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MATHEMATICAL MODELING OF HEALTH SERVICE UTILIZATION DATA USING MULTIPLE LOGISTIC REGRESSION

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ABSTRACT

Many women in Nepal experience life threatening complications during pregnancy and child birth. Place of delivery is an important aspect of maternal health services. By delivery at a health institution, women receive better facilities and assistance than delivery at home. Even though the rate of birth taking place in a health institution has increased, but still four out of five (81%) birth take place at home (NDHS 2006). This fact is serious obstacle to reduce maternal mortality in Nepal. For analyzing the use of maternal health services and delivery system in Nepal, data is extracted from individual recodes of a data file of NDHS 2006. The unit of analysis for this study is Ever Married Woman (EMW) who had at least one live birth in the five years preceding the survey. The sample of study consists of 4182 EMW. Statistical model is developed to establish a linkage between utilization of MH services (place of delivery) and several factors. In the process of development of model, logistic regression model is selected. We used Newton Raphson itetrative method to solve the equations which is known as iteratively weighted least square algorithm and the results are interpreted in terms of odd ratios. The result of this study shows that women with low education level, those residing in rural areas and those with low socio-economic status are less likely to use a health facility for delivery.

Keywords: logistic regression; maternal mortality; odd ratios; place of delivery; skilled birth attendant.

I. Introduction

Maternal healthcare is a crucial part of any health care system. Health care that a woman receives during pregnancy, at the time of child birth and soon after, is important for the survival and well being of mother and the new born [12]. Since the launch of the Safe Motherhood Initiative in 1987, awareness to reproductive health has increased globally and today it is recognized as critical part of overall health status of women. In 1991, National Health Policy was endorsed, then maternal health became a national health priority and several interventions have been implanted in recent years under the National Safe Motherhood Program in Nepal [16]. It stressed reduction of maternal and child mortality through expansion of services. However, use of maternal health services at national level is still low but the government of Nepal aspires to improve maternal health and has developed various strategies to move towards the commitment of Millennium Development Goals (MDGs) [13]. A number of studies in various regions of the world have found socio-economic and demographic characteristics, which influence the likelihood of using professional health care at birth. Most of these studies are based on population located in both rural and urban areas. A positive relationship was observed for economic and educational status ([4], [5]). Age pattern was inconsistent. Some studies found a positive correlation with older ages ([5], [3], [10]), while others found a curvilinear relationship with older age [2].

Globally, the indicators which are widely used to track maternal health care can be classified into four groups: Contraceptive use, antenatal care (ANC), delivery care and postnatal care (PNC). According to International Conference on

Population and Development (ICPD), maternal health services which are based on the concept of informed choice should include the following: education on safe motherhood, prenatal/antenatal care that is focused and effective, maternal nutrition programs, adequate delivery assistance and provision for obstetric emergencies, referral services for pregnancy, child birth and abortion complications, postnatal care and family planning [9]. In Nepal reports show that more maternal deaths are due to absence of adequate number of place of delivery and skilled assistance. So, regarding the maternal health services mentioned above, this study focuses on the importance of a place of delivery as maternal health services, because delivery at health facilities (government/private hospital/ hospital running by NGOs/ clinics/ centers or other type of health facility) women receive better facilities and assistance than delivery at home. Maternal health analysts also agree that, to substantially reduce both maternal and child deaths, care needs to be scaled up in a continuum, from safe sex and family planning to pregnancy and delivery care [11]. In Nepal, the percentage of births taking place in a health facility has doubled in last five years (9% in 2001 and 18% in 2006). Even though the rate of birth taking place in a health facility has increased, still four out of five (81%) births take place at home[15]. This fact is a serious obstacle to reduce maternal mortality as women get less facility at home than in a health facility. In Nepal three in four pregnant women (75%) receive antenatal care. About 57% of mothers who receive antenatal care reported that they were informed the sign of pregnancy complications [15]. Therefore it is safer to deliver at a health facility than at home. The objective of delivery at a health facility is to protect the life and health of the mother and her child by ensuring safe and hygienic condition during deliveries. The present study is an attempt to investigate some selected variables that are influencing women in delivery at health facility by using the prospective data obtained from the Nepal Demographic Health Survey (NDHS). However, there are other variables that influence the maternal health services such as quality and cost of delivery services, cultural factors, prejudices etc are also likely to influence the delivery at health facility. Due to lack of relevant data, the effect of these factors on the place of delivery could not be examined in this paper.

II. Method

A. Data

For analyzing the use of maternal health services delivery system in Nepal, data is extracted from individual recode data file of Nepal Demographic Health Survey (NDHS) 2006. NDHS is the comprehensive survey conducted in Nepal as part of the worldwide Demographic Health Survey (DHS) project. New Era implemented it, ORC Macro provided technical support and financial support was provided by the USAID. It is a nationally representative survey of 10,793 women of age 15-49 years. The unit of analysis for this study is Ever Married Women (EMW) who had at least one live birth in the five years preceding the survey. For those EMW, who had more than one birth, only utilization behavior of maternal health services associated with most recent pregnancy within five years was considered. So the sample of this study consists of 4182 EMW.

B. Variables used for this study

The dependent variable of the study is place of delivery (y), which is taken to be a binary one. Consider, $Y_i = 1$, if the i^{th} respondent delivered at a health facility and $Y_i = 0$, if the i^{th} respondent delivered at home. The health facility includes all type of facilities in government/private hospitals/ hospitals running by NGO's/clinics/centers or other health facility. Delivery at home includes respondent's home or others (non health facility). A number of covariates are taken into account based on a scientific literature review of socio-economic and demographic variables. Basic descriptions of independent variables are presented in Table1.

Table 1: Description of variables.

Variable code	Variable	Description
Y	place of delivery	Y = 1, as delivery at health facility Y = 0, as delivery at home
X_1	Age of the respondent	X_{10} = age group 15 -19 X_{11} = age group 20 -49
X_2	Place of residence	X_{20} = rural X_{21} = urban
X_3	Region	X_{30} = central X_{31} = eastern X_{32} = all western
X_4	Highest level of education	X_{40} = no education X_{41} = primary X_{42} =secondary X_{43} = higher
X_5	Wealth Index	X_{50} = poorer X_{51} = poor X_{52} = middle X_{53} = rich X_{54} = richer
X_6	ANC by provider	X_{60} =ANC provided by no one X_{61} = ANC provided by SBA X_{62} = ANC provided by others

III. Multiple Logistic regression Model

Logistic regression extended to model with multiple explanatory variables (X).

The model for π_i = P (Y_i = 1) probability that Y_i = 1 and 1 - π_i = P(Y_i = 0) at values X =(X_1, ,X_2, ...X_k) of k predictands and the subscript i denote i^th^ individual and the model assumed is

$$\pi_i = \frac{\exp\left(\beta_0 + \sum_{j=1}^{k} \beta_j X_{ij}\right)}{1 + \exp\left(\beta_0 + \sum_{j=1}^{k} \beta_j X_{ij}\right)}$$

Where X_j , (j =1, 2, ...*k*) are explanatory variables. Then logit or log odds of having Y_i = 1 is modeled as a linear function of the explanatory variables, that is

$$ln \frac{\pi_i}{1 - \pi_i} = \beta_0 + \sum_{j=1}^{k} \beta_j X_{ij}$$

$0 <= \pi_i <= 1$, j=0, 1, 2, k, i=1, 2… n.

Here we use a very effective and well known Newton-Ramphson iterative method to solve the equations, which is known as iteratively weighted least square algorithm. The computer package SPSS for window base 15.0 version has been used for the analysis and multiple logistic regression β_j's, j =1, 2, ..., k are iteratively obtain with the help of this program. Once the particular logistic regression model has been fitted, we begin the process of model assessment. The first step in the process is usually to assess the significance of predictors in the model. This usually involves formulation and testing of statistical hypotheses to determine whether the independent variables in the model are significantly associated to the response variable. The likelihood ratio test for the overall significance of all coefficients for the predictor as well as significance of single predictor in the model is shown in Table2.

Table2: Analysis of likelihood ratio chi square test.

Variable	step	χ^2 for individual regressor	d.f	Change in deviance (model χ^2)	d.f
X_5	1	783.559	4	783.559	4
X_6	2	270.886	2	1054.445	6
X_4	3	135.286	3	1189.713	9
X_2	4	24.473	1	1214.185	10
X_3	5	27.183	2	1241.369	12
X_1	6	17.231	1	1258.600	13
Initial -2loglikelihood = 4059.276			All have p value < 0.001		
Final -2loglikelihood = 2800.00			Chi square = 1258.600		

Likelihood ratio test is performed on the basis of the test statistics given by

$$G = 2\{LL\ (new) - LL\ (base)\}$$

where LL (new) is the likelihood of obtaining observations with all predictor incorporation into the model and LL (base) is the likelihood of obtaining the observations if the independent variables have no effect on the outcome under the null hypothesis.

The statistic G follows a chi-square distribution with 13 degree of freedom and measures how well the independent variable affect the outcome or response variable. In the study G = 1258.600 with p value <. 001, indicate that we reject the null hypothesis and we may infer that at least one and perhaps most of the coefficients are different from zero and we may infer as a whole the predictors have significant contribution to predict the response variable.

The change in deviance G approximately follows the chi-square distribution with respective degree of freedom. The chi square for individual predictors is shown in 3rdcolumn of table 2. The term deviance was designed by McCullagh and Nelder [17] and given by D = 2likelihood for the fitted model. If the deviance reduces as predictor Incorporated sequentially in the model, indicates the model fits the data well. The change is shown in 5th column in table 2.

The goodness of fit (the degree of closeness of the model-predicted value to the corresponding observed value) is useful for applying to the regression model. The Hosmer-Lemeshow goodness of fit statistics [7] proposes a Pearsons statistic to compare the observed and fitted counts for the partition. Let g denote the number of groups, n_k is the number observations in the kth group, O_k is the sum of Y's value for the k^{th} group and $\bar{\pi}_k$ is the average of the ordered π for k^{th} group then their statistic equals

$$\tau = \sum_{k=1}^{g} \frac{(O_k - n_k^{'}\bar{\pi}_k)^2}{n_k^{'}\bar{\pi}_k(1-\bar{\pi}_k)}$$

This test is also called chi-square test. It is more reliable than the traditional chi -square test [1]. In general, the Hosmer-Lemeshow goodness of fit test divides subject into deciles based on predicted probabilities and computes a chi square from observed and expected frequencies which is shown in Table 3.

Table 3: Contingency table for Hosmer-Lemeshow test:

Decile	Delivery at home		Delivery at health facility		Total	X^2	d.f	P value
	observed	expected	observed	expected				
1	595	593.938	15	16.017	610	14.226	7	0.056
2	372	369.786	15	17.214	387			
3	344	357.119	32	18.881	376			
4	440	434.430	27	32.172	467			
5	400	394.430	32	38.570	433			
6	362	360.806	49	50.194	411			
7	328	338.459	87	76.541	415			
8	289	269.076	128	127.925	417			
9	259	251.512	407	414.488	666			

Under the null hypothesis, the distribution of the statistic τ is well approximated by the chi-square distribution with g-2 degree of freedom. To support the model, a significance value greater than .05 is needed. We observed from the table3 that the Hosmer-Lemeshow chi-square statistic with seven degree of freedom, is 14.226 with p value 0.059.The large p value signifies that there is no difference between the observed and predicted values, implying that the model fits the data at an acceptable level.

We know that multicollinearity can affect the parameters of the regression model. Unfortunately SPSS did not have option for producing collinearity diagonsis in multiple logistic regression but we can obtain tolerance and variance inflated factor (VIF) by simply running a regression analysis using same predictor and outcome. Mernard [19] suggests that a tolerance value less than 0.1 almost certainly indicates a serious collinearity problem. Menard says that a VIF value greater than 10 is cause for concern but in our data all VIF values are less than 10. Therefore we can assume that there is no multi-collinearity problem in these variables. Table 4 shows multicollinearity diagnosis.

Table 4: Collinearity test

I.V	Tolerance	VIF
X_1	0.989	1.011
X_2	0.813	1.230
X_3	0.977	1.023
X_4	0.767	1.304
X_5	0.677	1.478
X_6	0.965	1.036

Based on these, we may conclude that the model performance is good. Table 5 shows the coefficient *β'*s, their standard errors, wald's chi-square statistics, associated p values, odd ratios and 95% confidence interval. The wald statistic is defined as

$$W = \frac{\hat{\beta}_i^{\,2}}{\{S.E(\hat{\beta}_i)\}^2}$$

Which has a chi-square distribution, where β_i hat stands for estimated regression coefficient and S.E(β_i) hat stands for standard error of β_I . It tell us whether the β coefficient is significantly different from zero. If the coefficient is significantly deferent from zero then we can assume that the predictor is making significant contribution to the prediction of outcome (*Y*).

More critical to the interpretation of likelihood ratio is the value of exp (*β*), which is an indicator of the change in odds resulting from a unit change in a predictor. When the predictor variable is categorical, exp (*β*) is easier to explain.

The odds of an event occurring are define as the probability of an event occurring divided by the probability of that event not occurring. In this study, P (event) is the probability of delivery at health facility and P (no event) is the probability of not delivery at health facility. Therefore

$$odd = \frac{P(event)}{P(no\ event)}$$

In order to calculate the proportionate change in odds, divide the odds after a unit change in the predictor by the odds before changes, that is

$$\Delta odd = \frac{odds\ after\ the\ unit\ change\ in\ predictor}{original\ odds}$$

This proportionate change in odds is exp(*β*), so we can interpret exp(*β*) in terms of the change in odds If the value is greater than 1, then it indicates that as the predictor increases, the odds of the outcome increases. If the value is less than 1 then as the predictor increases, the odds of the outcome decreases.

Table 5: Logistic regression for place of delivery of EMW.

I.V	Coefficient(β)	S.E	Exp(β)	95% C.I for exp(β)	
				Lower	Upper
Constant	-3.057^{*}	0.269	0.047		
X_{10} (R)					
X_{11}	-0.675^{*}	0.159	0.509	0.373	0.695
X_{20}(R)					
X_{21}	0.559^{*}	0.109	1.749	1.411	2.167
X_{30}(R)					
X_{31}	-0.575^{*}	0.138	0.563	0.429	0.738
X_{32}	-0.590^{*}	0.115	0.554	0.443	0.694
X_{40}(R)					
X_{41}	0.281^{*}	0.136	1.325	1.015	1.728
X_{42}	1.144^{*}	0.121	3.139	2.476	3.980
X_{43}	2.273^{*}	0.257	9.713	5.866	16.084
X_{50}(R)					
X_{51}	0.434^{**}	0.196	1.544	1.051	2.268
X_{52}	0.490^{**}	0.195	1.632	1.113	2.392
X_{53}	0.787^{*}	0.186	2.196	1.526	3.160
X_{54}	1.525^{*}	0.193	4.603	3.152	6.723
X_{60}(R)					
X_{61}	1.751^{*}	0.187	5.759	3.993	8.305
X_{62}	0.509^{**}	0.216	1.664	1.089	2.542

R = reference category, * = p value < 0.001, ** = p value < 0.005.

IV. Results

Considering age group 15-19 as reference category, the estimated coefficient of EMW for the age group 20 and above (X_{12}) is -0.675. It is negative in sign. The result illustrates that the women age group 20 and above are less likely to deliver in health facility and the result is statistically significant. The odd ratio for age group 20 and above is 0.509, which indicates that the women of age group 20 and above have (1-0.509)100 = 49% less likely to deliver at health facility as compared to reference category.

The estimated coefficient for the variable, the place of residence (X_{21}), is 0.559 and its corresponding odd ratio is 1.749. The change could be as little as 1.411 and as much as 2.167 with 95% confidence interval indicates that the women of urban areas are 1.75 times more likely to deliver at a health facility compare to the rural women.

The estimated coefficient of EMW under different development regions are obtained. Center lies in the capital with 25% respondent's sample and also population of center is the combination of interaction of all regions. Therefore center is considered as the reference category. The coefficients corresponding to eastern and western regions are -0.575 and -0.590 respectively and negative in sign, results are statistically significant. The odd ratio corresponding to eastern and western regions are 0.563 and 0.554. It indicates that the women of eastern and western have (.563)100 = 43.7% and (1-.554)100 = 44.6% less likely to deliver at health facility.

For the variable highest level of education (X_4), the fitted coefficient to primary, secondary and higher level of education is 0.281, 1.144 and 2.273 respectively. No education is considered as reference category. All the results are statistically highly significant except that primary level education. Primary level education is significance at p <= 0.005 level of significance. Women with secondary and higher education levels are almost

2.48 and 5.78 times more likely to deliver at health facility then women with no education.

The estimated coefficient of EMW under different wealth index (X_5) is computed. Poorest as a reference category, the coefficient corresponding to poorer, middle, richer and richest are 0.434, 0.490, 0.787 and 1.572 respectively. Results are statistically significant at $p <= 0.005$ for poor and middle, at $p <= .001$ for richer and richest. The odd ratios for richer and richest wealth index are almost 2.2 and 4.6 times more likely to deliver at health facility.

We found that, antenatal care is a key determinant of using maternal health services. In general a woman who goes for antenatal care is more likely to deliver at health facility than a woman who does not go for antenatal check up. The estimated coefficients to the antenatal check up by SBA and others are 1.751 and 0.509 respectively. Each has the expected sign. The odd ratios indicate that the women having antenatal care by SBA are likely to have 5.76 times higher to deliver at a health facility compared to women having no antenatal check up. The change could be as little as 3.99 or as much as 8.31 with 95 percent confidence interval.

V. Discussion

This study investigates the factors that are associated with place of delivery. We now turn to discussion on our findings based on the result of estimation of the binary logistic regression model. It is well recognized that women's current age plays important role in the health services utilization [8]. The result of this study shows that the women of age group 20 and above are less likely to deliver at a health facility compared to age group 15 -19. This indicates that development of modern medicine and improvement in educational opportunities for women in recent years, there is high probability of younger women, with enhanced knowledge, use health care services. It is also possible that younger women are just starting child bearing and are told to be in high risk group so they tend to fear home deliveries.

Several studies have found a strong association between education and utilization of MH services [18]. It is found that mother's education is the most consistent and important determinant of use of child and maternal health services. The result from this study also supports the positive association between the education and delivery at health facility. But in rural areas, it does not seem to have greatly improved delivery at health facility as increase in education level. As expected, higher proportion of urban women than rural women delivered at health facility. Since central region is more developed and it is easy to have access to maternal health services. As expected, the lower proportions of western and eastern women delivered at health facility compared to central women.

Women with higher wealth index more often have resources and ability to buy health services. It is obvious from our study that as the wealth index becomes high; delivery at health facilities is also increased in both urban and rural areas [6]. In the literature it is well established that antenatal visit, combined with the use of antenatal care, are associated with the reduction of maternal mortality. Antenatal care appears to be indispensable for the prevention of maternal death. The introduction of home based antenatal risk screening in Kenya resulted in the reduction of maternal mortality [14]. As expected, women having ANC by SBA are likely to have six times higher to deliver at health facility compared to women having no antenatal check up.

VI. Conclusion

There is no doubt that uses of maternal health services improve reproductive outcomes. In this analysis place of delivery is taken as dependent variable. The log odds of delivery at health facility are measure using several explanatory variables such as socio-economic and demographic variables. This study identified the factors which affect the delivery at health facility and it may be helpful for policy maker/ service provider regarding maternal health to make future plans or program for maternal health in Nepal.

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