Wongnaah *et al. BMC Public Health* (2025) 25:727
https://doi.org/10.1186/s12889-025-21397-0

BMC Public Health

RESEARCH

Open Access

Full vaccination coverage for children aged 12–23 months in Madagascar: Analysis of the 2021 Demographic and Health Survey

Florence Gyembuzie Wongnaah[1], Richard Gyan Aboagye[2,3], Augustus Osborne[4*], Abdul-Aziz Seidu[5] and Bright Opoku Ahinkorah[6,7]

Abstract

Background Vaccination plays a pivotal role in safeguarding the health and wellbeing of children worldwide, preventing the spread of infectious diseases, and reducing mortality rates. Despite significant progress in global immunisation efforts, disparities in vaccination coverage persist in Madagascar. This study examines the factors associated with full vaccination coverage among children aged 12–23 months in Madagascar.

Methods We analysed a cross-sectional dataset from the 2021 Madagascar Demographic and Health Survey (MDHS). A total of 2,250 mothers with children aged 12 to 23 months were extracted from the children's dataset. Vaccination coverage was evaluated based on maternal self-report and child vaccination card observations. A weighted multivariable binary logistic regression analysis was used to examine the factors associated with full vaccination coverage. Adjusted odds ratios (aORs) with 95% confidence intervals (CIs) were used to present the results of the factors associated with full vaccination coverage. Stata 13.0 was used to perform all the analyses.

Results We found that 48.9% of children aged 12–23 months were fully vaccinated. Vaccination coverage for Bacille Calmette-Guérin (BCG), third-dose polio, third-dose of diphtheria–tetanus–pertussis (DPT), and measles was 78.1%, 58.6%, 68.4%, and 63.9%, respectively. Mothers aged 35 to 49 (aOR: 1.69; 95% CI: 1.08–2.64) were more likely to have their children fully vaccinated compared to women aged 15–24. Children born to mothers with secondary or higher education (aOR:1.68; 95% CI:1.15–2.45) were more likely to receive full vaccination than those whose mothers had no formal education. Mothers within the middle-class wealth index (aOR: 1.48; 95% CI: 1.04–2.12) were more likely to have their children fully vaccinated compared to the poorest category. Mothers who were working (aOR: 1.45; 95% CI: 1.06–1.98) had higher odds of full childhood vaccination compared to those who were not working. Compared to mothers who delivered their babies at home or other places, those who delivered their babies at the health facility (aOR:1.57; 95% CI: 1.22–2.02) were more likely to vaccinate their children . Mothers who had less than eight (1–7) antenatal care visits (aOR: 3.63; 95% CI: 2.30–5.72) and those with 8 or more visits (aOR: 1.20; 95% CI: 1.35–6.51) were more likely to have their children vaccinated fully compared to those with zero antenatal care visits. Mothers exposed to media (aOR: 1.65; 95% CI: 1.26–2.16) were more likely to fully vaccinate their children than their unexposed counterparts.

*Correspondence:
Augustus Osborne
augustusosborne2@gmail.com

Full list of author information is available at the end of the article

Conclusion Full childhood vaccination coverage is low in Madagascar. Factors identified to be associated with vaccination coverage were maternal age, education, place of delivery, working status, antenatal care visits, and media access. Collaboration between the Ministry of Health and local authorities is recommended in Madagascar to improve vaccination coverage, promote antenatal care, clean delivery practices and access to skilled birth attendants, raise parental awareness, and enhance healthcare workers' communication about vaccination schedules through various media channels.

Keywords Full childhood vaccination, Coverage, Factors, Madagascar, Demographic and Health Survey

Introduction

Vaccination is among the most impactful and cost-effective public health interventions for combating childhood diseases [1]. Annually, vaccination averts 3.5-5 million deaths caused by vaccine-preventable diseases such as diphtheria, hepatitis B, measles, mumps, pertussis, pneumonia, polio, rotavirus diarrhoea, rubella, influenza, and tetanus [1]. In 2018, approximately 700,000 children died of vaccine-preventable diseases, with nearly 99% of these fatalities occurring in low-and middle-income countries (LMIC) [2]. An estimated 20 million children globally did not receive one or more doses of the diphtheria-pertussis-tetanus (DPT) vaccine in 2022 [3], even though around 20 million infants (89%) worldwide had received the third dose in the same year [3]. The disruptions caused by the COVID-19 pandemic strained health systems, exacerbating the situation and leading to 22 million children missing their routine first dose of the measles vaccine in 2022, a significant increase from 19 million in 2019 [1]. Notably, the under-five mortality rate in Madagascar remains alarmingly high at 66.3 deaths per 1000 live births [4], significantly surpassing the global target of 37 per 1000 live births set for 2020 [5].

Madagascar, an island country in sub-Saharan Africa, is inhabited by roughly 30 million people [6]. The Expanded Programme on Immunization (EPI) officially began in the country in 1976, following the World Health Organization (WHO) guidelines to establish a vaccine schedule [7]. Its primary objective has been to confer immunity to children against tuberculosis (Bacillus Calmette–Guérin), DPT, poliomyelitis, and measles. Over the past two decades, additional vaccines have been introduced, including yellow fever (introduced in 1998 for high-risk countries but adopted locally in 1998), hepatitis B – HepB (in 2007), Haemophilus influenzae type B – Hib (in 2008), pneumococcal conjugate vaccine – PCV (in 2012), rotavirus vaccine – RV (in 2014), inactivated polio vaccine – IPV (in 2015), measles (in 1976), and a second dose of measles-containing vaccine second – MCV2 (in 2012) [8, 9]. All vaccines, except the second dose of the MCV, should be administered to children before they reach one year of age [10]. Madagascar's vaccination program provides fixed and routine service delivery, augmented by two annual maternal and child health weeks introduced in 2006 [11].

Despite these sustained efforts, recent evidence indicates that vaccine coverage in Madagascar has been notably low for all recommended vaccines [12]. According to the WHO/UNICEF Estimates of National Immunization Coverage report, the coverage for the third dose of DTP/HepB and the second dose of MCV was 57% and 32%, respectively, in 2022 [13], placing the country among those with the greatest disparities in immunisation rates globally [14]. Suboptimal vaccination coverage may result in larger-than-usual outbreaks, a phenomenon referred to as "post-honeymoon" epidemics [15]. Following a prolonged period of minimal measles incidence, insufficient measles vaccination coverage (> 80% by 2017) [16] resulted in an outbreak that affected all 22 regions of Madagascar in September 2018, with more than 100,000 reported cases resulting in approximately 1,000 deaths [16]. Also, between 2014 and 2015, 12 cases of Vaccine-Derived Polio Virus (VDPV) were reported across seven regions of the country, confirming weak routine immunisation coverage [17].

LMICs typically exhibit lower vaccination coverage rates than other countries [18]. The low vaccine uptake rate in LMICs is linked to various factors, including insufficient political support for vaccination programs, limited access to healthcare facilities, diminished public awareness, and inadequate education and awareness about vaccines among healthcare workers and caregivers, particularly mothers [19–21]. Vaccine rate disparities also arise due to socioeconomic variations in geographical location, educational attainment, rural-urban residence, sex, cultural beliefs, misconceptions, and vaccine hesitancy that may affect parental decision-making regarding vaccination, among others [14, 19, 22, 23]. In Madagascar, Clouston et al. [24] found that insufficient infrastructure, the country's fragmented nature owing to an underdeveloped road network, staffing shortages, lack of energy sources, and limited supply of vaccines appear to contribute to reduced immunisation coverage as well as parental education and wealth status.

Limited research has been undertaken in Madagascar regarding the correlation between socio-demographic factors and full vaccination coverage. One of these studies included other countries [25], and another was conducted before the COVID-19 pandemic [24]. The more recent study by Ramaroson et al. [26] focused on structural, relational, and cultural constraints influencing vaccination coverage. Given the persistently low vaccination rates observed in previous years, falling below the WHO recommendation of at least 90% of all vaccine coverage [27], and the exacerbated decline in vaccination rates due to the COVID-19 pandemic, conducting a more specific post-COVID-19 analysis becomes essential to bolster vaccination rates. Therefore, this study aimed to identify factors associated with full vaccination coverage among children aged 12–23 months in Madagascar.

The expanded programme on immunization (EPI) schedule in Madagascar

Vaccine	Age of Administration
BCG	At birth
OPV0	At birth
DTP-HepB-Hib	6 weeks, 10 weeks, 14 weeks
OPV	6 weeks, 10 weeks, 14 weeks
PCV	6 weeks, 10 weeks, 14 weeks
Rotavirus Vaccine	6 weeks, 10 weeks
Measles Vaccine (MCV1)	9 months
Yellow Fever Vaccine	9 months
Inactivated Polio Vaccine (IPV)	14 weeks, 9 months
Measles Vaccine (MCV2)	15–23 months

Methods

Data source, design, and sampling procedure

We used data obtained from the 2021 Madagascar Demographic and Health Survey [28]. The MDHS used a cross-sectional study design, which was carried out by the National Institute of Statistics in conjunction with the Madagascar Ministry of Health in 22 regions of the country. The MDHS is a nationally representative survey that collects data on fundamental health indicators, such as mortality, morbidity, family planning service utilisation, fertility, and maternal and child health services such as vaccinations. Data were derived from the measure DHS, program (https://dhsprogram.com/data/dataset/Madagascar_Standard-DHS_2021.cfm?flag=1). The co untry's survey comprises a variety of datasets, including data on men, women, children, births, and households. This study used the children's record dataset (KR file). It comprises a women's questionnaire that measures sociodemographic characteristics of the mothers' information on reproductive health and service use behaviours, as well as information specific to childbirths in the past five years for women between the ages of 15 and 49. The MDHS used two stages of stratified sampling techniques to select respondents for the study. Enumeration Areas (EAs) were randomly selected in the first stage, households were identified in the second stage. This study included a weighted sample of 2,250 children aged 12–23 months in the final analysis. Figure 1 shows the inclusion and exclusion criteria of the study sample.

Variables

Outcome variable

The outcome variable was the full childhood vaccination status of children aged 12–23 months. According to the WHO recommendation, "a fully vaccinated child is the one who has received the following vaccines; BCG vaccination against tuberculosis; three doses of DPT vaccine to prevent diphtheria, pertussis, and tetanus ; at least three doses of polio vaccine; and one dose of measles vaccine [29]. Data on vaccination coverage were collected through vaccination cards or verbal reports from mothers. Mothers were asked to recall their child's vaccinations if a vaccination card was unavailable or incomplete. The outcome variable had five response categories: no, vaccination date on the card, reported by mother, vaccination marked on the card, and don't know. These were recoded into binary values: For mothers who responded 'no' were recorded as '' 0" and labelled not received, whereas the other responses '' vaccination date on the card, reported by mother, vaccination marked on the card were recorded together as "1" and labelled "received the vaccine". Children who received no or partial vaccination were labelled "no," while those who received all vaccines were labelled "yes."

Explanatory variables

We included sixteen explanatory variables. The explanatory variables were selected from the MDHS dataset based on prior knowledge and published literature [23–25, 30–34]. The variables include child sex (male and female), the birth order (1, 2–3, 4–5 and 6 and above), mother's age (15–24, 25–34, and 35–49 years), mother's occupation (not working and working), mother's education (no formal education, primary education and secondary or higher), father's education (no formal education, primary education and secondary or higher), number of children under the age of 5 years (0–1, 2 and 3 or more), wealth index (poorest, poorer, middle, richer and richest), number of living children (1 and 2+), number of antenatal care visits during pregnancy (no visits, less than eight visits (1-7 visits), and eight visits or more visits), place of delivery (home or other and health facility), postnatal care visits (no and yes), marital status (never married, married, cohabiting, widowed and divorced). Other variables included the place of residence (urban and rural), distance to health facility (big problem and not a big problem), and access to media—television, radio, and newspaper (not access and access). Table 1 shows the coding scheme of the study variables.

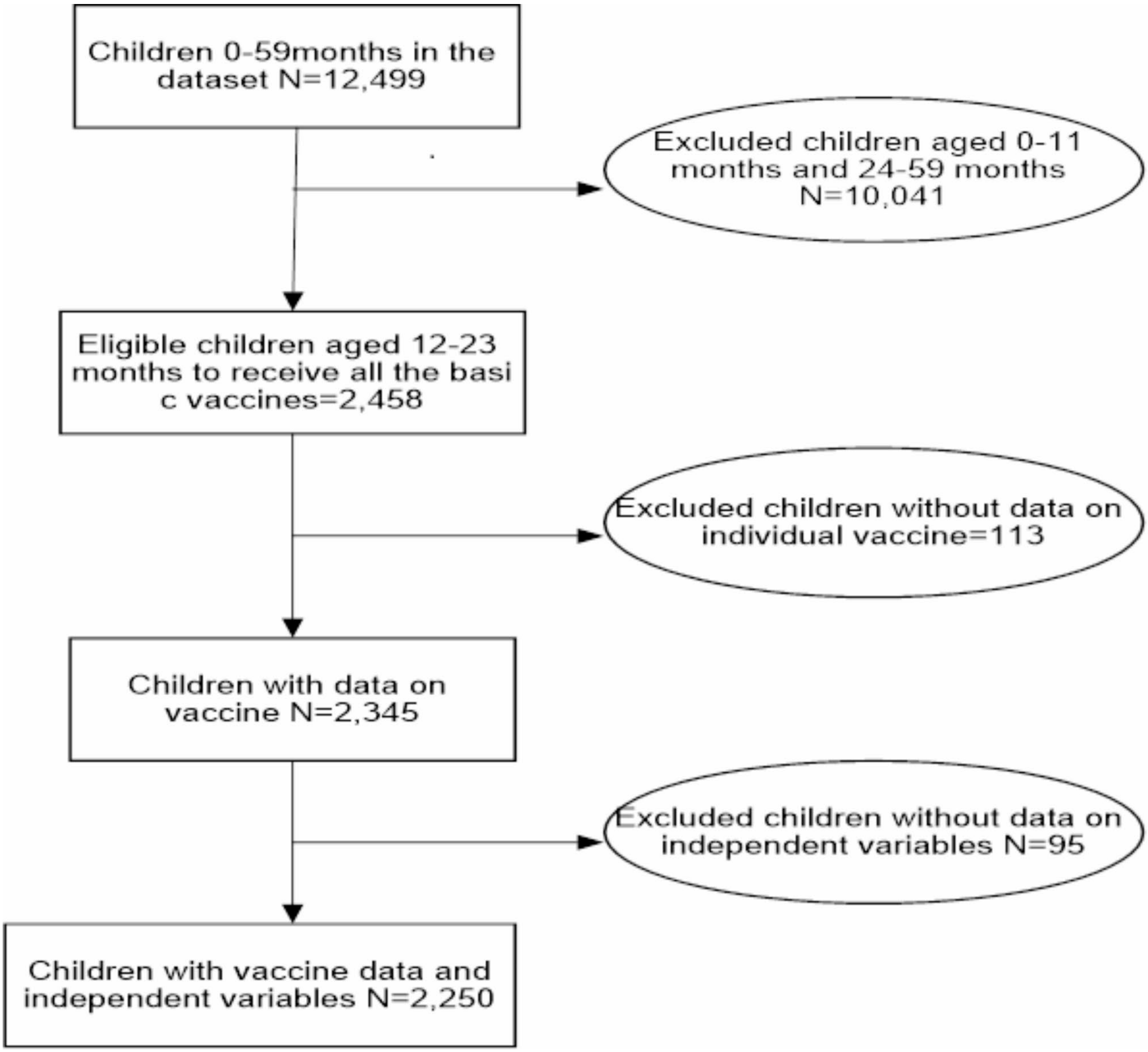

Fig. 1 Inclusion and exclusion criteria

Statistical analysis

Stata software version 13 was used for all the analyses. Descriptive statistics, including percentages, bar charts, and frequency tables, were used to describe the study respondents and to determine the proportion of full vaccination coverage by socio-demographic characteristics. Bivariate analysis was used to show the association between socio-demographic characteristics and full vaccination coverage. Variables were determined statistically significant at p-value < 0.25 during bivariate analysis, and few variables above the set significance level but had shown significant association in some studies were considered for adjustment in the multivariable logistic regression. Adjusted odds ratio (aOR) and 95% confidence interval (CI) were used to assess the strength of the association between full vaccination coverage and the explanatory variables. The statistical significance threshold was set at < 0.05. Sample weights were applied to compensate for the unequal probability of selection between the strata that have been geographically defined as well for non-responses. Details of the weighting procedure can be found in the MDHS 2021 (28). The "svy" command was used to weigh the survey data and to account for the complex nature of the DHS.

Ethical approval and consent to participate

Ethical clearance was not sought for this study due to the public availability of the 2021 MDHS data. We submitted a project proposal to the DHS program. Afterwards, permission was obtained to download and use

Table 1 Definition of the explanatory variables used in the analysis

Characteristic	Definition and coding
Child's sex	1 = Male; 2 = Female
Birth order	1 = 1; 2 = 2–3; 3 = 4–5; 4 = 6 +
Mother's age (age groups)	1 = 15–24; 2 = 25–34; 3 = 35–49
Mother's education	0 = No formal education; 1 = Primary education; 2 = Secondary or higher
Partner's education	0 = No formal education; 1 = Primary education; 2 = Secondary or higher
Place of residence	1 = Urban; 2 = Rural
Wealth index	1 = Poorest; 2 = Poorer; 3 = Middle; 4 = Richer; 5 = Richest
Place of delivery	1 = Home or other; 2 = Health facility
Number of antenatal visits	0 = No visits; 1 = Less than 8 contacts (1–7 visits) 2 = 8 contacts or more
Postnatal check-up of baby within two months of birth	0 = No; 1 = Yes
Marital status	0 = Never married; 1 = Married; 2 = Cohabiting; 3 = Widowed; 4 = Divorced
Number of under five children	1 = 0–1; 2 = 2; 3 = 3 or more
Media	0 = Not access; 1 = Access
Mothers working status	0 = Not working; 1 = Working
Distance to the health facility	1 = Big problem; 2 = Not a big problem
Number of living children	1 = 1; 2 = 2+

the children's (KR) dataset. No names of individuals or household addresses are in the data files.

Results

Descriptive characteristics of the respondents

A total of 2,250 women with children aged 12 to 23 months of age were included in the analysis. As shown in Fig. 1, the overall prevalence of fully vaccinated children in Madagascar in 2021 was 48.9%. The vaccination coverage for BCG, DPT3, Polio 3 and measles was 78.1%, 68.4%, 58.6% and 63.9%, respectively. Table 2 presents the baseline characteristics of the study population. More than half (52.1%) of the children were identified as males, and more than one-third (39.6%) were in the 2–3 birth cohort. Regarding maternal and household characteristics, approximately half of respondents were between the ages 15 and 24 years and 45.0% of respondents had primary school education. Furthermore, almost half (44.9%) of the respondents' partners also had primary school education. Most respondents (47.1%) had between 0 and 1 child under five years, and about two in three respondents (67.8%) were in marital union. Approximately a quarter was within grouped under the poorest wealth index. Regarding maternal care, a majority (87.2%) had less than eight contacts of ANC, and almost two-thirds (65.7%) had a postnatal check-up of their babies within two months of birth. Further, most respondents (84.2%) were living in rural residences, two-thirds indicated that distance to health facilities was not a big problem, and more than half (54.5%) had access to media.

Proportion of children 12–23 months vaccinated with essential vaccines

Figure 2 shows the vaccination coverage for children aged 12–23 months in Madagascar. Almost half 48.9% of the children had received full vaccination in Madagascar. There were variations in polio and DPT vaccination among the children. Vaccination coverage for BCG, third-dose polio, third-dose DPT, and measles was 78.1%, 58.6%, 68.4%, and 63.9%, respectively.

Bivariate analysis of full vaccination coverage among children aged 12–23 months

Similar proportions of male and female children had full vaccination coverage. Likewise, the vaccination coverage among mothers across different age groups as shown in Table 3. Full vaccination coverage was higher among mothers with secondary or higher education (61.9%). Partners with secondary or higher education had a greater proportion (60.2%) of full vaccination. Full vaccination coverage was higher among children who lived in urban areas (58.7%) and belong to richest wealth index (64.1%). Higher proportions of full vaccination were recorded among children whose mothers were never married (54.3%), those whose place of delivery was the health facility (61.1%) and those with no big problem getting to the health facility (51.9%). Also, 53.6% of the women had eight contacts or more antenatal care whereas 55.1% attended postnatal care. Additionally, a higher proportion of full vaccination was observed among mothers who had three or more children (41.4%) below the age of five years. Full vaccination coverage was high among women who had access to media (59.7%), those working (49.3%), and those who had only one child living (56.7%).

Factors associated with full childhood vaccination coverage of children aged 12–23 months

In Table 4, the multivariable analysis showed that male children were more likely to be fully immunized compared to females (aOR: 1.24; 95% CI: 1.01–1.53). Mothers aged 35–49 (aOR: 1.69; 95% CI: 1.08–2.64) were more likely to have their children fully immunized compared to women between 15 and 24 years. Children born to mothers with secondary or higher education were more likely to receive full vaccination than those whose mothers had no formal education. Mothers within the middle-class wealth index (aOR: 1.48; 95% CI: 1.04–2.12) were more likely to have their children fully vaccinated compared to the poorest category. Mothers who were working (aOR: 1.45; 95% CI: 1.06–1.98) were more likely to fully vaccinate their children compared to those who were not.

Table 2 Descriptive characteristics of women with children aged 12–23 months in Madagascar (N = 2,250)

Characteristic	Weighted sample(n)	Percentage and 95% CI
Child's sex		
Male	1,172	52.1 (49.9–54.3)
Female	1,078	47.9 (45.7–50.0)
Birth order		
1	619	27.5 (25.4–29.8)
2–3	892	39.6 (37.2–42.1)
4–5	395	17.6 (15.8–19.5)
6 +	344	15.3 (13.4–17.3)
Mother's age (age groups)		
15–24	954	42.4 (40.0-44.8)
25–34	890	39.5 (37.0-42.1)
35–49	406	18.1 (16.2–20.0)
Mother's education		
No formal education	482	21.4 (18.9–24.2)
Primary education	1012	45.0 (42.3–47.5)
Secondary or higher	756	33.6 (30.9–36.4)
Partner's education		
No formal education	368	20.5 (17.9–23.4)
Primary education	802	44.9 (41.9–47.9)
Secondary or higher	618	34.6 (31.7–37.5)
Place of residence		
Urban	355	15.8 (14.0-17.7)
Rural	1895	84.2 (82.3–86.0)
Wealth index		
Poorest	603	26.8 (23.4–30.5)
Poorer	497	22.1 (19.8–24.4)
Middle	459	20.4 (18.2–22.9)
Richer	360	15.9 (13.9–18.3)
Richest	331	14.7 (12.4–17.5)
Place of delivery		
Home or other	1,358	60.4 (57.2–63.6)
Health facility	892	39.6 (36.4–42.8)
Number of antenatal contacts		
No contact	222	10.4 (8.6–12.4)
Less than eight contacts	1,867	87.2 (85.1–89.1)
Eight or more contacts	51	2.40 (1.58–3.55)
Postnatal check-up of baby within two months of birth		
No	1,398	65.7 (62.9–68.4)
Yes	730	34.3 (31.6–37.1)
Marital status		
Never married	180	7.9 (6.83–9.31)
Married	1,526	67.8 (64.8–70.7)
Cohabiting	277	12.3 (10.3–14.6)
Widowed	19	0.8 (0.50–1.32)
Divorced	248	11.0 (9.4–12.9)
Number of under five children		
0–1	1,058	47.1 (44.5–49.6)
2	921	40.9 (38.7–43.1)
Three or more	271	12.0 (10.45–138)
Media		
Not access	1,024	45.5 (42.2–48.8)
Access	1,226	54.5 (51.2–57.8)
Mothers working status		

Table 2 (continued)

Characteristic	Weighted sample(*n*)	Percentage and 95% CI
Not working	338	15.1 (13.1–17.2)
Working	1,912	84.9 (82.8–86.9)
Distance to the health facility		
Big problem	811	36.0 (32.8–39.3)
Not a big problem	1,439	63.9 (60.7–67.2)
Number of living children		
1	632	28.1 (25.9–30.4)
2+	1,617	71.8 (69.6–74.0)

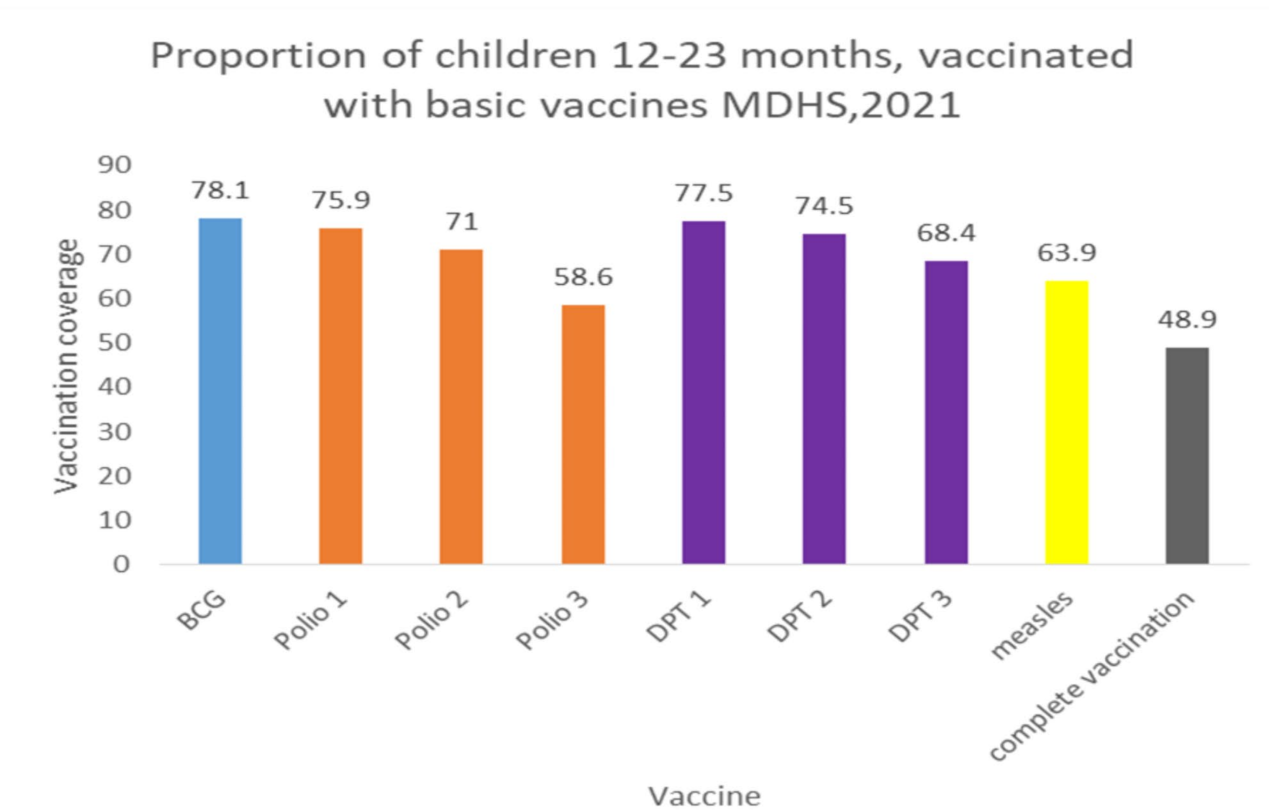

Fig. 2 The proportion of children 12–23 months vaccinated with essential vaccines, MDHS, 2021

Compared to mothers who delivered their babies at home or other places, mothers who delivered their babies at the health facility were more likely to vaccinate their children fully (aOR: 1.57; 95% CI: 1.22–2.02). Mothers who had less than eight antenatal care visits (aOR: 3.63; 95% CI: 2.30–5.72), and those with eight or more visits (aOR: 1.20; 95% CI: 1.35–6.51) were more likely to have their children vaccinated fully compared to those with no antenatal care visits. Mothers exposed to media were more likely to fully vaccinate their children than their counterparts (aOR: 1.65; 95% CI: 1.26–2.16).

Discussion

This study examined the full vaccination coverage and its associated factors among children aged 12–23 months in Madagascar. We found the proportion of full vaccination coverage among the children was 48.9%. Factors associated with full vaccination coverage were the child's sex, mother's age, mother's education, place of delivery, number of antenatal care visits, wealth index, mother's working status, and media access.

In this study, the coverage of full childhood vaccination stood at 48.9%, indicating that most children (51.1%) did not receive all recommended childhood vaccinations. The proportion of full vaccination coverage observed in our study is similar to findings from studies conducted in

Table 3 Bivariate analysis of full vaccination coverage of children 12–23 months in Madagascar

Characteristic	Partial vaccination *n* = 1154 *n* (%)	Full vaccination *n* = 1,096 *n* (%)	Chi-square/ *p*-value
Child's sex			2.617/0.1627
Male	621 (52.9)	552 (47.1)	
Female	533 (49.5)	544 (50.5)	
Birth order			39.82/<0.001
1	270 (43.6)	349 (56.4)	
2–3	439 (49.2)	453 (50.8)	
4–5	234 (50.1)	162 (40.9)	
6 +	211 (61.4)	132 (38.6)	
Mother's age (age groups)			0.29/0.891
15–24	494 (51.8)	460 (48.2)	
25–34	450 (50.6)	440 (49.4)	
35–49	210 (51.6)	196 (48.4)	
Mother's education			129.272/<0.001
No formal education	344 (71.2)	139 (28.8)	
Primary education	522 (51.6)	489 (48.4)	
Secondary or higher	288 (38.1)	468 (61.9)	
Partner's education			75.78/<0.001
No formal education	251 (68.5)	116 (31.5)	
Primary education	404 (50.3)	399 (49.7)	
Secondary or higher	246 (39.8)	372 (60.2)	
Place of residence			16.874/0.0012
Urban	147 (41.3)	208 (58.7)	
Rural	1,007 (53.2)	888 (46.8)	
Wealth index			137.961/<0.001
Poorest	414 (68.6)	189 (31.4)	
Poorer	276 (55.6)	221 (44.4)	
Middle	206 (44.9)	253 (55.1)	
Richer	139 (38.7)	221 (61.3)	
Richest	119 (35.9)	212 (64.1)	
Place of delivery			90.92/<0.001
Home or other	807 (59.4)	551 (40.6)	
Health facility	347 (38.9)	545 (61.1)	
Number of antenatal visits			117.78/<0.001
No visits	189 (85.1)	33 (14.9)	
Less than eight contacts	872 (46.7)	995 (53.3)	
Eight contacts or more	24 (46.4)	27 (53.6)	
Postnatal check-up of baby within two months of birth			16.26/0.0012
No	756 (54.1)	642 (45.9)	
Yes	328 (44.9)	402 (55.1)	
Marital status			27.93/0.007
Never married	82 (45.7)	98 (54.3)	
Married	740 (48.5)	786 (51.5)	
Cohabiting	169 (60.9)	109 (39.1)	
Widowed	9 (51.6)	9 (48.4)	
Divorced	153 (61.9)	95 (38.3)	
Number of under five children			17.79/0.0027
0–1	495 (46.8)	563 (53.2)	
2	500 (54.3)	421 (45.7)	
3 or more	159 (58.6)	112 (41.4)	
Media access			130.16/<0.001
Not access	660(64.4)	364(35.6)	
Access	494(40.3)	732(59.7)	

Table 3 (continued)

Characteristic	Partial vaccination *n* = 1154 *n* (%)	Full vaccination *n* = 1,096 *n* (%)	Chi-square/ *p*-value
Mothers working status			1.85/0.253
Not working	185 (54.7)	153 (45.3)	
Working	969 (50.7)	943 (49.3)	
Distance to the health facility			16.63/0.006
Big problem	462 (57.0)	349 (43.0)	
Not a big problem	691 (48.1)	748 (51.9)	
Number of living children			22.48/0.001
1	274 (43.3)	358 (56.7)	
2+	880 (54.4)	738 (45.6)	

Ethiopia [35], Uganda [36], and Mozambique [37]. However, our results exceed previous studies, reporting 18.8% in Guinea [36] and 33.3% in Ethiopia [38]. Additionally, our findings are lower than those of other studies, reporting 85% in Burundi [33], 93.1% in China [39], and 85.6% in sub-Saharan Africa [40]. Although our study did not investigate specific reasons behind the low vaccination rate among children, prior studies in Madagascar have linked this issue to vaccine stockouts, hindering access to vaccination services, and factors such as a shortage of adequately trained personnel to administer the vaccines [41] and unreliable access to electricity for maintaining the cold chain [24]. Ill-treatment of women by medical professionals, such as being hostile, demeaning, or violent, could have resulted in a decrease in the uptake of vaccination services. Evidence shows that health providers punished women who forgot their child's vaccination card, skipped an appointment, or had a dirty or poorly dressed child [41]. Mothers who experience this abuse from their providers may feel embarrassed and be discouraged from vaccinating their children. These beliefs may exacerbate postpartum depression in mothers, which could have detrimental effects on their health [42]. Nevertheless, the differences in vaccination coverage between countries could be attributable to socio-cultural differences, changes in healthcare coverage and legislation, discrepancies in sample size, and differences in vaccination access among the study settings [43, 44].

The study found that male children were more likely than female children to have received all recommended vaccinations, possibly due to a preference for male children in some cultures [39]. However, contrasting findings from a systematic review in Madagascar indicated similar vaccination coverage in both boys and girls. Nevertheless, three of the four articles noted slightly higher vaccination rates among girls than boys [23]. As per the findings of Fang et al. [45] there has been a decline or complete elimination of male and female discernment concerning health state and the general understanding of the notion of "male preference" in recent times. The results may differ based on the study setting, but gender discernment has a mixed impact on vaccination status. There has been some shift in male affection and a possible decrease in gender bias, particularly in households where only one child is permitted. However, we cannot ignore sex differences in vaccine access because, in some places, male preference still has a significant impact on children's health [39, 45].

Mothers aged 35 to 49 were more likely to fully vaccinate their children than those aged 15 to 24. This is consistent with studies reported in Nigeria [46] and East African countries [33]. This phenomenon could be attributed to the increased accessibility of maternal health services as mothers age, including antenatal care visits, supervised deliveries, and postnatal care visits, which serve as platforms for introducing mothers to child vaccination [47, 48]. Furthermore, with advancing age, mothers tend to acquire a more comprehensive understanding of childhood diseases and the importance of vaccination in preventing them [49].

The study revealed a significant association between full vaccination coverage and maternal educational attainment. Children of mothers with secondary or higher education had a higher likelihood of being fully vaccinated than those without formal education. This may be attributed to educated mothers being more informed about vaccination benefits, having access to relevant information, and ensuring their children adhere to the recommended vaccine schedule. Previous studies have shown that vaccination inclination increases with educational attainment [50, 51]. Previous research conducted in Nigeria [52], India [53], and Pakistan [54] supports this finding. However, a study in Ghana found no association between full vaccination and the educational status of the mother [55].

Mothers who were working demonstrated a significantly higher likelihood of fully vaccinating their children than those who were not. This finding aligns with existing literature in rural Nigeria, which suggests that employment may provide some psychological motivation

Table 4 Multivariable logistic regression analysis of factors associated with full vaccination coverage among children 12–23 months

Characteristic	aOR (95%CI)
Child's sex	
Female	1.00
Male	1.24 (1.01-1.53)*
Birth order	
1	1.00
2–3	1.21 (0.59–2.46)
4–5	0.96 (0.43- 2.16)
6 +	0.85 (0.35- 2.06)
Mother's age (age groups)	
15–24	1.00
25–34	1.34 (0.99–1.80)
35–49	1.69 (1.08- 2.64)*
Mother's education	
No formal education	1.00
Primary education	1.54 (1.08–2.20)
Secondary or higher	1.68 (1.15–2.45)*
Place of residence	
Urban	1.00
Rural	0.93 (0.64–1.37)
Wealth index	
Poorest	
Poorer	1.15 (0.83–1.59)
Middle	1.48 (1.04–2.12)*
Richer	1.51 (0.98–2.31)
Richest	1.12 (0.68–1.84)
Place of delivery	
Home or other	1.00
Health facility	1.57 (1.22–2.02)*
Number of antenatal contacts	
No visits	1.00
Less than eight contacts	3.63 (2.30–5.72)**
Eight contacts or more	1.20 (1.35–6.51)*
Postnatal check-up of baby within two months of birth	
No	1.00
Yes	1.10 (0.88- 1.38)
Marital status	
Never married	1.00
Married	0.98 (0.65–1.47)
Cohabiting	0.64 (0.36–1.12)
Widowed	0.96 (0.36–2.57)
Divorced	0.67 (0.40–1.12)
Number of under five children	
0–1	1.00
2	1.03 (0.79–1.33)
3 or more	1.47 (0.95–2.28)
Media access	
Not access	1.00
Access	1.65 (1.26–2.16)**
Mothers working status	
Not working	1.00
Working	1.45 (1.06–1.98)*
Distance to the health facility	
Not a big problem	1.00

Table 4 (continued)

Characteristic	aOR (95%CI)
Big problem	1.04 (0.83–1.32)
Number of living children	
1	1.00
2+	0.63 (0.31–1.29)

(***)$P < 0.0001$, (**) $P < 0.001$), (*) $p < 0.05$

to access optimal child care, including vaccination [56]. It could also result from the fact that employment may enhance a mother's financial capacity, increasing access to healthcare services, including vaccination programs. Employment may also promote greater exposure to health education and awareness campaigns, as workplaces can serve as channels for disseminating public health information. Amoah et al. [57] reported in their study in sub-Saharan Africa that maternal employment, education, and decision-making capacity were positively associated with the full vaccination of children . Moreover, employed mothers might also experience social influences, such as peer encouragement, which can positively affect their health-seeking behavior, including vaccination uptake. To enhance vaccination coverage and reduce disparities, efforts should focus on addressing social determinants of health, ensuring access to quality healthcare, and removing barriers to maternal health-seeking behaviors [41].

Our study found that middle-class mothers were more likely to fully vaccinate their children than the poor. This highlights the role of socioeconomic factors in improving vaccination uptake. Middle-class families may benefit from better access to healthcare services, education, and resources that facilitate maternal health-seeking behaviors [58]. However, the association was not significant among the wealthiest categories, suggesting that factors like complacency, competing priorities, or misperceptions in health systems might influence their decisions [59, 60]. These findings emphasize the need for tailored public health strategies to address barriers across all economic groups.

Similar to previous research [5, 53, 61], our study also shows that complete childhood vaccination was more likely to be received by children born in a health facility than those born at home or in other locations. Likewise, a study in India found that home-born infants were either fully or partially unvaccinated [62]. Also, in line with our findings, Pandey et al. [53] demonstrated that approximately 75% of infants born in medical facilities had received all recommended vaccinations [54]. Infants born in hospitals may have access to critical medical services necessary for vaccination programs [62]. Additionally, mothers who give birth in a medical facility are more likely to receive vaccine instruction from medical professionals. As a result, their children are more likely to acquire subsequent vaccinations since they are more aware of the risks and benefits of immunisation [50]. For example, children in a hospital have access to the first dose of the BCG vaccine, which is given shortly after delivery, and parents will be taught about subsequent vaccinations [50, 63].

Our study showed a significant association between the number of antenatal care visits and full childhood vaccination. In comparison to mothers who had no antenatal care visit, those who had fewer than eight contacts and eight contacts or more had a higher chance of having their children fully vaccinated. This finding is consistent with previous research conducted in Zimbabwe [50] and Northwest Ethiopia [44], which also found that children whose mothers did not have antenatal care contact with medical personnel were less likely to have received recommended vaccinations. This is attributed to the fact that mothers who do not receive antenatal care are less likely to adhere to antenatal care practice guidelines, including the administration of required vaccines during pregnancy. Consequently, they exhibit reduced utilisation of health services and adherence to vaccination guidelines for their children. Conversely, children whose mothers have received antenatal care services, benefitting from their familiarity with healthcare systems and medical professionals' support have a higher likelihood of receiving all recommended vaccinations [64].

Another factor linked to full childhood vaccination coverage is media access. Compared to their counterparts, women exposed to the media had a higher likelihood of vaccinating their children in full. This result is consistent with research from East Africa [33], Zimbabwe [50], and Ethiopia [65], as well as a previous study in Madagascar [23]. Media exposure is the most effective way to reach the population and encourage better healthcare-seeking behavior [33]. According to Lee et al. [67], media exposure is essential for influencing public opinion and disseminating information regarding childhood vaccination programs. Exposure to mass media should be stressed due to its strong positive correlation with vaccination completion, as demonstrated in an earlier study [51]. Based on the successful outcomes of preceding studies, information and sensitisation campaigns and messages should be carefully designed and distributed through radio, newspapers, and television stations [40, 68].

Strengths and limitations

This research has a lot of strengths. First, the study's data came from the most current, nationally representative, and large population-based survey sample covering every area and administrative division in Madagascar. Secondly, there is a typical design across the DHS surveys, with standard variables allowing cross-context comparisons. The results could therefore be relevant to other developing countries. It is important to note the limitations of this study's conclusions. First, the analysis employed potential predictor elements from the 2021 MDHS. However, factors like the quality of vaccination services not included in the DHS data set are probably important drivers of children receiving all recommended vaccinations. Secondly, recall bias is possible because the data on childhood full vaccination was collected retrospectively (via vaccination cards and maternal self-report). Third, drawing inferences about causal relationships between explanatory variables and a comprehensive childhood vaccination is made more difficult because the analyses were based on data from a cross-sectional survey. As a result, it is essential to confirm the validity of the observed connections using data collected longitudinally across time.

Conclusion

The overall prevalence of full childhood vaccination was 48.9% in Madagascar. Predictors such as child's sex, maternal age, maternal education, place of delivery, number of antenatal care visits, wealth index, mother's working status and media access were significantly associated with full childhood vaccination. Our findings indicated that full childhood vaccination coverage falls short of the WHO's EPI coverage objective of at least 90%. It is recommended that the Ministry of Health in Madagascar collaborate with regional health departments and local administrative levels to achieve the recommended coverage. To address systemic challenges in vaccination coverage in Madagascar, key actionable points include improving vaccine supply chains through better logistics and infrastructure, enhancing training for healthcare workers to ensure respectful care to caretakers during vaccination sessions, and increasing access to media for public health campaigns that raise awareness about vaccination importance. Strengthening antenatal care services with integrated vaccination education, promoting the use of immunization cards, and engaging community leaders to mobilize support for vaccinations are essential. Additionally, conducting regular assessments of vaccination programs can help identify barriers and tailor interventions to improve uptake and public health outcomes. They should also inform mothers about the various vaccination plans and the need to keep the vaccination cards through media channels, such as radio, television, community information systems and even phone calls.

Abbreviations

aOR	Adjusted odds ratio
CI	Confidence interval
DHS	Demographic and health survey
MEASURE DHS	Monitoring and evaluation to assess and use results demographic and health surveys
MDHS	Madagascar Demographic and Health Survey
EPI	Expanded Programme on Immunisation
WHO	World Health Organization
LMICs	Low-and Middle-Income Countries
BCG	Bacillus Calmette–Guérin
DPT	Diphtheria–Tetanus–Pertussis
MCV	Measles-Containing Vaccine
PCV	Pneumococcal Conjugate Vaccine
VDPV	Vaccine-Derived Polio Virus
IPV	Inactivated Polio Vaccine
RV	Rotavirus Vaccine

Acknowledgements
We thank the MEASURE DHS Program for supporting and making the dataset freely accessible.

Author contributions
FGW and BOA contributed to the study design and conceptualisation. FGW and BOA performed the analysis. FGW, RGA, AO, AS, and BOA drafted the initial manuscript. All the authors critically reviewed the manuscript for its intellectual content. All authors read and amended drafts of the paper and approved the final version. AO had the final responsibility of submitting it for publication.

Funding
The study received no funding.

Data availability
The data used for this study is freely available at https://dhsprogram.com/data/dataset/Madagascar_Standard-DHS_2021.cfm?flag=1.

Declarations

Ethics approval and consent to participate
Ethical clearance was not sought for the study since the secondary dataset is freely available in the public domain. A detailed description of the ethical issues regarding the DHS and its dataset usage can be assessed at http://goo.gl/ny8T6X.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Global Public Health, Karolinska Institutet, Stockholm, Sweden
[2]School of Population Health, University of New South Wales, Sydney, NSW 2052, Australia
[3]Department of Family and Community Health, Fred N. Binka School of Public Health, University of Health and Allied Sciences, Hohoe, Ghana
[4]Department of Biological Sciences, School of Basic Sciences, Njala University, PMB, Freetown, Sierra Leone
[5]Public Health and Tropical Medicine, James Cook University, Townsville, QLD 4811, Australia
[6]REMS Consultancy Services Limited, Sekondi-Takoradi, Western Region, Ghana
[7]Faculty of Health and Medical Sciences, The University of Adelaide, Adelaide, Australia

Received: 27 May 2024 / Accepted: 9 January 2025
Published online: 21 February 2025

References

1. World Health Organization. Vaccines and immunization. Available from: https://www.who.int/health-topics/vaccines-and-immunization#tab=tab_1 2024 [cited 2024 May 23].
2. Frenkel LD. The global burden of vaccine-preventable infectious diseases in children less than 5 years of age: implications for COVID-19 vaccination. How can we do better? Allergy Asthma Proc. 2021;42(5):378–85.
3. World Health Organization. Childhood immunization begins recovery after COVID-19 backslide. Available from: https://www.who.int/news/item/18-07-2023-childhood-immunization-begins-recovery-after-covid-19-backslide 2023 [cited 2024 April 21].
4. UNICEF. Immunization coverage estimates dashboard. Available from: https://unicef-dapm.shinyapps.io/wuenic-analytics-2023/ 2023 [cited 2024 April 21].
5. World Health Organization. Child mortality (under 5 years. Available from: https://www.who.int/news-room/fact-sheets/detail/levels-and-trends-in-child-under-5-mortality-in-2020 2022 [cited 2024 April 21].
6. World Population Review. Madagascar Population 2024. Available from: https://worldpopulationreview.com/countries/madagascar-population 2024 [cited 2024 April 21].
7. Ratovoson R, Masquelier B, Andriatahina T, Mangahasimbola R, Andrianirina Z, Pison G et al. Inequalities in cause-specific mortality in children and adolescents in the Moramanga health survey, Madagascar. Int J Public Health. 2020;65(6):781–90. Available from: https://doi.org/10.1007/s00038-020-01409-z
8. World Health Organization. Vaccine introduction in Madagascar. Available from: https://immunizationdata.who.int/pages/vaccine-intro-by-country/mdg.html?YEAR= 2023 [cited 2024 April 21].
9. Wesolowski A, Mensah K, Brook CE, Andrianjafimasy M, Winter A, Buckee CO, et al. Introduction of rubella-containing-vaccine to Madagascar: implications for roll-out and local elimination. J R Soc Interface. 2016;13:117.
10. Center for Disease Control and Prevention. Child and Adolescent Immunization Schedule by Age. Available from: https://www.cdc.gov/vaccines/schedules/hcp/imz/child-adolescent.html 2023 [cited 2024 April 21].
11. World Health Organization, Philippines, UNICEF estimates of immunization coverage. WHO and : 2021 revision. 2023;1–29. Available from: https://cdn.who.int/media/docs/default-source/country-profiles/immunization/2022-country-profiles/immunization_phl_2022.pdf [cited 2024 April 21].
12. Rajaonarifara E, Bonds MH, Miller AC, Ihantamalala FA, Cordier L, Razafinjato B, et al. Impact of health system strengthening on delivery strategies to improve child immunisation coverage and inequalities in rural Madagascar. BMJ Glob Heal. 2022;7(1):1–13.
13. World Health Organization. Immunization dashboard, Madagascar. Available from: https://immunizationdata.who.int/dashboard/regions/african-region/MDG 2023 [cited 2024 May 23].
14. van den Ent MMVX, Yameogo A, Ribaira E, Hanson CM, Ratoto R, Rasolomanana S et al. Equity and immunization supply chain in Madagascar. Vaccine. 2017;35(17):2148–54. Available from: https://doi.org/10.1016/j.vaccine.2016.11.099
15. Mensah K, Heraud JM, Takahashi S, Winter AK, Metcalf CJE, Wesolowski A. Seasonal gaps in measles vaccination coverage in Madagascar. Vaccine. 2019;37(18):2511–9. Available from: https://doi.org/10.1016/j.vaccine.2019.02.069
16. Raherindrasana A, Jessica Metcalf C, Heraud JM, Cauchemez S, Winter A, Wesolowski A, et al. Towards better targeting: lessons from a posthoneymoon measles outbreak in Madagascar, 2018–2019. BMJ Glob Heal. 2020;5(10):2018–9.
17. Mengouo Nimpa M, Ravelomanana Razafiarivao N, Robinson A, Randriatsarafara Fidiniaina M, Razafindratsimandresy R, Masembe YV et al. Efforts towards Polio Eradication in Madagascar: 1997 to 2017. J Immunol Sci. 2021;(2):102–11.
18. Phillips DE, Dieleman JL, Lim SS, Shearer J. Determinants of effective vaccine coverage in low and middle-income countries: a systematic review and interpretive synthesis. BMC Health Serv Res. 2017;17(1).
19. Ahmed Ali H, Hartner AM, Echeverria-Londono S, Roth J, Li X, Abbas K et al. Correction: Vaccine equity in low and middle income countries: a systematic review and meta-analysis (International Journal for Equity in Health, 2022;1(82):21. https://doi.org/10.1186/s12939-022-01678-5). Int J Equity Health. 2022;21(1):1–30.
20. Wigle J, Coast E, Watson-Jones D. Human papillomavirus (HPV) vaccine implementation in low and middle-income countries (LMICs): Health system experiences and prospects. Vaccine. 2013;31(37):3811–7. Available from: https://doi.org/10.1016/j.vaccine.2013.06.016
21. Ver AT, Notarte KI, Velasco JV, Buac KM, Nazareno J, Lozañes JA, et al. A systematic review of the barriers to implementing human papillomavirus vaccination programs in low- and middle-income countries in the Asia-Pacific. Asia Pac J Clin Oncol. 2021;17(6):530–45.
22. Restrepo-Méndez MC, Barros AJD, Wong KLM, Johnson HL, Pariyo G, Wehrmeister FC, et al. Missed opportunities in full immunization coverage: findings from low- and lower-middle-income countries. Glob Health Action. 2016;9(1):1–6.
23. Hahesy E, Cruz-Espinoza LM, Nyirenda G, Tadesse BT, Kim JH, Marks F et al. Madagascar's EPI vaccine programs: a systematic review uncovering the role of a child's sex and other barriers to vaccination. Front Public Heal. 2022;10.
24. Clouston S, Kidman R, Palermo T. Social inequalities in vaccination uptake among children aged 0–59 months living in Madagascar: An analysis of Demographic and Health Survey data from 2008 to 2009. Vaccine. 2014;32(28):3533–9. Available from: https://doi.org/10.1016/j.vaccine.2014.04.030
25. Verrier F, de Lauzanne A, Diouf JBN, Zo AZ, Ramblière L, Herindrainy P et al. Vaccination Coverage and Risk Factors Associated With Incomplete Vaccination Among Children in Cambodia, Madagascar, and Senegal. Open Forum Infect Dis. 2023;10(4):1–11. Available from: https://doi.org/10.1093/ofid/ofad136
26. Ramaroson HJV, Mattern C, Huysmans E, Razafiarimanana H, Brazy-Nancy E, Haritiana Ranaivoharimina M et al. Obstacles to routine immunization immunisation in Madagascar: Structural, relational and cultural constraints. Vaccine X. 2023;15(July).2.
27. Implementing the Immunization Agenda. 2030. WHO. 2021;1–32. Available from:https://cdn.who.int/media/docs/default-source/immunization/strategy/ia2030/ia2030_frameworkforactionv04.pdf?sfvrsn=e5374082_1&download=true.
28. Institut National de la Statistique (INSTAT) et ICF. Enquête Démographique et de Santé à Madagascar,2021. Antananarivo, Madagascar et Rockville, Maryland, USA : INSTAT et ICF. 2022.https://dhsprogram.com/pubs/pdf/FR376/FR376.pdf
29. WHO vaccine-preventable diseases. : monitoring system 2010 global summary WHO vaccine-preventable diseases : monitoring system 2010 global summary. 2010.
30. Ntenda PAM, Sixpence A, Mwenyenkulu TE, Mmanga K, Chirambo AC, Bauleni A et al. Determinants of pentavalent and measles vaccination dropouts among children aged 12–23 months in The Gambia. BMC Public Health. 2022;22(1):1–11. Available from: https://doi.org/10.1186/s12889-022-12914-6
31. Ntenda PAM, Chuang KY, Tiruneh FN, Chuang YC. Analysis of the effects of individual and community level factors on childhood immunization in Malawi. Vaccine. 2017;35(15):1907–17. Available from: https://doi.org/10.1016/j.vaccine.2017.02.036
32. Aalemi AK, Shahpar K, Mubarak MY. Factors influencing vaccination coverage among children age 12–23 months in Afghanistan: Analysis of the 2015 Demographic and Health Survey. PLoS One. 2020;15(8 August):1–16. Available from: https://doi.org/10.1371/journal.pone.0236955
33. Tesema GA, Tessema ZT, Tamirat KS, Teshale AB. Complete basic childhood vaccination and associated factors among children aged 12–23 months in East Africa: a multilevel analysis of recent demographic and health surveys. BMC Public Health. 2020;20(1):1–14.
34. Lakew Y, Bekele A, Biadgilign S. Factors influencing full immunization coverage among 12–23 months of age children in Ethiopia: evidence from the national demographic and health survey in 2011. BMC Public Health. 2015;15(1):1–8.
35. Fenta SM, Fenta HM. Individual and community-level determinants of childhood vaccination in Ethiopia. Archives Public Health. 2021;79(1):1–11.
36. Ameyaw EK, Kareem YO, Ahinkorah BO, Seidu AA, Yaya S. (2021). Decomposing the rural-urban gap in factors associated with childhood immunization in sub-saharan Africa: evidence from surveys in 23 countries. BMJ Global Health, 6(1), e003773.
37. Shemwell, S. A., Peratikos, M. B., Gonzalez-Calvo, L., Renom-Llonch, M., Boon, A.,Martinho, S., … Moon, T. D. (2017). Determinants of full vaccination status in children aged 12–23 months in Gurùé and Milange districts, Mozambique:

results of a population-based cross-sectional survey. International Health, 9(4), 234–242.
38. Geweniger A, Abbas KM. Childhood vaccination coverage and equity impact in Ethiopia by socioeconomic, geographic, maternal, and child characteristics. Vaccine. 2020;38(20):3627–38.
39. Cao L, Zheng JS, Cao LS, Cui J, Duan MJ, Xiao QY (2018). Factors influencing the routine immunization status of children aged 2–3 years in China. PLoS One, 13(10), e0206566.
40. Budu, E., Ahinkorah, B. O., Aboagye, R. G., Armah-Ansah, E. K., Seidu, A. A., Adu,C., … Yaya, S. Maternal healthcare utilsation and complete childhood vaccination in sub-Saharan Africa: a cross-sectional study of 29 nationally representative surveys.BMJ Open. 2021;11(5):e045992.
41. Bobo FT, Asante A, Woldie M, Dawson A, Hayen A. Child vaccination in sub-saharan Africa: increasing coverage addresses inequalities. Vaccine. 2022;40(1):141–50.
42. Silveira, M. F., Buffarini, R., Bertoldi, A. D., Santos, I. S., Barros, A. J., Matijasevich,A., … Victora, C. G. (2020). The emergence of vaccine hesitancy among upper-class Brazilians: Results from four birth cohorts, 1982–2015. Vaccine. 2020;38(3):482–488.
43. Mbengue MA, Mboup A, Ly ID, Faye A, Camara FB, Thiam M, Ndiaye BP, Dieye TN, Mboup S. Vaccination coverage and immunization timeliness among children aged 12-23 months in Senegal: a Kaplan-Meier and Cox regression analysis approach. The Pan African Medical Journal. 2017;27(Suppl 3).
44. Tesfaye TD, Temesgen WA, Kasa AS. Vaccination coverage and associated factors among children aged 12–23 months in Northwest Ethiopia. Volume 14. Human Vaccines & Immunotherapeutics. 2018;10:2348–54.
45. Fang R, Feng H, Hu M, Khan MK, Wang L, Zhou Y, Zhao J. Evaluation of immune responses induced by SAG1 and MIC3 vaccine cocktails against Toxoplasma Gondii. Vet Parasitol. 2012;187(1–2):140–6.
46. Oleribe O, Kumar V, Awosika-Olumo A, Taylor-Robinson SD. Individual and socioeconomic factors associated with childhood immunization coverage in Nigeria. Pan Afr Med J. 2017;26:1–14.
47. Sondaal SF, Browne JL, Amoakoh-Coleman M, Borgstein A, Miltenburg AS, Verwijs M, Klipstein-Grobusch K. Assessing the effect of mHealth interventions in improving maternal and neonatal care in low-and middle-income countries: a systematic review. PLoS One 2016 May 4;11(5):e0154664.
48. Atnafu A, Otto K, Herbst CH. The role of mHealth intervention on maternal and child health service delivery: findings from a randomized controlled field trial in rural Ethiopia. mHealth. 2017;3:39–39.
49. Feyisetan BJ, Asa SEJ. Mothers' management of childhood diseases in Yorubaland: the influence of cultural beliefs. Heal Transit Rev. 1997; Available from: https://pubmed.ncbi.nlm.nih.gov/10176379/
50. Mukungwa T. Factors associated with full immunization coverage amongst children aged 12–23 months in Zimbabwe. Afr Popul Stud, 2015;29(2).
51. Negussie A, Kassahun W, Assegid S, Hagan AK. Factors associated with incomplete childhood immunization in Arbegona district, southern Ethiopia: a case–control study. BMC Public Health. 2015;16(1):1–9.
52. Oleribe O, Kumar V, Awosika-Olumo A, Taylor-Robinson SD. Individual and socioeconomic factors associated with childhood immunization coverage in Nigeria. The Pan African Medical Journal. 2017;26.
53. Pandey S, Ranjan A, Singh CM, Kumar P, Ahmad S, Agrawal N. Socio-demographic determinants of childhood immunization coverage in rural population of Bhojpur district of Bihar, India. J Family Med Prim care. 2019;8(7):2484.
54. Ameen M, Rasul S, ul Haq MA, Mahmood QK. Determinants of factors associated with childhood immunization in Punjab, Pakistan: evidence from the multiple indicator cluster survey. J Public Health. 2018;26:495–9.
55. Moran EB, Wagner AL, Asiedu-Bekoe F, Abdul-Karim A, Schroeder LF, Boulton ML. Socioeconomic characteristics associated with the introduction of new vaccines and full childhood vaccination in Ghana, 2014. Vaccine. 2020;38(14):2937–42.
56. Adeleye OA, Mokogwu N. Determinants of full vaccination status in a rural community with accessible vaccination services in South-South Nigeria. J Community Med Prim Heal Care. 2016;28(1):1–7.
57. Amoah A, Issaka J, Ayebeng C, Okyere J. Influence of women empowerment on childhood (12–23 months) immunization coverage: recent evidence from 17 sub-saharan African countries. Trop Med Health. 2023;51(1).
58. Ahmed S, Creanga AA, Gillespie DG, Tsui AO. Economic status, education and empowerment: implications for maternal health service utilization in developing countries. PLoS One. 2010;5(6).
59. Cata-Preta B, de O, Wehrmeister FC, Santos TM, Barros AJD, Victora CG. Patterns in Wealth-related Inequalities in 86 Low- and Middle-Income Countries: Global Evidence on the Emergence of Vaccine Hesitancy. Am J Prev Med. 2021;60(1):S24–33. Available from: https://doi.org/10.1016/j.amepre.2020.07.028
60. Majid U, Ahmad M. The factors that promote vaccine hesitancy, rejection, or Delay in Parents. Qual Health Res. 2020;30(11):1762–76.
61. Devasenapathy N, Jerath SG, Sharma S, Allen E, Shankar AH, Zodpey S. (2016). Determinants of childhood immunisation coverage in urban poor settlements of Delhi, India: a cross-sectional study. BMJ Open, 2016;6(8):e013015.
62. Gupta P, Prakash D, Srivastava JP. Determinants of immunization coverage in Lucknow district. North Am J Med Sci. 2015;7(2):36.
63. Ntenda PA. Factors associated with non-and under-vaccination among children aged 12–23 months in Malawi. A multinomial analysis of the population-based sample. Pediatrics & Neonatology. 2019;60(6):623-33.
64. Abadura SA, Lerebo WT, Kulkarni U, Mekonnen ZA. Individual and community level determinants of childhood full immunization in Ethiopia: a multilevel analysis. BMC Public Health. 2015;15(1):1–10.
65. Girmay A, Dadi AF. Full immunization coverage and associated factors among children aged 12–23 months in a hard-to-reach areas of Ethiopia. International Journal of Pediatrics. 2019.
66. Debie A, Lakew AM, Tamirat KS, Amare G, Tesema GA. Complete vaccination service utilization inequalities among children aged 12–23 months in Ethiopia: a multivariate decomposition analyses. Int J Equity Health. 2020;19(1):1–16.
67. Lee YB, Lee JH, Kim YJ, Yoon JH, Lee HS. The effect of therapeutic vaccination for the treatment of chronic hepatitis B virus infection. J Med Virol. 2015;87(4):575–82.
68. Adedokun ST, Uthman OA, Adekanmbi VT, Wiysonge CS. Incomplete childhood immunization in Nigeria: a multilevel analysis of individual and contextual factors. BMC Public Health. 2017;17(1):1–10.

Publisher's note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.