HUMAN VACCINES & IMMUNOTHERAPEUTICS
2020, VOL. 16, NO. 2, 363–370
https://doi.org/10.1080/21645515.2019.1649553

RESEARCH PAPER

Determinants of childhood immunizations in Senegal: Adding previous shots to sociodemographic background

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ABSTRACT

Introduction. Today, in Sub-Saharan Africa, vaccine-preventable diseases still contribute heavily to high child mortality. Maintaining high coverage rates for childhood vaccines and reducing related social inequalities are public health priorities in Senegal. Our aim was to investigate the determinants of childhood vaccination, including sociodemographic factors and previous vaccine-related decision-making.

Methods. Data come from the 2016 Senegalese Demographic and Health Survey, a nationally representative household survey targeting women aged 15–49, with a questionnaire focusing on health and reproductive issues, including their children's health. We restricted the analysis to children aged 12–23 months (n = 1,143). We used bivariate and multivariate analyses for investigating the determinants of several childhood vaccinations (Bacillus Calmette-Guérin, pentavalent, polio, measles and yellow fever vaccines), including sociodemographic factors and previous shots.

Results. We identified two main sociodemographic predictors of childhood vaccination in Senegal: the mother's education level, which was strongly and positively correlated to every vaccination considered, except from the BCG vaccination, and the region of residence, with higher vaccination coverage rates in the Centre and West of Senegal. Moreover, previous shots were also strongly predictive of subsequent shots.

Conclusion. The positive impact of mother's education on child vaccination illustrates the wide-ranging benefits of educating girls, while the regional variability of immunization rates requires more research to be better understood. Previous shots are probably a proxy variable for unobservable factors strongly correlated to vaccinations, but beyond this 'proxy effect', they may also have their own specific effect on following shots. We believe this topic deserves further research.

ARTICLE HISTORY
Received 7 May 2019
Revised 5 July 2019
Accepted 22 July 2019

KEYWORDS
Childhood vaccination; coverage; immunization; socioeconomic; Senegal

Introduction

Today, the highest rates of child mortality worldwide are still observed in Sub-Saharan Africa (74 per 1000 live births) and vaccine-preventable diseases contribute heavily to high child mortality.[1] In Senegal, the infant mortality rate is still high with 51 per 1000 live births in 2016 (CI: 43–58) but it has been divided by three since 1990.[2] Thanks to the Expanded Program of Immunization (EPI) launched in 1979, vaccines are routinely provided free of charge in public health facilities, as well as during specific mass immunization campaigns. Despite such efforts, Senegal is nevertheless struggling to maintain high coverage rates for childhood vaccines, and recurrent measles and rotavirus diarrhea outbreaks still occur among infants.[3–5] In addition to maintaining high coverage rates, another priority goal is reducing social inequalities in childhood vaccination uptake, as Senegalese authorities endorsed the Global Vaccine Action Plan (GVAP), which aims at '*extending by 2020 and beyond the full benefits of immunization to all people, regardless of where they are born, who they are, or where they live*'.[6]

In order to assess accurately childhood vaccination rates, the Senegalese National Agency of *Statistics and* Demography (ANSD) carries out regularly nationally representative household surveys. Regarding GVAP goal, these surveys also provide the opportunity to investigate the sociodemographic factors correlated to childhood vaccinations. In the present article, we conducted a secondary analysis of the 2016 Demographic and Health Survey (DHS).[7] The question addressed was about the relative impact of sociodemographic factors and of previous vaccine-related decision-making on immunization coverage.

In addition to specific effects of shots previously received on subsequent vaccine-related decision-making, previous shots may also be a proxy for unobservable variables relating to either supply-side or demand-side effects. While people are supposed to endorse vaccine-specific behaviors,[8,9] these behaviors could depend, at least in part on non-specific factors such that proximity/availability of immunization services (supply-side effect) or trust towards health authorities (demand-side effect). As a result, addressing the issue of relative impact of sociodemographic factors and previous

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vaccine-related decision-making on immunization coverage also require accounting for the positive association between vaccination history and current vaccination, as it has been for example shown between previous childhood vaccinations and parental acceptance of the Human Papillomavirus (HPV) vaccination.[10–12] More specifically, we focused on children aged between 12 and 23 months, and we investigated factors associated with routine immunization uptake, from Bacillus Calmette-Guérin (BCG) vaccine, administered soon after birth, to yellow fever and measles vaccines, administered at 9 months.

Methods

The DHS program

Our data are drawn from the DHS carried out in Senegal in 2016.[7] and downloaded from the DHS program website (dhsprogram.com). The DHS program was established by the United States Agency for International Development (USAID) in 1984. Since 1984, more than 130 nationally representative household-based surveys have been completed under the DHS project in about 70 countries. These surveys are designed to collect data on marriage, fertility, family planning, reproductive health, child health, and HIV/AIDS. Due to their subject matter, they focus on men and women of reproductive age (15–49), with distinct questionnaires for individuals and households. The main purpose of the household questionnaire is to identify children under five.[13]

Data collection

The study carried out in Senegal in 2016 was a nationally representative household survey with a two-stage stratified cluster sampling design. In the first stage, the primary sampling units (PSUs), which are the census districts, were selected with probability proportional to the PSU population size. At the second stage, households were selected and enumerated within each area segment. The sample was stratified by urban and rural areas. Data collection started on March 2016 and ended on November 2016. Overall, 4,500 occupied households were selected with a response rate of 98.6% (n = 4,437). Among the households interviewed, 9,244 women aged 15–49 were eligible for the individual survey with a response rate of 95.9% (n = 8,865).

Study population

Among all women interviewed in the 2016 DHS sample in Senegal, a set of questions examine immunization coverage of their young children (aged under 5, n = 6,417). The present study focuses on the following vaccines: the BCG vaccine (which is recommended at birth), the pentavalent vaccine (for diphtheria, tetanus, pertussis, haemophilus influenza b and hepatitis b, three doses recommended at 6, 10 and 14 weeks), the polio vaccine (oral vaccine, three doses recommended at 6, 10 and 14 weeks), the measles vaccine and the yellow fever vaccine (both recommended at 9 months).

As in previous studies devoted to childhood vaccination in various Sub-Saharan African countries,[14–17] we restricted the analysis to children aged between 12 and 23 months at the time of the survey (weighted sample size, n = 1,143), and we relied on two sources to collect information on children's vaccination status: either the vaccination card shown by mothers to interviewers (n = 853) or mothers' recall of vaccination if the card is missing (n = 290). Such restriction was expected to minimize the proportion of missing cards (which is higher for older children), to limit memory bias regarding mothers' recall, and to ensure that recommendations from the EPI (which change over time, as new vaccines are regularly introduced[14]) were the same for all these children.

Measurement of variables

Regarding children's immunization status, we built five binary outcomes, coded 0 or 1 (1 for those who received the single shot for BCG, measles and yellow fever vaccines; 1 for those who completed the three shots for pentavalent and polio vaccines).

Based on existing literature,[14–17] we considered the following associated factors: child's characteristics (sex, birth order: 1,2–3,>3); mother's characteristics (age at child birth: 14–19;20–30;>30 years old, education level: no education, primary, secondary or higher education); household's characteristics (education level of household head, region of residence: North, West, Center, South (see[7] for more details), area of residence: rural or urban, and wealth index). The household wealth index is a composite measure of a household's cumulative living standard. It is calculated with a principal component analysis using easy-to-collect data on a household's ownership of selected assets, such as televisions and bicycles; materials used for housing construction; and types of water access and sanitation facilities. We used the quintiles computed from this continuous score. The full methodology of construction of the index is available on the DHS program website.[18]

Statistical analysis

In the DHS survey, the sample is selected with unequal probability to expand the number of cases available for certain areas or subgroups for which statistics are needed. Thus, sampling weights were applied to all statistics to produce the proper representation as well as corrections for differential response rates for certain areas or subgroups.

For bivariate analysis, we used weighted unadjusted logistic regressions to identify factors associated with the five binary outcomes separately. Regarding the relationships between subsequent vaccines, we also computed immunization coverage rates according to previous vaccinations.

Then we performed multivariate analyses using stepwise weighted logistic regression models. Missing values were imputed with the category with the highest frequency. Except for the BCG vaccine, two separate models were carried out in order to explicitly account for the potential effects of sociodemographic characteristics on previous vaccine-related decision-making. In Model A, all covariates listed in the previous section (child's, mother's and household's characteristics) were included in the stepwise selection process. In Model B, we added to this list one covariate counting previous vaccinations: when modelling pentavalent and polio vaccinations (shots recommended between 6 and 14 weeks), we added the binary outcome corresponding to BCG vaccination (recommended at birth); and when modelling vaccinations against measles and yellow fever (recommended at 9 months) we added a discrete variable summing the three binary outcomes corresponding respectively to BCG, pentavalent and polio vaccinations. Thus Models B allowed us to identify factors associated with each vaccination while adjusting on past immunizations. Using an indicator measuring previous shots as a covariate in a multivariate analysis modelling a subsequent vaccination acted as a proxy for unobservable effects relating to either supply-side or demand-side effects.

For the stepwise selection process, both values of significance level for entry and stay were set at 0.05. The goodness of fit of each model was tested using the Hosmer-Lemeshow test.[19] All analyses were based on two-sided *p*-values, with statistical significance defined by $p \leq 0.05$. They were performed with SAS 9.4 statistical software (SAS Institute, Cary, NC). Due to the two-stage stratified cluster sampling design of the survey, we used the SAS survey procedures (SURVEYFREQ, SURVEYLOGISTIC) for correct estimation of standard errors of the population parameters.

Results

Vaccination coverage rates and bivariate analyses

The study population included 1,323 children aged between 12 and 23 months at the time of the survey (weighted sample size: n = 1,143). Table 1 shows the vaccination coverage rates and the bivariate analyses of the factors associated with each vaccination. Overall, immunization coverage rates ranged from 80.6% (for the measles vaccine) to 94.1% (for the BCG vaccine). Regarding children's characteristics, sex was rarely correlated with vaccination, and birth order tended to be negatively correlated to some vaccinations. Regarding mothers' characteristics, immunization coverage rates were lower for the youngest ones (aged 14–19 at child birth), and these rates were significantly higher for the more educated ones.

Regarding households' characteristics, we found a similar relationship between vaccinations and household head's educational level. The five studied vaccinations were also positively correlated to the household wealth quintile:

Table 1. Characteristics and immunization coverage of children aged 12–23 months (Senegal DHS 2016 – n = 1,143).

			Immunization coverage (%)				
	n	%	BCG	Pentavalent†	Polio†	Measles	Yellow fever
All	1,143	100	94.1	89.8	81.4	80.6	82.0
Sex of the child							
Male (ref.)	578	50.6	94.4	89.2	80.3	82.4	83.9
Female	565	49.4	93.7	90.4	82.6	78.7*	80.1*
Birth order							
1 (ref.)	296	25.9	94.4	92.1	85.3	80.9	83.9
2–3	371	32.5	96.9*	91.5	82.7	84.8	85.6
4+	476	41.6	91.6	87.1**	78.0***	77.1	78.1**
Mother's age							
14–19	160	14.0	90.3*	86.8	75.3*	72.6***	74.9***
20–30 (ref.)	590	51.6	94.2	89.1	81.6	82.2	83.3
>30	393	34.4	95.4	92.2*	83.7	81.3	82.9
Mother's education level							
No education (ref.)	744	65.1	92.0	85.9	76.7	75.2	76.7
Primary	244	21.3	97.4***	96.7***	89.9***	87.2***	88.5***
Secondary or higher	155	13.6	98.6***	98.2***	90.8***	96.1***	97.3***
Household head's education level							
No education (ref.)	865	75.7	92.6	87.7	79.6	78.4	80.1
Primary	146	12.8	99.0***	96.0***	88.9***	85.3**	85.8*
Secondary or higher	91	8.0	99.0**	97.7***	84.2	87.3**	87.8*
Missing	41	3.6	97.6	95.1	87.3	95.1**	95.1**
Household wealth quintile							
Poorest	302	26.4	87.3***	79.8***	72.8**	72.0***	72.6***
Poorer	287	25.1	93.3*	88.4**	82.2	78.9*	80.5**
Middle (ref.)	199	17.4	96.7	94.4	81.6	84.5	87.2
Richer	166	14.5	98.5	94.0	84.0	83.7	84.0
Richest	189	16.5	99.4*	99.6***	91.7***	89.9*	92.3*
Place of residence							
Urban (ref.)	368	32.2	97.5	94.1	86.1	85.1	86.2
Rural	774	67.8	92.4***	87.8***	79.2***	78.4***	80.0***
Region							
North (ref.)	228	19.9	90.1	82.7	78.1	69.7	72.4
West	323	28.3	99.0***	96.8***	87.0***	90.6***	90.8***
Center	383	33.6	97.0***	94.2***	84.7**	84.3***	87.1***
South	208	18.2	85.3*	78.8	70.2**	69.9	69.4

Ref.: reference category for categorical covariates.
†: three doses completed.
*: $p < 0.1$; **$p < 0.05$; ***$p < 0.01$ – weighted logistic univariate regression.

vaccination coverage rates ranged from 72.0% (for the measles vaccine) to 87.3% (for the BCG vaccine) among the first quintile corresponding to the poorest households, versus 89.9% (for the measles vaccine) to 99.6% (for the pentavalent vaccine) among the fifth quintile corresponding to the richest households. Finally, these rates were also significantly lower in rural areas than in urban areas, as well as in the North and South of Senegal when compared to the West and Center.

Immunization coverage and previous shots

Table 2 displays immunization coverage rates according to previous shots: children who had received the BCG vaccine were much more likely to have received subsequent vaccines (from 83.8% for the measles vaccine to 93.5% for the three doses of the pentavalent vaccine, versus respectively 29.7% and 32.7% among those who had not received the BCG vaccine). Similarly, children who had received the three doses of the pentavalent or the polio vaccines were much more likely to have been vaccinated against the measles or the yellow fever.

Factors associated with vaccinations, multivariate analyses

In multivariate analysis, three characteristics were significantly associated with increased odds of reporting BCG vaccination (see Table 3). Children who had at least three older siblings were less likely to have been vaccinated (OR = 0.24), as well as those whose mother was aged 14–19 at their birth (OR = 0.37). The BCG vaccination was also much more frequent for children living in the West (OR = 8.74) or the Center (OR = 3.88) of Senegal (OR = 8.74 and 3.88 respectively, versus 1 for the North (reference category) and 0.68 for the South). After adjustment on those three variables, no other covariate was significantly correlated to BCG vaccination.

Regarding the pentavalent vaccine, in Model A we found three significant factors: having received the three shots of this vaccine was positively correlated to mother's education level and household wealth, and it was also more frequent for children living in the West and Centre of Senegal. After introduction of BCG vaccination as a covariate, the effects of mother's education level and region of residence remained significant, the effect of household wealth became non-significant, while BCG vaccination had a very strong impact on pentavalent vaccination (OR = 18.75). Finally, regarding the polio vaccine, in both models completed vaccination was positively associated with mother's education level, while the effect of the region of residence vanished after introduction of BCG vaccination in Model B, which had again a very strong impact (OR = 10.05). One should also note that the sex of the child, the household head's education level and the area of residence (rural vs urban) were never selected as significant factors for the considered vaccinations.

Regarding vaccination against measles, only two factors remained significant predictors in the multivariate analysis: mother's educational level and region of residence (see Table 4). Children whose mother has reached secondary or higher education were much more likely to have received this vaccine (versus no education: OR = 7.08), as well as those living in the North or Centre of Senegal. In Model B, only the effect of mothers' education level remained statistically significant, and previous shots were strongly predictive of vaccination against measles: having completed one vaccine (either the BCG, the pentavalent or the polio vaccine) increased by 4.34 the odds of being vaccinated against measles.

Regarding vaccination against the yellow fever, Model A provided very similar results, with mother's education level and region of residence being the only significant predictors selected in the model. In Model B, these effects remained significant, and the number of previous vaccinations was a strong predictor of yellow fever vaccination (OR = 4.90). Moreover, after adjustment on this covariate, another effect became significant (as girls appeared to be less likely to be vaccinated than boys, OR = 0.61). Finally, several covariates were never selected as significant predictors of vaccination against either measles or the yellow fever: birth order, mother's age at birth, household head's education level and wealth, and place of residence.

Discussion

Main results

Multivariate analyses identified two main sociodemographic predictors of childhood vaccination in Senegal, namely mother's education level and region of residence. First, the mother's education level was strongly and positively correlated to every vaccination considered, except for the BCG

Table 2. Immunization coverage of children aged 12–23 months according to previous vaccinations (Senegal DHS 2016 – n = 1,143).

		Immunization coverage according to previous vaccinations (%)			
Previous vaccinations		Pentavalent†	Polio†	Measles	Yellow fever
BCG	No (ref.)	32.7	32.2	29.7	27.1
	Yes	93.5***	84.5***	83.8***	85.5***
Pentavalent†	No (ref.)			13.2	12.7
	Yes			88.2***	89.9***
Polio†	No (ref.)			46.6	46.3
	Yes			88.3***	90.1***

†: three does completed.
*: $p < 0.1$; **p < 0.05; ***p < 0.01 – weighted logistic univariate regression.
Reading example: among children who have received the BCG vaccine, 93.5% did receive the three doses of the pentavalent vaccine, versus 32.7% among those who did not ($p < 0.01$).

Table 3. Factors associated with immunization (BCG, Pentavalent and polio vaccines) of children aged 12–23 months – Multivariate weighted logistic regressions (Senegal DHS 2016 – n = 1,143).

	BCG vaccine	Pentavalent vaccine†		Polio vaccine†	
	OR 95% CI††	OR 95% CI†† Model A	OR 95% CI†† Model B	OR 95% CI†† Model A	OR 95% CI†† Model B
Sex of the child					
Male (ref.)	NS	NS	NS	NS	NS
Female					
Birth order					
1 (ref.)	1	NS	NS	NS	NS
2–3	1.21[0.57;2.56]				
4+	0.24[0.10;0.56]				
Mother's age					
14–19	0.37[0.17;0.81]	NS	NS	NS	NS
20–30 (ref.)	1				
>30	2.50[1.15;5.41]				
Mother's education level					
No education (ref.)	NS	1	1	1	1
Primary		3.04[1.56;5.89]	3.60[1.80;7.20]	2.60[1.43;4.72]	2.41[1.32;4.40]
Secondary or higher		4.43[1.50;13.07]	6.26[2.21;17.76]	2.86[1.30;6.27]	2.51[1.12;5.61]
Household head's education level					
No education (ref.)	NS	NS	NS	NS	NS
Primary					
Secondary or higher					
Missing					
Household wealth quintile					
Poorest	NS	0.42[0.18;1.01]	NS	NS	NS
Poorer		0.63[0.28;1.42]			
Middle (ref.)		1			
Richer		0.82[0.22;3.07]			
Richest		9.07[0.99;82.69]			
Place of residence					
Urban (ref.)	NS	NS	NS	NS	NS
Rural					
Region					
North (ref.)	1	1	1	1	NS
West	8.74[1.12;68.39]	2.32[0.76;7.07]	3.07[0.84;11.24]	1.39[0.65;2.96]	
Center	3.88[1.76;8.57]	3.26[1.40;7.58]	2.61[1.03;6.57]	1.51[0.76;3.02]	
South	0.68[0.33;1.40]	0.84[0.36;1.93]	0.83[0.38;1.80]	0.61[0.30;1.22]	
BCG vaccine at birth					
No (ref.)	___	___	1	___	1
Yes			18.75[9.09;38.67]		10.05[5.89;17.13]

†: three doses completed.
††: Adjusted odds ratios and 95% confidence intervals.
Ref.: reference category for categorical covariates.
NS: non statistically significant ($p > 0.05$) after stepwise selection.

vaccination. Secondly, for every vaccine considered we found a strong contrast between the Centre and West of Senegal (with higher vaccination coverage rates) *versus* the North and South (with lower rates). Once controlled for these effects, most of the other potential determinants of vaccination became statistically no-significant, including factors related to the household's socioeconomic level (household head's education level and wealth index), or living in a rural *versus* urban area. Moreover, immunizations rates greatly varied depending on previous shots, which were also strongly predictive of subsequent shots in multivariate analyses (the BCG vaccination for pentavalent and polio vaccinations; BCG, pentavalent and polio vaccinations for vaccinations against the measles and the yellow fever).

Sociodemographic determinants of childhood vaccination

In our multivariate analyses, two sociodemographic factors were never selected as significant factors, namely the household head's education level and the place of residence (rural *versus* urban), while household's wealth was only correlated to pentavalent vaccination (this effect becoming non-significant after adjustment on previous vaccinations). This is an important result regarding social inequalities in childhood vaccination uptake, and it is consistent with results from the 2011 DHS in Senegal and strongly contrasts with some other African countries, including Ethiopia, Zimbabwe, Uganda and Ghana.[17,20–22] Some others were hardly ever statistically significant, and their significant effects were generally consistent with previous studies: The BCG vaccination was negatively correlated to the number of children in the household (as for completion of child vaccinations in Ethiopia,[23] Zimbabwe[20] and Nigeria[16]) and positively correlated with mother's age (as for completion of child vaccinations in Uganda[24] and in deprived urban areas in Kenya,[15] but the correlation was negative in Nigeria[16]); while girls were less likely than boys to be vaccinated against yellow fever (as for completion of child vaccinations in Ethiopia[23] and in a Senegalese rural area[25]).

On the contrary, two sociodemographic characteristics were strongly significant determinants for almost every vaccination considered here. On the demand side of vaccination, mother's education level was positively correlated to every vaccination, except for the BCG vaccine, with estimated odds ratios ranging from to 2.51 to 9.71 (when comparing mothers with secondary or higher education to non-educated

Table 4. Factors associated with immunization (measles, yellow fever) of children aged 12–23 months – Multivariate weighted logistic regression (Senegal DHS 2016 – n = 1,143).

	Measles vaccine		Yellow fever vaccine	
	OR 95% CI† Model A‡	OR 95% CI† Model B‡	OR 95% CI† Model A‡	OR 95% CI† Model B‡
Sex of the child				
Male (ref.)	NS	NS	NS	1
Female				0.61[0.38;0.98]
Birth order				
1 (ref.)	1	NS	NS	NS
2–3				
4+				
Mother's age at birth				
14–19	NS	NS	NS	NS
20–30 (ref.)				
>30				
Mother's education level				
No education (ref.)	1	1	1	1
Primary	1.86[0.93;3.72]	1.42[0.62;3.23]	2.02[0.96;4.22]	1.28[0.55;2.99]
Secondary or higher	7.08[3.08;16.27]	5.55[2.48;12.45]	9.71[4.05;23.30]	6.74[2.78;16.36]
Household head's education level				
No education (ref.)	NS	NS	NS	NS
Primary				
Secondary or higher				
Missing				
Household wealth quintile				
Poorest	NS	NS	NS	NS
Poorer				
Middle (ref.)				
Richer				
Richest				
Place of residence				
Urban (ref.)	NS	NS	NS	NS
Rural				
Region				
North (ref.)	1	NS	1	1
West	3.20[1.38;7.44]		2.77[1.15;6.64]	2.17[0.92;5.10]
Center	2.34[1.30;4.20]		2.58[1.37;4.85]	2.04[1.18;3.53]
South	0.95[0.53;1.69]		0.80[0.43;1.48]	1.15[0.68;1.96]
Number of previous vaccinations††		4.34[3.49;5.41]		4.90[3.93;6.11]

†: Adjusted odds ratios and 95% confidence intervals.
††: from 0 to 3: BCG, Pentavalent, Polio.
Ref.: reference category for categorical covariates.
NS: non statistically significant ($p > 0.05$) after stepwise selection.

mothers). The impact of mother's education on child vaccination has been already found in a number of studies conducted in Sub-Saharan Africa.[14–16,23,24] Our results highlight the magnitude of such impact, and differentiate it for different vaccines. They also illustrate the long-term and wide-ranging benefits brought by educating girls, especially in developing countries.[26]

The region of residence was another strong determinant of childhood vaccination, as corresponding effects were always significant, except for polio and measles vaccinations after adjustment on previous shots, with a consistent pattern opposing the West and Center of Senegal (where vaccination coverage rates are higher) to the North and South (with lower rates). The region of residence is generally considered a supply-side determinant of vaccination, as both the quantity and the quality of health care and immunization services may greatly vary from one region to another, but variations in immunization rates across regions may also reflect demand-side determinants, such as different attitudes toward vaccination due to cultural specificities.[14] From a supply-side perspective, access to immunization services is usually more difficult in rural areas, thus the effects measured for the region of residence may mediate the urban/rural opposition. Our results support only partially this interpretation. Indeed, the North and South of Senegal are 'rural' regions (in the DHS sample, the proportion of participants living in a rural area reached 81% in the North and 78% in the South), while the West is an 'urban' one (only 31% living in a rural area), but in the Center (where immunization rates were higher than in the North and South) the proportion of rural residents reached 85%.

Previous shots and childhood vaccination

Table 2 showed the strong statistical relationship between subsequent vaccinations, and multivariate analyses confirmed that previous shots had a very strong impact (BCG vaccination for pentavalent and polio vaccinations; BCG, pentavalent and polio vaccinations for measles and yellow fever vaccinations). To a certain extent, founding that a previous shot predicts a following one may seem tautological. Nevertheless, subsequent vaccinations are not necessarily positively correlated, especially with regards to contemporary vaccine hesitancy, which affects every continent including Africa.[27,28] Indeed, one important aspect of vaccine hesitancy is that people tend to endorse vaccine-specific attitudes and behaviors, accepting some vaccines and delaying or declining others.[8,9]

As stated in Introduction, the strong statistical relationship between subsequent shots is probably explained in part by factors which are not adequately measured in the DHS but are heavily correlated to any child vaccination. For example, proximity to health facilities is likely to be strongly correlated to any childhood vaccination. Thus, when a previous vaccination is introduced as a covariate for modelling a subsequent one, its estimated effect reflects mechanically the strong correlation of both vaccinations with this proximity. Nevertheless, and beyond such 'proxy effect', previous shots were shown to have their own specific effect on following shots. For example, a previous shot may have been the occasion for parents to build a trustful relationship with vaccinators, therefore increasing the odds for the following vaccination. Moreover, from a human capital perspective,[29] vaccinating a child can be considered an investment, it increases the child's value, therefore providing an incentive for further vaccination. Finally, as the making of decisions is costly, people may be prone to 'inertia', choosing the same option as before instead of engaging again in a decision process.[30] More generally, childhood vaccination can be considered a sequence of repeated decisions, and past decisions and their consequences can influence subsequent choices in various ways that remain to be investigated.

Limitations of the study

First, we relied on two sources to collect information on children's vaccination status: either the vaccination card shown by mothers to interviewers (n = 853) or mothers' recall of vaccination if the card is missing (n = 290). In the latter case, data collected can be subject to either recall bias or social desirability bias. Nevertheless, according to previous studies conducted in similar contexts, maternal recall is almost similar compared to data collected from the vaccination card.[31,32] Secondly, there was also a potential bias due to child mortality: vaccine preventable diseases contribute heavily to it, and the DHS does not collect data on deceased children. Thirdly, sociodemographic factors were measured at the time of the survey, not at the time of each vaccination considered, so statistical relationships should be interpreted cautiously (for example, a child living in an urban area at the time of the survey may have been living in a rural area when getting the BCG vaccine).

Conclusion

Using the 2016 DHS, we investigated sociodemographic factors associated to childhood vaccinations in Senegal (for five vaccines: the BCG, polio, pentavalent, measles and yellow fever vaccines), among children aged 12–23 months. We identified only two major sociodemographic determinants of childhood vaccinations: mother's education level and region of residence. The positive impact of mother's education on child vaccination illustrates the wide-ranging benefits of educating girls, while the regional variability of immunization rates, which only partially reflects the opposition between urban and rural areas, requires more research to be better understood. We also found that previous shots were strong determinants of subsequent ones. Previous shots are probably a proxy variable for unobservable factors strongly correlated to vaccinations. Nevertheless, beyond this 'proxy effect', they may also have their own specific effect on following shots, especially if one considers childhood vaccination as a sequence of repeated decisions. We believe this topic deserves further research that should involve collecting more information regarding supply-side determinants of vaccination and endorse a diachronic perspective.

Acknowledgments

This study was made possible thanks to the DHS Program-Senegal

Disclosure of potential conflicts of interest

No potential conflicts of interest were disclosed.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors; participating in the study involved no financial retribution to any of the authors. This publication reflects the author's views and not the UNICEF.

Ethics approval

Ethical approval for the DHS survey in Senegal was granted by the Ethics Committee of the National Statistical Office of Senegal.

The 2016 DHS data are available to the general public by request from the Measure DHS website [http://www.dhsprogram.com]. We submitted a request to the DHS program by describing the purpose and objectives of the study and thereafter received permission to download the dataset.

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