile populations are at greater risk of having inadequate vaccinations, having delayed vaccinations and defaulting on appointments making it is difficult for health care providers to ensure adequate and timely vaccinations (Hu *et al*, 2013; Antai, 2010; Kasuma *et al*, 2010).

In our study 62.7% of study subjects were fully vaccinated during the first year, similar to the results of a study from Ethiopia, where 64.3% of children aged 12-23 months were fully vaccinated (Mekonnen *et al*, 2020). Our result is higher than the 51.9% reported in a study among Myanmar migrant school children in Thailand (Kaji *et al*, 2016) and 56.7% among Myanmar migrant children aged 1-2 years in Thailand (Prakunwisit and Areesantichai, 2015).

In our study, the vaccine with the greatest coverage was the BCG vaccine (95.3%), similar to a previous study among children of migrant workers living in Thailand along the Thai-Myanmar border (90%) (Pinna *et al*, 2020). Although children should receive both the BCG and HepB vaccines at birth, the proportions of our study subjects who received both these vaccines were significantly different from each other. The lower coverage with the HepB vaccine at birth might be due to inadequate supplies to meet the demand of the Hep B vaccine first dose at the healthcare facilities in the study area. Studies have reported an association between vaccination coverage and the location of vaccination (Mekonnen *et al*, 2020; Rainey *et al*, 2011; Moyer *et al*, 2013). In this study, receiving a vaccine at the Health Promotion Hospital was significantly positively associated

with improved vaccination coverage (p = 0.005).

In our study, 15.1% of vaccines were given in a timely manner which is lower than the 31.9 of subjects reported in a study from Ethiopia (Mekonnen *et al*, 2020). Other studies have also reported inadequate timeliness of vaccinations (Gram *et al*, 2014; Yadav *et al*, 2012; Janusz *et al*, 2021; Kiely *et al*, 2018). The median delays in vaccinations among subjects in our study were 7.7 weeks for the HepB vaccine birth dose, 11.5 weeks for the BCG vaccine and 22.6 weeks for the MMR vaccination, which are longer than the median delays reported in a study from rural Ghana (2-4 weeks) (Gram *et al*, 2014) and Ballabgarh, India (3-8 weeks) (Yadav *et al*, 2012). Delays in the first dose of a vaccine can lead to delays in subsequent doses of that vaccine, and in other vaccines, increasing the risk for vaccine-preventable diseases (Zaidi *et al*, 2014).

In our study, caregiver literacy in the Thai language was positively associated with complete and timely vaccination among study subjects similar to the findings reported by other studies (Mekonnen *et al*, 2020; Janusz *et al*, 2021; Xeuatvongsa *et al*, 2017; Nanthavong *et al*, 2015; Lim *et al*, 2013; Muhsen *et al*, 2012; Wang *et al*, 2018; Zaidi *et al*, 2014). In our study, more than half the caregivers were illiterate in the Thai language; they could not read the contents of the child health booklets and vaccination appointment dates. Previous studies have reported the importance of increasing caregiver knowledge to improve vaccination coverage (Munsawaengsub *et al*, 2011; Hu *et al*, 2013; Prakunwisit and Areesantichai, 2015). In Thailand, village health volunteers could give health education and can verbally remind caregivers about appointments for vaccinations which might reduce the frequency of missing and delayed vaccinations (Limtrakul *et al*, 1989).

In our study, younger subjects were significantly more likely to have full vaccination coverage. These findings are in agreement with a previous study from Greece that reported younger subjects were significantly more likely to have complete vaccination coverage (Pavlopoulou *et al*, 2013).

In our study, if a subject was the first or second child and if the number of other children in the household was not many, the child was significantly more likely to have full vaccination coverage. Other studies have reported being born later in birth order of siblings or if there are many children in the household, there may be insufficient resources or time to vaccinate the older and later children (Negussie *et al*, 2016; Legesse and Dechasa, 2015).

In our study, subjects born in a healthcare facility were significantly more likely to have timely vaccinations. Previous studies have reported missed immunizations are more common when a child is born at home (Creati *et al*, 2007; Muranjan *et al*, 2011). Other studies

have reported being born in a healthcare facility is significantly positively associated with adequate immunization coverage (Nath *et al*, 2007; Kumar *et al*, 2010; Mutua *et al*, 2011) and timely vaccinations (Boulton *et al*, 2019; Mansour *et al*, 2018).

In our study, household wealth was significantly associated with vaccination timeliness; longer delays in time to vaccination occurred among subjects from poorer families who did not receive money sent from relatives who lived outside the home. Many Karen living along the Thai-Myanmar border travel to the city seeking work and then send money back to support their families; their children are often left with the mother or family (Parker *et al*, 2014). This financial familial support could make it easier for the study subject population to access the health care system. This same positive association between vaccinations and wealth has been reported from Pakistan (Zaidi *et al*, 2014), Ethiopia (Kasuma *et al*, 2010) and countries of sub-Saharan Africa (Gram *et al*, 2014; Janusz *et al*, 2021; Akmatov *et al*, 2015; Babirye *et al*, 2012). In our study population, vaccinations are free but the caregiver must still pay for transport to the healthcare facility and incur financial loss due to time off work to attend the healthcare facility (Abadura *et al*, 2015; Tesfaye *et al*, 2014).

A limitation of our study was that about 40% of the 496 children in the 11 child development centers did not have vaccination records and were excluded from the study. This excluded population might have affected our vaccination coverage percentages. To improve health record keeping, it would be good to have a better designed vaccination card (Usman *et al*, 2011) written in Thai, Myanmar and Karen (Kaji *et al*, 2016), making it easier to keep records no matter where the vaccines are received. It would also be helpful to develop a rapid, inexpensive point-of-care test to determine immunity to vaccine-preventable diseases to enable health care providers to know what vaccines should be given (Kaji *et al*, 2016; Fowkes *et al*, 2013; de la Fuente *et al*, 2013).

In summary, among our study subjects the vaccination coverage was inadequate (<90%) for the BCG, HepB, OPV and DTP vaccines but adequate for the MMR vaccine during the first year but the great majority of vaccines were not given in a timely manner and the only factors associated with this were the caregiver being literate in Thai language, a young study subject, the birth order of the study subject and where the vaccines are given. We conclude, timely reminders need to be given to caregivers, especially those who are illiterate in the Thai language, those who have at least 3 children, those with older children and those who do not live near a hospital, in order to improve first year vaccination rates in the study population. Further studies are needed to determine if these efforts can improve these vaccination rates.

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