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Research Article

Modeling the Factors Associated with Incomplete Immunization among Children

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Immunization is a precautionary measure that helps to stop diseases before their occurrence. Vaccine-preventable diseases are a primary cause of death among children under the age of five in many developing nations. The purpose of this study is to investigate the immunization status and associated demographic characteristics among children aged 12–23 months in Punjab, Pakistan. The study used the data from the Multiple Indicator Cluster Survey (MICS) for Punjab, Pakistan. Data were collected from caregivers using interviewer-administered questionnaires. To summarize the data, descriptive statistics are computed, and logistic regression is used to identify the significant factors that are responsible for complete immunization among the children in Punjab. Odds ratios, 95% CI, and Chi-square statistics were computed to identify the factors associated with no or partial immunization. The prevalence of complete immunization coverage was 89.1%. Women in the rich wealth quantile had the highest odds of completing the immunization for their children (AOR = 2.314; 95% CI: 1.642–3.261) compared to those who are poor. Those in rural areas were more likely to fully vaccinate their children (AOR = 1.54; 95% CI: 1.232–1.925) compared to those in urban areas. Those in the highest level of the educational group (AOR = 2.639; 95% CI: 1.800–3.87) are more likely to complete vaccination for their children compared to those with no formal education. However, female children are less likely to complete immunization compared to male children (AOR = 0.813; 95% CI: 0.687–0.963). The immunization status of children shows a significant association with maternal education, wealth status, and area of residence.

1. Introduction

Vaccination is one of the simplest and most cost-effective ways available to public to improve health [1], averting at least 37 million deaths between 2000 and 2019. It is the process in which a child is vaccinated against particular diseases such as polio, tuberculosis, hepatitis B, diphtheria, tetanus, and measles. It prevents 2 to 3 million deaths of children every year all over the world. Since the expanded program on immunization began in 1974, there has been an enormous increase in immunization rates worldwide, and the gap between rich and poor countries is getting smaller [2]. A global effort to immunize children with (at the time) six-core vaccinations was initiated by WHO in May 1974 [3]. Policymakers can use return on investment analysis to improve and expand immunization programs in the world's poorest countries [4]. To maximize the advantages of immunization programs, decision-makers must estimate the value of the worldwide investment in immunization programs [5]. The pandemic COVID-19 shows how important vaccines are in preventing disease, saving lives, and creating a wealthier future. Strong immunization systems will be

required in the future to protect people from COVID-19 and other diseases. The World Health Assembly (WHA) endorsed the Immunization Agenda 2030 (IA2030) to solve these difficulties over the next decade and save over 50 million lives. Improved health and well-being for everybody is IA2030s vision. It aspires to retain hard-won immunization achievements, recover from COVID-19 setbacks, and go beyond leaving no one behind in whatever situation or stage of life [2].

Logistic regression is employed to investigate whether an event occurred. It is extensively employed in health sciences investigations involving disease state (diseased or well) and decision-making. Polychotomous or multinomial logistic regression is the name given to the more complicated variant of logistic regression that can handle scenarios in which the variable being predicted can fall into more than two distinct groups [6]. It is necessary to make certain assumptions before fitting the model to the data, and linearity is one of them [7]. Logistic regression does not presume that the dependent variable is linearly related to the regressors [8]. In addition to its many applications in different fields, it is increasingly being employed in medical research to find the effect of different factors on the categorical response [9].

A series of life-saving vaccines were sought by the World Health Assembly (WHA) in May 1974. Effective surveillance systems provide data to guide program design, priority setting, resource mobilization, and resource allocation. The World Health Assembly recognized this when it suggested that member states build or maintain immunization and surveillance programs (WHA 27.57, May 1974) [10]. There was a large gap between high- and low-income countries by 1980, with only around 20% of the world's population which received the recommended three doses of a vaccine that protects against diphtheria, tetanus, and pertussis (DTP3). In response, in 1984, the United Nations Children's Fund (UNICEF) and the World Health Organization (WHO) launched the universal childhood immunization effort with the lofty goal of boosting DTP3 coverage to 80% globally by 1990. The percentage of people with access to DTP3 services nearly quadrupled over the course of a decade from 25% in 1980 to 75% in 1990 [11]. This increase was most noticeable in the world's poorest countries, where coverage jumped from 5% to 62% in these countries during the same time period.

Only six vaccine-preventable diseases (VPDs) caused 1.5 million fatalities in children under the age of five years in 2008 according to WHO estimates [11]. VPDs are still a leading cause of death among children in developing countries [12] even though the health and economic benefits of immunizing children have been demonstrated. There are still not enough children getting vaccinated, especially in developing countries. In 2016, about 19.5 million babies around the world had no access to regular immunization facilities. Sixty percent of these children live in just ten countries, and unfortunately, Pakistan is also one of them. The remaining nine countries are Angola, Brazil, Iraq, India, the Democratic Republic of the Congo, Indonesia, Nigeria, Ethiopia, and South Africa. Given these facts, it is essential that we conduct the present investigation. This is the first attempt at assessing vaccination coverage in Pakistan, using the most recent MICS survey, to the best of our knowledge. Although few researchers have used the MICS secondary data [13], the focus was on the overall socioeconomic well-being of the country.

2. Materials and Methods

2.1. Source and Description of Data. The Multiple Indicator Cluster Survey (MICS) 2018 was the source of the information that was utilized in this investigation. MICS is a household survey that is carried out by nations as a part of a program that was designed by the United Nations Children's Fund. UNICEF facilitates and assists the countries in the process of collecting and analyzing data in order to address data gaps for the purpose of monitoring the status of children and women. The organization primarily focuses on issues that are directly affecting the lives of children and women.

The first round of MICS was conducted around 1995, but in Pakistan, it was conducted in 2003-04. In this cross-sectional study, we used information collected during the 5^{th} MICS in Punjab. The Punjab Multiple Indicator Cluster Survey (MICS) was conducted in 2017–2018 by the Punjab Bureau of Statistics in partnership with the United Nations Children's Fund as part of the Global MICS Programme (UNICEF).

The primary goal of the 2017-18 MICS survey was to produce estimates for a wide range of indicators measuring the status of children and women across the province in both urban and rural areas and in each of the 36 districts that make up the province of Punjab. Each district's primary sampling strata were its urban and rural areas, and a two-stage process was used to select the sample of households. Using a probability distribution that scaled with the size of the area, a specific number of census enumeration areas were randomly selected from each stratum. The Pakistan Bureau of Statistics provided a list of households in each sample enumeration area from the 2017 census, and from that list, a random sample of 20 households was drawn in each sample enumeration area. This was done so that the results would be accurate when extrapolated to the entire population. There were a total of 53,840 households in the sample, and they were split into 2,692 different groups. The mothers (or other caretakers) of any children living in the family who were under the age of five were given a questionnaire to fill out. Among them, the children aged 12–23 months were included (7867 children) in the sample. As the main purpose of this study was to investigate the coverage of basic immunization, all children above 23 months or below 12 months were also excluded. During the data preprocessing, the respondents with missing information were excluded from the analysis. Thus, the final sample comprised 6111 respondents/children.

2.2. Variables Included. The response variable was complete or full immunization versus partial or incomplete immunization. The predictors used for the analysis include socio-

demographic status such as residence, education level, and wealth status etc. A child is considered to have "complete or full immunization" coverage if he/she has received one dose of BCG, three doses of pentavalent, pneumococcal conjugate (PCV), and oral polio vaccines (OPV), two doses of Rotavirus vaccine, and one dose of measles vaccine, according to the WHO guideline [14].

On the basis of the information found on the child's vaccination card and the mother's reports, the variables indicating the vaccination status were coded again. The value '0' was assigned if a child had not received the required dosage of vaccination and '1' if the recommended dosage was received. This was done so that we could make more precise comparisons between the two different groups.

2.3. Statistical Analysis. For the purpose of describing the amount of complete immunization coverage based on socio-demographic characteristics, descriptive statistics were utilized. Bivariate and multivariate logistic regression analyses were used to determine the variables of complete immunization. We used logistic regression because our response variable was binary with only two categories. In the multivariable analysis, only those variables were included if their p-values in the bivariate logistic regression analysis were less than 0.2. The adjusted odds ratio (AOR) and 95 percent confidence interval (CI) were calculated to investigate the strength of association between the response and the independent factors. The statistical significance level was set at 0.05. To assess the socio-demographic variables of immunization status, multiple logistic regression with a 5% significance level was used. All the computations were carried out in the statistical programming language R.

2.3.1. Multiple Logistic Regression Model. The logistic regression is used to measure the effect of predictors on a categorical response (binary or more than two categories). Suppose that X_1, X_2, ..., X_p are the independent variables and Y is the response variable, that is, the immunization status of a child. It may take the value 1 if the child has taken the recommended dosages of vaccination and 0 otherwise. The model in the form of logarithm of odds is written as

$$\ln\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_p X_p + u_i, \quad (1)$$

where $p_i = E(Y_i = 1|X_i)$, and u_i is the stochastic error term. Taking the antilogarithm and simplifying, we obtain

$$P(Y_i = 1|X_i) = \frac{e^{\beta_0+\beta_1 X_1+\beta_2 X_2+\ldots+\beta_p X_p}}{1 + e^{\beta_0+\beta_1 X_1+\beta_2 X_2+\ldots+\beta_p X_p}}. \quad (2)$$

The logistic regression model establishes a causal relationship between the predictor variables and the probability of Y. The goal of LR is to provide reasonable approximations for the $p+1$ unknown parameters in the equation. This is accomplished by using an estimation method known as maximum likelihood, which is an estimation technique that allows us to find the parameters for which the probability of the observed data is the highest. The regression coefficients show how strongly the independent variables are related to the dependent variable. Each coefficient represents the expected change in the response variable resulting from a one-unit change in the predictor variable. The findings of the investigation are presented as an odds ratio here for convenience.

2.3.2. Wald Chi-Square Test. The Wald Chi-Squared test, also known as the Wald Test, is a statistical measure that is used to determine whether or not a group of independent variables as a whole can be considered to be "significant" for a given model. In addition to this, it is utilized for determining whether or not each independent variable that is included in a model is significant. The Wald statistic is computed by $W_i = \beta_i^2/\mathrm{SE}^2(\beta_i)$, and it follows a Chi-square distribution asymptotically.

3. Results

A total of 6111 respondents were used for the current study. The vast majority of women (73.98%) lived in rural areas, and nearly half (40.02%) had never completed elementary school. Half of the sample that is 52.35% of the children were male, and 20.93% of the participants belonged to the quintile of wealth that was the lowest. The majority (98.28%) of the women had no functional disability. The results on counts and percentages with respect to immunization status are given in Table 1.

As a first step, the chi-square test of independence is implemented to investigate whether the selected variables have any association with the immunization status of the children. The significant variables include mother's education, wealth status, child's gender, native language, and mother's functional disability ($p < 0.05$). The area of residence is insignificant ($p = 0.248$) indicating that immunization status is not associated with their residential area.

3.1. Inferential Results. Multiple logistic regression analysis revealed that maternal education and literacy, child's gender, area of residence, and wealth status were the most important predictors of completing immunization (Table 2). The results for the logistic regression model along with the Wald statistics used to test the statistical significance of the regression coefficients are shown in Table 2. Multiple logistic regression analysis revealed that maternal education and literacy, child's gender, area of residence, and wealth status were the most important predictors of completing immunization as the p-value of their corresponding Wald statistics is less than 0.05 ($p < 0.05$). Specifically, those in the rich wealth quantile had the highest odds of completing the immunization for their children (AOR = 2.314; 95% CI: 1.642–3.261) compared to those who are poor. Those in rural areas were more likely to fully vaccinate their children (AOR = 1.54; 95% CI: 1.232–1.925) compared to those in urban areas. Those in the highest level of the educational group (AOR = 2.639; 95% CI: 1.800–3.87) are more likely to complete vaccination for their children compared to those with no formal education. However, female children are less likely to complete immunization compared to male children

Table 1: Results for the counts, percentages, and chi-square statistics.

Variable	Categories	Immunization status		Total	Chi-square	p-value
		Incomplete 619 (10.1)	Complete 5492 (89.9)			
Mother's education	None/Preschool	337 (13.8)	2100 (86.2)	2437 (39.88)	70.534	<0.001
	Primary	124 (9.6)	1165 (90.4)	1289 (21.09)		
	Middle	46 (6.8)	634 (93.2)	680 (11.13)		
	Secondary	65 (7.4)	815 (92.6)	880 (14.4)		
	Higher	47 (5.7)	778 (94.3)	825 (13.5)		
Wealth status	Poorest	196 (15.3)	1083 (84.7)	1279 (20.93)	60.941	<0.001
	Poor	137 (10.4)	1178 (89.6)	1315 (21.52)		
	Middle	120 (8.8)	1241 (91.2)	1361 (22.27)		
	Rich	74 (6.2)	1115 (93.8)	1189 (19.46)		
	Richest	92 (9.5)	875 (90.5)	967 (15.82)		
Gender	Male	297 (9.3)	2902 (90.7)	3199 (52.35)	5.267	0.022
	Female	322 (11.1)	2590 (88.9)	2912 (47.65)		
Area of residence	Urban	173 (10.9)	1417 (89.1)	1590 (26.02)	1.332	0.248
	Rural	446 (9.9)	4075 (90.1)	4521 (73.98)		
Native language	Urdu	18 (7.2)	231 (92.8)	249 (4.07)	12.328	0.006
	Punjabi	428 (10)	3845 (90)	4273 (69.92)		
	Saraiki	146 (10.2)	1292 (89.8)	1438 (23.53)		
	Other	27 (17.9)	124 (82.1)	151 (2.47)		
Mother's functional disability	Yes	17 (16.2)	88 (83.8)	105 (1.72)	4.312	0.038
	No	602 (10)	5404 (90)	6006 (98.28)		

Table 2: Inferential results.

Variable	Categories	Coefficients	S.E.	Wald	p-value	Odds Ratio	95% CI for OR	
Mother's education	None/Preschool			32.499	<.001			
	Primary	0.285	0.119	5.800	0.016	1.330	1.055	1.678
	Middle	0.642	0.177	13.201	<.001	1.900	1.344	2.685
	Secondary	0.602	0.164	13.441	<.001	1.825	1.323	2.517
	Higher	0.97	0.195	24.694	<.001	2.639	1.800	3.87
Wealth status	Poorest			29.948	<.001			
	Poor	0.396	0.123	10.305	0.001	1.485	1.167	1.891
	Middle	0.491	0.139	12.527	<.001	1.634	1.245	2.144
	Rich	0.839	0.175	22.992	<.001	2.314	1.642	3.261
	Richest	0.296	0.193	2.355	0.125	1.344	0.921	1.960
Gender	Male							
	Female	−0.207	0.086	5.779	0.016	0.813	0.687	0.963
Area of residence	Urban							
	Rural	0.432	0.114	14.392	<.001	1.540	1.232	1.925
Native language	Urdu			13.817	0.003			
	Punjabi	−0.288	0.257	1.249	0.264	0.750	0.453	1.242
	Saraiki	0.011	0.274	0.002	0.968	1.011	0.591	1.729
	Other	−0.707	0.335	4.466	0.035	0.493	0.256	0.950
Mother's functional disability	Yes							
	No	0.424	0.273	2.417	0.12	1.528	0.895	2.609

(AOR = 0.813; 95% CI: 0.687–0.963). Moreover, the mothers without any functional disability are more likely to complete the immunization of their children (AOR = 1.528; 95% CI: 0.895–2.609) as compared to those women having some functional disability.

Table 2 also contains information regarding the influence of the independent variables that were taken into consideration. To determine whether or not these variables affect the immunization status of children, all these variables were regressed on the response and the resulting coefficients, and their standard errors are reported in the Table. It can be seen that the values of coefficients for mothers' education and wealth status are positive. Compared with mothers with no preschooling, the mothers with primary, middle, secondary, and higher education (coefficients = 0.285, 0.642, 0.602, 0.97, respectively) have an increased likelihood of

their children being fully vaccinated. The p values of the corresponding Wald statistic ($p < 0.05$) show their significance toward the response variable. The odds ratio (1.33) indicates that the mothers with primary education have 33% more chances of getting their children fully vaccinated as compared to illiterate mothers. Similarly, the children of mothers with middle, secondary, and higher education have 90%, 82.8%, and 163.9% higher chances for being fully vaccinated as compared to illiterate mothers. Identical patterns emerge when looking at socioeconomic standing.

However, the gender of the child has a negative coefficient for the female ($\beta = -0.207$) taking the male as the reference category. The Wald statistic is significant (Wald = 5.779, $p < 0.05$) showing that the gender of a child has a significant effect on the immunization status. Compared with male children, female children were found to have a decreased probability of the event. The negative sign of the estimated coefficient and odds ratio is less than 1 ($\beta = -0.207$, $p < 0.05$, AOR = 0.813) for female children which shows that the probability of being fully vaccinated is higher for male than female children; that is, the relative probability of getting full immunization decreases by 18.7% if the child is a female.

4. Discussion

The current study examined the prevalence and factors associated with incomplete immunization among children aged 12–23 months in Pakistan. We found that the overall prevalence of complete immunization was 89.9%. This finding is consistent with prior studies in Senegal [15], Swaziland [16], Bangladesh [17], Brazil [18], and Malaysia [19]. Our finding is, nevertheless, higher than previous findings including 48% in Mozambique [20], 51.3% in Pakistan [21], 65% in India [22], and 62.8% in Senegal [23] but lower than the study conducted by the study in Ref. [24] in China (93.1%). A plausible explanation for the relatively high completion of immunization among children in Pakistan could be due to the increased levels of provision and the use of immunization services in the country [25]. Nevertheless, the differences in immunization coverage between nations could be attributable to socioeconomic and cultural differences, changes in healthcare coverage, legislations on immunizations, and sample size differences [23, 26].

In this study, we discovered wealth status, place of residence, mother's educational level, and gender of the child to be substantially related to incomplete immunization in Pakistan. In comparison to their impoverished counterparts, mothers of children in the richest wealth quintile had the highest odds of completing their children's immunizations. There is both direct and indirect cost associated with immunization updates such as transportation to the nearest point to receive the services [26]. As a result, mothers from wealthier families may have a better chance of getting modern health care for their families, especially their children, implying greater liberty [27]. Children of mothers in the poorest wealth quintile, on the other hand, are less likely to fully vaccinate their children due to difficulty in access to facilities such as transportation fees [27].

The mothers' educational level was also found to be significantly associated with immunization. The findings of our study demonstrate that educated women are more likely than uneducated mothers to immunize their children. Mothers with the highest level of education, such as a bachelor's degree, are more likely to immunize their children. Holding all things constant, mothers with higher education are more knowledgeable and conscious of the importance and advantages of immunization [28, 29]. This finding is consistent with prior studies in Pakistan [25], India [22], Bangladesh [30], and Nigeria [31].

Furthermore, we found that in Pakistan, a place of residence is associated with complete immunization. Mothers in rural areas were more likely than their urban counterparts to achieve complete immunization for their children. This finding is in line with a study conducted in China [24]. This could be because mothers in rural areas have more time to devote to their children's well-being and will ensure that their children are properly vaccinated because they do not have as many other employment commitments as those in urban areas [24].

We also found that a child's gender was strongly linked to full immunization. In our study, we noticed those female children were less likely than male children to undergo immunizations. This could be owing to the fact that in many locations, male children are given preference and priority [24]. Other studies in low- and middle-income nations [32] and Pakistan [33] have found similar results. However, another study [24] indicated that female children exhibited a greater likelihood of achieving complete immunization than male children in China. According to Ref. [34], gender discernment in terms of health status and widespread knowledge of the concept of "male preference" has decreased or even disappeared in recent years. Generally, the effects of gender discernment on immunization status are mixed, and the findings may vary depending on the study environment.

4.1. Strength and Limitations. The main strength of the paper is the use of nationally representative data with reactively large sample size. Rigorous statistical analyses were also conducted to control for possible confounders. Despite this, the study employed a cross-sectional design; as a result, only associations can be drawn but not causal inferences. There is also the possibility of recall and social desirability biases among the mothers who provided responses on immunization.

5. Conclusion

The overall prevalence of complete immunization was 89.9% in Pakistan. Factors such as the mother's education, wealth status, place of residence, and gender of the child were found to be significantly linked to complete immunization. This shows the relevance of female literacy and female education in the use of immunization services and the enhancement of socioeconomic status. It is also important to raise people's awareness in urban areas to encourage urban women to take the health of their children seriously so as to achieve complete immunization of their children.

Data Availability

The data used in this study can be requested from the corresponding author.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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