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Trends in childhood vaccination in Pakistan and associated factors; 2006–2018

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ABSTRACT

Introduction: Pakistan still has ongoing transmission of wild type polio virus. This study aims to determine changes in full vaccination with recommended Expanded Program on Immunization vaccines, including polio, by several socio-economic and demographic factors.

Methods: We used three waves of Pakistan's Demographic and Health Survey, a population-based cross-sectional study from 2006–07 (N = 1471), 2012–13 (N = 1706), and 2017–18 (N = 1549), analyzed by residence, wealth, and sociodemographic factors. Analysis was limited to children aged 12–23 months in Punjab, Sindh, Northwest Frontier Province/Khyber Pakhtunkhwa and Balochistan. Full vaccination was measured as receipt of one Bacillus Calmette–Guérin dose, one measles dose, 3 polio doses, and 3 Diphtheria-Tetanus-Pertussis doses. Odds ratios (ORs) and 95 % confidence intervals (CIs) from logistic regression were used to determine associations between undervaccination and demographic variables.

Results: Full vaccination coverage was 50.6 % in 2006–07, 54.7 % in 2012–13, and 68.3 % in 2017–18. In 2006–07, the odds of undervaccination were significantly higher in Sindh (OR: 1.74, 95 % CI: 1.30, 2.31) than Punjab, and disparities across province changed over time ($P < 0.0001$); notably, undervaccination was significantly higher in Sindh, KPK, and Balochistan than Punjab in 2017. Compared to the middle wealth quintile, the poorest had significantly higher odds of undervaccination in 2006–07 (OR: 2.58, 95 % CI: 1.76, 3.78), and this did not significantly change over time ($P = 0.2168$). The proportion of those with a polio birth dose increased across waves from 56.3 % in 2006–07 to 83.7 % in 2017–18; receiving three or more polio vaccine doses remained unchanged.

Conclusion: This study showed that the proportion of fully vaccinated children in Pakistan increased across three waves. Full vaccination and administration of polio vaccine birth doses have increased recently in Pakistan. The association between undervaccination with province differed significantly across the waves, with vaccination disparities between provinces increasing. Those in the poorest wealth quintile had the greatest odds of undervaccination.

1. Introduction

The World Health Organization (WHO) established the Expanded Programme on Immunization (EPI) in 1974 to help ensure free access to vaccines for children in all countries and improve vaccination coverage of a recommended set of childhood vaccines [1]. Those recommended vaccines originally comprised a single dose of the Bacillus Calmette–Guérin (BCG) vaccine (for tuberculosis), three doses of polio vaccine, three doses of the Diphtheria-Tetanus-Pertussis (DTP) vaccine, and the first dose of the measles vaccine [2]. Vaccine additions to the EPI have included Hepatitis B in 1992, rotavirus in 2006, the pneumococcal conjugate vaccine (PCV) in 2007, and the *Haemophilus influenzae* type b (Hib) vaccine in 2009. In 2018, it was estimated that worldwide, 700,000 children under 5 years of age died from vaccine-preventable infectious diseases [3]. That number, while still unacceptably high, represents a dramatic improvement from an estimated 5.5 million deaths in 1990 [4]. Currently, the overwhelming majority of children (99 %) who die from vaccine-preventable diseases live in low- and middle-income countries [3].

As a lower-middle income country, Pakistan had the third greatest

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absolute number of childhood deaths (<5 years) in 2020, and globally has one of the highest mortality rates for children under 5 years old, estimated at 65 per 1000 live births in 2018 [5,6]. Communicable diseases and maternal, prenatal and nutrition conditions accounted for 39 % of deaths in 2012, and 36 % of deaths in 2016 [7]. Routine immunization has reduced deaths in children due to vaccine preventable diseases. For example, between 2009 and 2019, the rate of deaths from pertussis decreased from 27 to 19 per 100,000 children < 5 years, and for measles, the death rate decreased from 12 to 7 per 100,000 children < 5 [8,9]. Overall, the burden of vaccine-preventable diseases is still stubbornly high, and this is reflected most particularly through the situation of polio.

There has been an especially intensive public health effort to rid the world of polio initiated by the World Health Assembly when it launched the Global Polio Eradication Initiative in 1988 [10]. Since then, wild cases of poliovirus have decreased by over 99 % and today, only two countries continue to experience endemic transmission of wild poliovirus – Afghanistan and Pakistan. While cases of wild poliovirus type 1 (WPV1) have decreased in Pakistan across recent years, many of the cases that do still occur are among children who do not receive any vaccines (i.e. zero-dose children) [11].

Previous national immunization studies in Pakistan have consistently revealed relatively high levels of non-vaccinated and under-vaccinated children. One study published in 2014 found that the proportion of children who had not received any vaccinations was 6.2 % [12]; another study published in the same year estimated that 66 % of children were incompletely immunized or under-vaccinated [13]. Other research has documented provincial disparities with increasing full vaccination among children in Punjab from 2006 to 2012, and decreased coverage in Balochistan in the same time period [14]. A 2017 polio-specific study found that only 56.4 % of Pakistani children were fully vaccinated against polio [15]. Other relevant studies have also found that socioeconomic factors, such as parental education, household wealth status, province of residence, and urbanicity are significantly associated with vaccination [16,17].

The Pakistani government has initiated a number of programs to promote vaccine uptake between 2006 and 2017 [18,19]. It would therefore be informative to examine whether childhood vaccination has increased and vaccination disparities have decreased following implementation of these programs, and to further ascertain if these improvements have extended to more remote, rural regions of Pakistan. As such, in this study, we examine Pakistan's trends in childhood vaccination and disparities in vaccination status by wealth, province, and other factors using several waves of the Demographic and Health Survey including the most recent data from 2017 to 2018.

2. Materials and methods

2.1. Study population

Sample data were limited to children aged 12–23 months, and to four of seven total administrative units (the main provinces of Punjab, Sindh, Northwest Frontier Province/Khyber Pakhtunkhwa, and Balochistan), since not all administrative units were included in all three waves of the DHS due to security concerns and other reasons [20–22]. These four provinces include almost 97 % of Pakistan's population, according to the 2017 census [23].

2.2. Derived variables

The Women's Questionnaire, a subsection of the DHS survey tool, collected data from ever-married women aged 15–49 years old on background characteristics and child immunization information, among other topics. Specifically, women were asked about their eligible children's vaccination status using information from the child's vaccination card or based on maternal recall. Using this information, we created a full vaccination variable based on the immunization schedule recommended by the Expanded Programme on Immunization (EPI) in Pakistan. Full vaccination was defined as receipt of one dose of Bacillus Calmette–Guérin (BCG) vaccine at birth, at least three doses of any polio vaccine at 2, 4, and 6–18 months, at least three doses of Diphtheria-Tetanus-Pertussis (DTP) vaccine at 2, 4, and 6 months, and one dose of measles vaccine at 9 months. Children were considered partially vaccinated if they had received some, but not all of the recommended vaccine doses, and non-vaccinated if they had not received any doses of any of these vaccines.

2.3. Statistical analysis

Survey procedures were used in analyses because the datasets were weighted to achieve a nationally representative sample. In each wave of the DHS, proportions of full, partial, and non-vaccination in sampled children were estimated, as well as proportions of children who had received the enhanced EPI schedule consisting of BCG, polio, measles, pneumococcal, and DTP-HBV-Hib (pentavalent) vaccines. Logistic regression models were used to estimate odds ratios (ORs) and 95 % confidence intervals (CIs) of not being fully vaccinated in each wave of the DHS by maternal age, maternal education, wealth quintile, province, and urbanicity. P-values were additionally estimated for an interaction term between each of these demographic variables and the year of the survey. Analyses were done using SAS Version 9.4 (Cary, North Carolina).

2.4. Ethical approval

As this study only used previously collected, publicly available, de-identified data, IRB committee review was not required.

3. Results

Three waves of the DHS were used: from 2006 to 07 (n = 1,541), 2012–13 (n = 1,706), and 2017–18 (n = 1,549), yielding a total total sample size for all waves included in this study of 4,796 children. A similar distribution of maternal age is seen across all three waves with most (2006–07: 53.3 %; 2012–13: 55.8 %; 2017–18: 58.7 %) respondent mothers ages 25–34 years. A majority of mothers in the 2006–07 (62.3 %) and 2012–13 (54.0 %) waves lacked any formal education, while only 44.7 % of mothers did not have any formal education in 2017–18 (Table 1). The proportion of mothers living in each of the four included provinces remained relatively stable. In the 2006 and 2012 waves, 68.2 % and 69.1 % of respondents lived in rural areas, respectively; in the 2017 wave, 65.0 % of the respondents lived in rural areas.

The proportion of fully vaccinated children increased across the three waves, from 50.6 % in 2006, to 54.7 % in 2012, to 68.3 % in 2017 (Table 2). In Punjab and KPK, the proportion of fully vaccinated children increased over all waves (Fig. 1). In Sindh, there was an overall increase from 2006 to 2018 in fully vaccinated children; in Balochistan, we observed an overall decrease in fully vaccinated children from 37 % to 31 % (Fig. 1). The proportion of fully vaccinated children increased in all wealth quintiles across waves; however, those who are wealthier consistently have higher proportions of fully vaccinated children than those who are poorer (Fig. 2).

We observed increases over waves in the percentage of children receiving a birth dose of polio vaccine, and in those receiving three or more doses of polio vaccine (full polio vaccination) (Table 2). The proportion of those receiving one dose of measles vaccine increased across all waves (Table 2). The proportion of children who received three doses of the pentavalent vaccine decreased from 57.4 % in 2006 to 50.5 % in 2012, and then increased to 76.1 % in 2017.

Maternal age, maternal education, wealth quintile, and urbanicity's associations with undervaccination did not change significantly across waves (Table 3). Having no maternal education was associated with

Table 1
Demographic distribution of respondents across multiple DHS waves, ages 12–23 months, Pakistan.

	2006–07	2012–13	2017–18
Overall	N = 1541	N = 1706	N = 1549
Age			
15–19	64 (3.6 % ± 0.5 %)	65 (3.2 % ± 0.5 %)	67 (3.2 % ± 0.4 %)
20–24	393 (25.2 % ± 1.2 %)	450 (25.9 % ± 1.3 %)	375 (24.5 % ± 1.4)
25–29	447 (28.5 % ± 1.3 %)	535 (32.4 % ± 1.4 %)	524 (33.5 % ± 1.3 %)
30–34	357 (24.8 % ± 1.4 %)	384 (23.4 % ± 1.3 %)	357 (25.2 % ± 1.4 %)
35–39	199 (12.5 % ± 1.0 %)	182 (10.2 % ± 0.9 %)	177 (10.7 % ± 1.0 %)
40–44	51 (3.6 % ± 0.6 %)	67 (3.7 % ± 0.5 %)	35 (2.0 % ± 0.4 %)
45–49	30 (1.8 % ± 0.4 %)	23 (1.2 % ± 0.3 %)	14 (0.7 % ± 0.3 %)
Maternal education			
No education	994 (62.3 % ± 1.3 %)	950 (54.0 % ± 1.5 %)	771 (44.7 % ± 1.7 %)
Primary	220 (15.2 % ± 1.0 %)	255 (17.4 % ± 1.3 %	207 (15.6 % ± 1.2 %)
Secondary	234 (16.3 % ± 1.0 %)	317 (19.5 % ± 1.2 %)	349 (25.3 % ± 1.4 %)
Higher	93 (6.3 % ± 0.7 %)	184 (9.0 % ± 0.8)	222 (14.3 % ± 1.1 %)
Wealth			
Poorest	327 (20.6 % ± 0.9 %)	365 (21.9 % ± 1.2 %)	314 (19.0 % ± 1.2 %)
Poorer	345 (21.8 % ± 1.2 %)	331 (21.4 % ± 1.2 %)	288 (18.6 % ± 1.2 %)
Middle	306 (19.1 % ± 1.1 %)	342 (19.3 % ± 1.2 %)	345 (24.0 % ± 1.4 %)
Richer	295 (20.2 % ± 1.1 %)	343 (21.2 % ± 1.3 %)	283 (17.7 % ± 1.3 %)
Richest	268 (18.2 % ± 1.0 %)	325 (16.2 % ± 1.2 %)	319 (20.7 % ± 1.5 %)
Province			
Punjab	628 (56.9 % ± 0.5 %)	593 (59.3 % ± 1.0 %)	532 (56.3 % ± 1.7 %)
Sindh	435 (24.5 % ± 0.4 %)	417 (21.3 % ± 0.8 %)	391 (22.6 % ± 1.3 %)
Northwest Frontier Province/Khyber Pakhtunkhwa	317 (14.6 % ± 0.4 %)	422 (15.1 % 0.6 %)	397 (17.0 % ± 1.1 %)
Balochistan	161 (4.0 % ± 0.1 %)	274 (4.3 % ± 0.2 %)	229 (4.1 % ± 0.4 %)
Urbanicity			
Urban	554 (31.8 % ± 0.6 %)	707 (30.9 % ± 0.9 %)	736 (35.0 % ± 1.8 %)
Rural	987 (68.2 % ± 0.6 %)	999 (69.1 % ± 0.9 %)	813 (65.0 % ± 1.8 %)

Table 2
Measures of vaccination status across multiple DHS waves, ages 12–23 months, Pakistan.

	2006–07	2012–13	2017–18
Overall	N = 1541	N = 1706	N = 1549
EPI			
Fully vaccinated	745 (50.6 %)	853 (54.7 %)	972 (68.3 %)
Partially vaccinated	670 (43.4 %)	716 (39.9 %)	484 (28.1 %)
Unvaccinated	126 (6.0 %)	137 (5.4 %)	93 (3.7 %)
Polio			
Birth dose	852 (56.3 %)	1183 (69.6 %)	1254 (83.7 %)
≥3 doses	1328 (88.5 %)	1444 (88.3 %)	1349 (91.1 %)
≥1 inactivated dose	–	–	896 (64.4 %)
Birth dose + 3 doses	746 (48.9 %)	1032 (62.2 %)	1112 (76.0 %)
Measles (among all children 12–23 months)			
0 doses	642 (39.9 %)	713 (38.6 %)	494 (26.0 %)
1 dose	893 (60.1 %)	992 (61.4 %)	1055 (74.0 %)
Measles (among children 15–23 months)			
0 dose	–	–	340 (26.1 %)
1 dose	–	–	237 (19.5 %)
2 doses	–	–	522 (54.4 %)
Pneumococcal			
≥1 dose	–	–	1253 (85.9 %)
3 doses	–	–	1084 (75.4 %)
DTP/Pentavalent			
≥1 dose	1060 (71.1 %)	995 (62.1 %)	1272 (87.0 %)
3 doses	848 (57.4 %)	787 (50.5 %)	1097 (76.1 %)

higher odds of undervaccination in the 2012–13 and 2017–18 waves (2012: OR = 1.67, 95 % CI = 1.11, 2.50; 2017: OR = 1.84, 95 % CI = 1.15, 2.92), compared to having primary education. A similar association was seen with being in the poorest wealth quintile across all waves (2006: OR = 2.58, 95 % CI = 1.76, 3.78; 2012: OR = 2.42, 95 % CI = 1.22, 4.81; 2017: OR = 2.27, 95 % CI = 1.31, 3.94). Living in a rural area compared to an urban area did not appear to be associated with undervaccination (2006: OR = 0.91, 95 % CI = 0.69, 1.21; 2012: OR = 1.14, 95 % CI = 0.79, 1.64; 2017: OR = 0.69, 95 % CI = 0.44, 1.10). Those mothers in the oldest age group (35–49 years) had lower odds of child undervaccination compared to those in the 25–29 years age group (OR = 0.65, 95 % CI = 0.46, 0.93), although this association was not consistent across waves.

Disparities increased over time among provinces; the extent to which province of residence impacts undervaccination changed significantly ($p < 0.0001$) (Table 3). Compared to Punjab, the odds of not being fully vaccinated were higher in Balochistan, and this disparity significantly increased over time (OR 2006: 1.58 (1.00, 2.50), OR 2012: 5.67 (2.74, 11.70), OR 2017: 6.44 (3.80, 10.91)).

In 2017, by province, and in comparison to those in Punjab, the odds of having zero doses of polio vaccine were higher in Sindh (OR = 6.05, 95 % CI = 1.79, 20.46), KPK (OR = 4.70, 95 % CI = 1.13, 19.54), and Balochistan (OR = 26.02, 95 % CI = 6.74, 100.43) (Supplementary Table 1). We did not see significant differences in polio vaccination by wealth index, but there was a significant difference by education. Higher odds of having 1–2 polio vaccine doses compared to those vaccinated with the full series were seen in those with no maternal education (OR = 4.74, 95 % CI: 1.57, 14.33) compared to those with a primary education. Finally, those living in rural areas had lower odds of receiving 1–2 polio vaccine doses compared to those living in urban areas (OR: 0.47, 95 % CI: 0.25, 0.88).

Those with no maternal education also showed higher odds of not having received an inactivated polio dose compared to those with primary education (OR = 1.89, 95 % CI:1.24, 2.90). Those in the poorest wealth quintile also had higher odds of not receiving an inactivated dose of polio vaccine compared to those in the middle wealth quintile (OR = 1.72, 95 % CI: 1.06, 2.79).

Pneumococcal vaccine series completion varied significantly by province. Compared to those living in Punjab, those in Balochistan had 16.56 (95 % CI = 8.46, 32.42) times higher odds of no PCV vaccination (and 5.03 times higher odds of only having 1 dose of PCV vaccine (95 % CI = 1.38, 18.35)) compared to having the full 3-dose series (Supplementary Table 2). Those living in Sindh (OR = 3.88, 95 % CI = 1.92, 7.85) and KPK (OR = 4.13, 95 % CI = 2.04, 8.38) also had higher odds of no PCV vaccination compared to having the full series. Those with

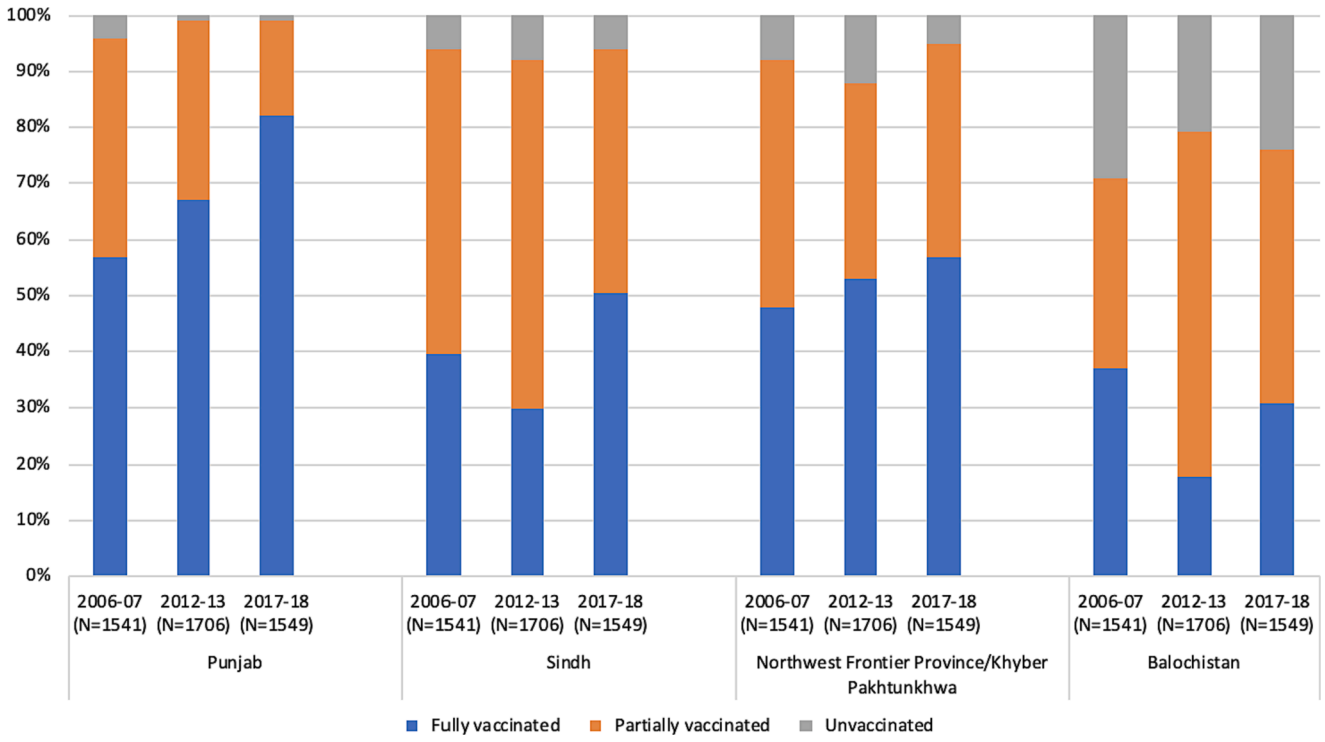

Fig. 1. Proportions of fully vaccinated, partially vaccinated, and unvaccinated children across all waves, by province of residence.

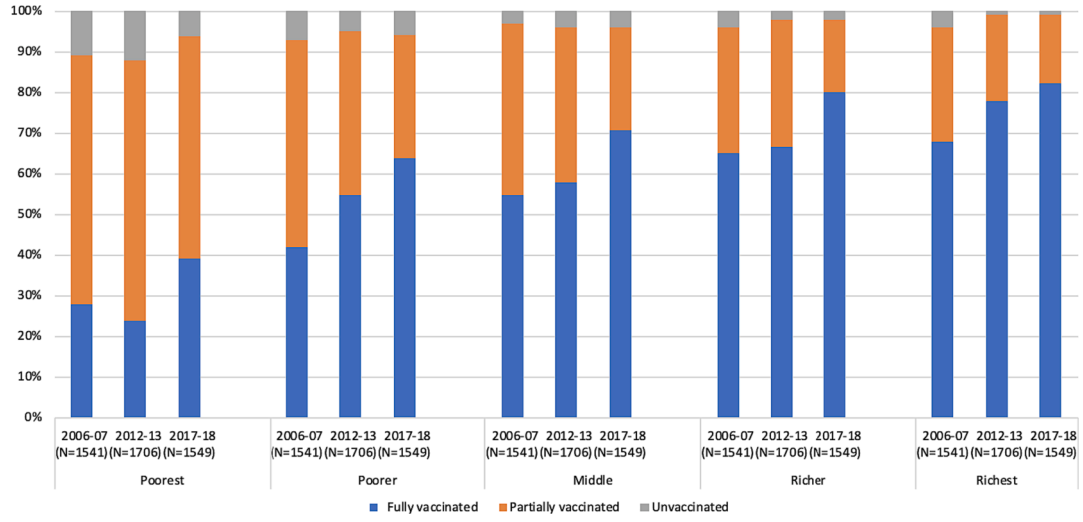

Fig. 2. Proportions of fully vaccinated, partially vaccinated, and unvaccinated children across all waves, by wealth quintile.

higher maternal education were observed to have lower odds of having zero pneumococcal vaccine doses compared to those with secondary education (OR: 0.05, 95 % CI = 0.01, 0.14) (Supplementary Table 2).

4. Discussion

Over the three DHS waves included in this study, childhood full vaccination increased substantially in Pakistan, which may relate to a number of government-sponsored programs, such as the EPI and related outreach programs, and the Pakistan Polio Eradication Programme, that have been enacted over this time to promote vaccine uptake in children [24,25]. Additionally, the proportion of zero-dose children decreased from 6.0 % to 3.7 % during these three DHS waves.

However, despite overall improvement, there is still a notable proportion of children who are either under- or non-vaccinated. In 2017, the most recent wave included in this study, we found that almost one third of the population studied were not fully vaccinated, and Pakistan remains among the top 10 countries with the most zero-dose children globally in 2020 [26]. Consistent with prior research, there were persistent disparities in childhood vaccination by sociodemographic factors, including maternal age and education [27,28]. These disparities can interact with larger structural reasons for not receiving a vaccine, including lack of access, awareness, and affordability [29].

We found substantial disparities in childhood vaccination by province and wealth. We observed this association for complete immunization, as well as for polio and pneumococcal vaccination specifically. A study done in Sindh in 2020 found that low vaccination rates in the province had more to do with limited access to and awareness of

Table 3
Odds of undervaccination across multiple DHS waves, ages 12–23 months, Pakistan.

	2006–07 (N = 1541)	2012–13 (N = 1706)	2017–18 (N = 1549)	
	OR (95 % CI)	OR (95 % CI)	OR (95 % CI)	P-value of interaction term between attribute and year
Maternal age (years)				0.3008
15–24	1.01 (0.72, 1.40)	1.08 (0.75, 1.55)	0.77 (0.54, 1.12)	
25–29	ref	ref	ref	
30–34	0.82 (0.61, 1.11)	1.06 (0.73, 1.54)	1.05 (0.69, 1.59)	
35–49	0.65 (0.46, 0.93)	1.01 (0.62, 1.64)	0.85 (0.54, 1.35)	
Maternal education				0.7886
No education	1.32 (0.95, 1.85)	1.67 (1.11, 2.50)	1.84 (1.15, 2.92)	
Primary	ref	ref	ref	
Secondary	0.53 (0.36, 0.79)	0.66 (0.40, 1.09)	0.77 (0.45, 1.32)	
Higher	0.40 (0.22, 0.72)	0.68 (0.40, 1.14)	0.52 (0.25, 1.08)	
Wealth				0.2168
Poorest	2.58 (1.76, 3.78)	2.42 (1.22, 4.81)	2.27 (1.31, 3.94)	
Poorer	1.54 (1.05, 2.24)	0.90 (0.57, 1.42)	1.09 (0.71, 1.66)	
Middle	ref	ref	ref	
Richer	0.76 (0.53, 1.10)	0.89 (0.58, 1.42)	0.67 (0.41, 1.07)	
Richest	0.89 (0.58, 1.36)	0.48 (0.26, 0.91)	0.81 (0.50, 1.32)	
Province				<0.0001
Punjab	ref	ref	ref	
Sindh	1.74 (1.30, 2.31)	4.51 (3.13, 6.50)	2.88 (1.86, 4.47)	
Northwest Frontier Province/ Khyber Pakhtunkhwa	1.16 (0.84, 1.59)	1.50 (1.01, 2.22)	2.87 (1.72, 4.79)	
Balochistan	1.58 (1.00, 2.50)	5.67 (2.74, 11.70)	6.44 (3.80, 10.91)	
Urbanicity				0.2562
Urban	ref	ref	ref	
Rural	0.91 (0.69, 1.21)	1.14 (0.79, 1.64)	0.69 (0.44, 1.10)	

services, rather than a lack of knowledge or refusal [30]. Additionally, routine immunization services were often preempted by polio specific vaccine campaigns given the intense focus on polio eradication [30]. Another study in Sindh done in 2017 found inadequate infrastructure at immunization centers, which also may contribute to low vaccination rates and disparities between poorer or more rural provinces – an especially important consideration, as in 2021, 63 % of Pakistan's population lived in rural areas [31,32]. Similar to the findings of this study, Imran et al. documented substantially lower vaccination coverage in Balochistan compared to Punjab. They recommended strategies are needed to target vaccination programs towards poorer families with lower educational attainment [33]. Such strategies could include deploying teams of female community health workers to areas of low vaccination coverage to provide immunization counseling, administer vaccines, and record data [34]. Mobile vaccine clinics have also been used in a variety of settings, including Afghanistan, Haiti, and Palestine, to more easily provide access to vaccines [35].

While clearly a complex and nuanced issue, the disruption caused in country violence and militancy, only exacerbated by the United States' interference, is likely associated with interruption of vaccination and related health campaigns. One study looking at the impacts of terrorist events in Pakistan, published in 2019, found a reduction in vaccination up-take if a violent event occurred immediately before birth [36]. Additionally, the northern areas of Pakistan, including the Federally Administered Tribal Areas (FATA) and Khyber Pakhtunkhwa, experienced more violence than other areas; these regions also reported a majority of the polio cases in Pakistan [37]. Following an increase in armed militancy, polio cases rose from 2007 to 2011, propaganda against vaccination was carried out by militants, and anti-west sentiment increased [37].

At the same time, the United States carried out counterinsurgency operations, including drone strikes, and a fake vaccination campaign which was actually attempting to locate Osama bin Laden, only increasing militants' suspicions regarding vaccination campaigns [38]. This increase in tension led to polio vaccination healthcare workers being killed by Pakistani militants, as they were thought to be spies for the United States [39]. Additionally, one study published in 2017 showed that the number of drone strikes and drone strike fatalities closely resembled the trends in the number of polio cases in Pakistan between 2003 and 2015, demonstrating that not only violence within Pakistan, but violence perpetrated by the United States negatively impacted the region's attempts to eradicate polio [38].

5. Strengths and limitations

This study was strengthened by its use of multiple waves of data to examine changes in vaccination over time, as well as the use of the nationally representative Demographic and Health Survey data. Additionally, questions used from the surveys were asked similarly across waves, which improved comparability. However, we were not able to include all regions from all waves due to safety concerns during data collection. Information on a child's vaccination status was also collected using self-reported information from mothers, as well as vaccine card information, increasing the possibility of recall bias. Finally, as these were cross-sectional surveys, we are unable to understand the temporal relationships between associated factors and outcomes investigated. We also acknowledge that other factors, like religion, ethnicity, and migration status, could impact vaccination status but these were not consistently collected in the DHS datasets.

6. Conclusions

In this study using three waves of DHS data from Pakistan, we found that childhood vaccination has increased in general. We also observed differences in vaccination status related to various demographic factors, such as maternal education, wealth, and province of residence. Going forward, it will be important to address the disparities in vaccination. Interventions are needed, and must be tailored to the needs of different populations and areas of Pakistan, while keeping in mind the possibility of disruption in efforts due to violence. Additionally, educational interventions may be more effective in rural or poor areas, rather than only interventions focused on improving health services and access to health services [40,41].

Competing interests

All authors declare that they have no conflicts of interest. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data is publicly available and can be downloaded on the Demographic and Health Survey website.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.vaccine.2024.01.014.

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