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GEE Models for Maternal Morbidity in Rural Bangladesh

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Abstract: The maternal morbidity data in Bangladesh is scanty. This paper employs the prospective data on maternal morbidity in rural Bangladesh to identify the potential risk factors associated with pregnancy related complications. The data were collected by the Bangladesh Institute of Research for Promotion of Essential and Reproductive Health and Technologies (BIRPERHT) during November, 1992 to December, 1993. The GEE models with different correlation structures are used and tested for the maternal morbidity data. The logistic regression model based on exchangeable correlation structure for the repeated observations appears to be the best. The findings indicate that the risk of suffering from complications is higher for unwanted pregnancy, lower level or no schooling, lower age at marriage, 5 or more pregnancies prior to the index pregnancy.

Zusammenfassung: Daten über Erkrankungen von Müttern in Bangladesh sind knapp. Wir verwenden prospektive Daten über mütterliche Erkrankungen im ländlichen Bangladesh, um mögliche Risikofaktoren für schwangerschaftsbezogenen Komplikationen zu identifizieren. Die Daten wurden vom Bangladesh Institute of Research for Promotion of Essential and Reproductive Health and Technologies (BIRPERHT) von November 1992 bis Dezember 1993 erhoben. GEE Modele mit unterschiedlichen Korrelationsstrukturen wurden für die Daten über mütterliche Erkrankungen verwendet und getestet. Ein logistisches Regressionsmodell mit austauschbarer Korrelationsstruktur für die wiederholten Beobachtungen scheint am geeignetsten zu sein. Diese Erkenntnisse deuten darauf hin, dass das Risiko an derartige Komplikationen zu leiden höher ist bei ungewollter Schwangerschaft, wenig oder keiner Schulbildung, jungem Alter bei der Verheiratung, fünf oder noch mehr vorangegangenen Schwangerschaften.

Keywords: Repeated Observations, Generalized Estimating Equations, Antenatal Morbidity, Correlation Structures, Logistic Regression.

1 Introduction

The factors that contribute to maternal morbidity and mortality are too numerous to enumerate. The causes are multiple, interrelated and tiered and are deeply rooted in the

adverse social, cultural, political and economic environment of societies and especially the environment that societies create for women (Fortney and Smith, 1999; Okolocha et al., 1998). Some of the major causes include malnutrition and anemia, infections, hemorrhage, eclampsia, fits, convulsion, diabetes, hepatitis and morbidity following from unsafe deliveries and traditional exercises. Conditions such as pelvic sepsis, vesico vaginal fistulae and prolapse do not always result in deaths but may have serious social and physical consequences for women.

Pregnancy and childbirth related complications are the leading causes of maternal mortality and morbidity in Bangladesh. Approximately, 16.000 maternal deaths occurred in Bangladesh due to pregnancy and delivery-related complications in the year 2000 (WHO, UNICEF, and UNFPA, 2002). However, information on the extent and determinants of maternal morbidity in Bangladesh is not adequate (BRAC, 1994). The most important causes of maternal deaths in Bangladesh are identified as anemia, eclampsia, septic abortion, postpartum sepsis, obstructed labor and antepartum and postpartum hemorrhage in various studies (Jahan and Begum, 1986; Koenig et al., 1988). Most of the pregnancies in the country are attended either by traditional practitioners or are not attended at all (Fauveau et al., 1989; Goodburn et al., 1995). This reflects the poor access to health care facilities during the pregnancy as well as at the time of delivery.

Severe anemia increases the risk of death though there is a poor evidence of increased risk associated with mild or moderate anemia (Rush, 2000). Due to poor nutritional status and poor access to necessary health care during pregnancy, pregnancy anemia is an important cause of maternal morbidity and mortality which results in various pregnancy related complications. Maternal deaths and morbidity due to postpartum hemorrhage are 50 times more common in developing countries than in England and Wales (Haththotuwa et al., 1995). Poor nutrition also increases the risk of prematurity and even some of the medical complications of pregnancy, while nutritional interventions during pregnancy such as calcium supplementation reduces the risk of some complications including high blood pressure and pre-eclampsia (Kulier et al., 1998).

Social factors like the type of housing, age at marriage, maternal education, household income, gainful employment were found to have direct bearing on pregnancy and its outcome (Bhargava et al., 1991). The women's health and well being during pregnancies are also influenced by unwanted pregnancies (Ray, 1995). Due to the male dominated social structure in Bangladesh, many of the working and earning women have little liberty to spend even their own earnings. Malnutrition, poor economic, social and legal status, and above all, lack of proper education prevent women to take better charge of themselves. Hence female literacy is expected to be a very fruitful strategy to change the tide of maternal death (Choolani and Ratnam, 1995).

In this paper an attempt is made to identify the factors associated with some life threatening and high-risk complications that emerge among the rural women of Bangladesh during pregnancy. This study is based on a follow-up study on maternal morbidity in rural Bangladesh conducted by Bangladesh Institute of Research for Promotion of Essential and Reproductive Health and Technologies (BIRPERHT) in 1993. The study had cross-sectional and prospective components, for which the total study duration was 23 months. The results of cross-sectional study were published in Akhter et al. (1996). We analyze the data from the prospective survey for this paper.

2 Data

We used the data on Maternal Morbidity in Bangladesh, which was collected by BIRPERHT, during the period from November 1992 to December 1993. BIRPERTH conducted this study with the intention to identify the risk factors for maternal morbidity in Bangladesh. The study had two components, cross-sectional and prospective. The latter component is used in this paper.

A multistage random sampling was exercised. In the first stage, one district was selected from each of four divisions. In the second stage, one thana (a Thana is comprised of several Unions, while Union is the smallest administrative geographical unit in Bangladesh, comprising of a population of size 0.2 million to 0.25 millions) from each selected district was chosen randomly. At the end, two unions (unions are comprised of several wards which are small geographical boundaries comprising of villages in rural areas) from each selected thana were considered as study area (total eight unions from four thnanas of four districts). Finally, for the prospective study, 1020 pregnant women (pregnancy less than 6 months) were interviewed. Prospective subjects were followed up with interval on an average of one month, through full-term pregnancy, delivery and till 90 days postpartum period or 90 days after any other pregnancy outcome.

The data on socio-economic, background, pregnancy-related care and practice, extent of morbidity during the index pregnancy, delivery and postpartum period or abortion were collected on 1020 women. Out of these 1020 women, 993 had at least one antenatal follow-up, and 1005 had information on pregnancy termination. Finally, 1006 had at least one postpartum follow-up.

The most remarkable feature of different surveys conducted in South Asian countries is that the towering majority of respondents undergo some identifiable problem or illness during pregnancy or during labor and delivery.

2.1 Variables

Though there are numerous factors, we considered only a few selected variables in our study due to unavailability of data on other factors.

Response Variables: Presence of complications such as hemorrhage, fits, convulsion, cough or fever for more than three days or edema are considered as complications in this study. Instead the number of symptoms we have considered life-threatening and high-risk conditions during pregnancy. These available figures are self-reports. Complications with few symptoms may be under-reported. The problems that demand relatively sophisticated diagnosis may be under reported, or misreported as something else, or lumped into a extensive symptomatic part that does not allow particular diagnosis.

Independent Variables: The covariates taken into account are economic status of the respondents, wanted pregnancy, gainful employment, level of education of respondents, number of pregnancies prior to the index pregnancy, age at marriage and duration of pregnancy. Age at marriage is converted to a binary variable that distinguish between age at marriage up to 15 or less than 15 years. We have also used information on education and have grouped the women into those with primary education and those with secondary education. Respondents without having any formal schooling are the reference category.

Table 1: Percent distribution of respondents by complications during pregnancy and by selected characteristics

Variable	Category	Complications	
		No	Yes
Economic Status	Low	66.9	33.1
	High	59.6	40.4
Wanted Preg.	No	60.2	39.8
	Yes	68.3	31.7
Gainful Empl.	Unemployed	65.9	34.1
	Employed	64.8	35.2
Education	Primary	69.9	30.1
	Secondary	71.1	28.9
#(Preg's)	0	61.8	38.2
	1-4	65.6	34.4
	5+	62.8	37.2
Age at Marriage	≤ 15	63.8	36.2
	15+	69.0	31.0

The factor counting the number of pregnancies prior to the index pregnancy has levels no prior pregnancy, 1-4 pregnancies (taken as reference level), and 5 or more pregnancies. Table 1 represents percent distribution of respondents by complications during pregnancy and by selected characteristics. Data show that 33% of the respondents of low economic status suffer from one of the conditions as compared to that of 40.4% of high economic status. The respondents who did not want the index pregnancy suffered from complications at a higher proportion (40%) than those who wanted the index pregnancy (around 32%). Reported complications during pregnancy are higher in the group of women who don't have any formal education as compared to those having primary or secondary education. The high-risk group women are women who are pregnant for the first time as well as those who have had experienced at least 5 pregnancies prior to the current pregnancy. It is observed that the life threatening or high-risk complications are prevalent at a higher proportion among the high-risk groups. Also we observe that the prevalence of complications is relatively low for those with age at marriage 15 or higher as compared to those who reported their age at marriage less than 15 years. In rural areas of Bangladesh, the gap between the age at marriage and birth of first child is not much. So those who get married at very young age begin their childbearing at a younger age as well when, physically as well as mentally, they are unfit to become a mother.

Table 2 represents the distribution of respondents with or without complications during the different stages of pregnancy by follow-up. We observe the highest percentage of respondents with complications during the first 3 months, particularly at the first visit. This might be attributable to accumulation effect at the first visit or the problems associated with pregnancy at an early stage. Those who entered late in the study, for instance at the fifth follow-up, the rate of complication is still too high (about 42%). During the next 3 months, the percentage of respondents with complications increases at later follow-ups

Table 2: Number of respondents at different follow-ups by duration and complication

Follow-ups	Duration of pregnancy					
	-3 months		3-6 months		6+ months	
	No	Yes	No	Yes	No	Yes
1	565	427	-	-	-	-
2	621	293	2	1	-	-
3	496	223	38	14	-	-
4	78	56	340	120	-	-
5	1	0	244	125	-	-
6	-	-	98	47	3	0
7	-	-	2	4	21	7
8	-	-	-	-	0	1

(in follow-ups 3 and 4 around 26-27% and in follow-ups 5-6 in 32-34%).

3 Method

Different methods for the analysis of repeated observations (e.g., transitional models, survival models, multistate and multistage models) are widely used and found in the literature (e.g., Cox, 1972; Islam and Singh, 1992; Islam, 1994). In this study, the generalized estimating equation (GEE) approach of Zeger and Liang (1986) or Liang and Zeger, 1986) is applied to observe how the covariates are associated with repeated observations on status of complications at different follow-ups. The GEE approach gives the less number of parameter estimates and give an average estimates on the basis of follow-ups. Here, the GEE has been applied to the data of one to eight repeated binary observations of the individuals registered at BIRPERHT for the study. We applied the GEE method for unequal number of follow-ups and we used S-plus to analyze the data and to get parameter estimates.

Let us assume that the ith individual is observed at T_i occasions giving a $T_i \times 1$ response vector $Y_i = (Y_{i1}, \ldots, Y_{iT_i})^T$, $i = 1, \ldots, N$. Here the response is dichotomous. We further take k independent variables, so for the ith individual we have a $T_i \times k$ matrix of covariates $X_i = (X_{i1}, \ldots, X_{iT_i})^T$, where $X_{ij} = (X_{ij1}, \ldots, X_{ijk})^T$, $j = 1, \ldots, T_i$. We further denote the mean of Y_i as $\mu_i = (\mu_{i1}, \ldots, \mu_{iT_i})^T$ with $\mu_{ij} = P(Y_{ij} = 1|X_{ij})$, and its variance is $\mu_{ij}(1 - \mu_{ij})$.

Following Liang and Zeger's approach we chose estimating equations for β of the form

$$U(\beta) = \sum_{i=1}^{N} X_i^T A_i V_i^{-1}(y_i - \mu_i) = 0\,, \tag{1}$$

where $A_i = \mathrm{diag}(\mathrm{var}(Y_{i1}), \ldots, \mathrm{var}(Y_{iT_i}))$ is a $T_i \times T_i$ diagonal matrix and V_i is a working or approximate covariance matrix of Y_i which can be expressed as

$$V_i = A_i^{1/2} R_i(\alpha) A_i^{1/2}\,. \tag{2}$$

The vector α represents the parameters associated with a specified model for $\mathrm{cor}(Y_i)$. The correlation matrix is denoted by $R_i(\alpha)$. It is assumed that $R_i(\alpha)$ is fully specified by α for all subjects.

The GEE approach allows the time dependence to be specified in various ways. Some common specifications for $\mathrm{cor}(Y_i)$ are

(a) independence correlation: $R_i(\alpha) = \mathrm{cor}(Y_i) = I$,

(b) exchangeable correlation: $(R_i(\alpha))_{st} = \mathrm{cor}(Y_{is}, Y_{it}) = \alpha$, if $s \neq t$,

(c) autoregressive correlation: $(R_i(\alpha))_{st} = \mathrm{cor}(Y_{is}, Y_{it}) = \alpha^{|s-t|}$, $s \neq t$,

(d) unstructured or pairwise correlation: $(R_i(\alpha))_{st} = \mathrm{cor}(Y_{is}, Y_{it}) = \alpha_{st}$, $s \neq t$, where, $\alpha_{s,s+1} = \alpha_{s+1,s}$, $s = 1, \ldots, T$.

4 Results

Now we present the resulting estimates of the coefficients obtained under the assumption of different correlation structures. Under the independence assumption (Table 3) we observe that economic status, wanted pregnancy, primary education, secondary education,

Table 3: GEE estimates for maternal morbidity assuming different correlation models

Variables	Working Independence			Exchangeable Correlation		
	Coeff. (S.E.)	O.R.	CI	Coeff. (S.E.)	O.R.	CI
Constant	-0.020 (0.098)	0.98	(0.81, 1.19)	-0.025 (0.080)	0.98	(0.84, 1.14)
Economic Status	0.493 (0.091)	1.64	(1.37, 1.96)	0.450 (0.069)	1.57	(1.37, 1.79)
Wanted Preg.	-0.404 (0.080)	0.67	(0.57, 0.78)	-0.482 (0.059)	0.62	(0.55, 0.69)
Gainful Empl.	0.064 (0.076)	1.07	(0.92, 1.24)	0.122 (0.056)	1.13	(1.01, 1.26)
Prim. Education	-0.393 (0.081)	0.68	(0.58, 0.79)	-0.354 (0.060)	0.70	(0.62, 0.79)
Sec. Education	-0.483 (0.110)	0.62	(0.50, 0.77)	-0.521 (0.085)	0.59	(0.50, 0.70)
#(Preg's) = 0	0.034 (0.086)	1.04	(0.87, 1.23)	0.101 (0.065)	1.11	(0.97, 1.26)
#(Preg's)≥ 5	-0.170 (0.105)	0.84	(0.69, 1.04)	-0.175 (0.078)	0.84	(0.72, 0.98)
Age at Marriage	-0.220 (0.077)	0.80	(0.69, 0.93)	-0.139 (0.057)	0.87	(0.78, 0.97)
Duration	-0.115 (0.023)	0.89	(0.85, 0.93)	-0.119 (0.022)	0.89	(0.85, 0.93)
	Autoregressive Correlation			Pairwise Correlation		
Constant	-0.039 (0.090)	0.96	(0.81, 1.15)	0.013 (0.137)	1.01	(0.78, 1.33)
Economic Status	0.495 (0.083)	1.64	(1.39, 1.93)	0.462 (0.133)	1.59	(1.22, 2.06)
Wanted Preg.	-0.398 (0.073)	0.67	(0.58, 0.78)	-0.386 (0.120)	0.68	(0.54, 0.86)
Gainful Empl.	0.070 (0.070)	1.07	(0.94, 1.23)	0.033 (0.114)	1.03	(0.83, 1.29)
Prim. Education	-0.399 (0.074)	0.67	(0.58, 0.78)	-0.383 (0.121)	0.68	(0.54, 0.87)
Sec. Education	-0.494 (0.101)	0.61	(0.50, 0.74)	-0.420 (0.160)	0.66	(0.48, 0.90)
#(Preg's) = 0	0.039 (0.079)	1.04	(0.89, 1.21)	0.025 (0.127)	1.03	(0.80, 1.32)
#(Preg's)≥ 5	-0.172 (0.096)	0.84	(0.70, 1.02)	-0.147 (0.156)	0.86	(0.64, 1.17)
Age at Marriage	-0.218 (0.070)	0.80	(0.70, 0.92)	-0.250 (0.113)	0.78	(0.62, 0.97)
Duration	-0.112 (0.022)	0.89	(0.86, 0.93)	-0.112 (0.021)	0.89	(0.86, 0.93)

age at marriage, and duration of pregnancy are significant at the 5% level. The prevalence of the complications appears to be significantly higher among the respondents of better economic status. The odds ratio shows that there is a 63% increase in the risk of suffering from these complications among the women of higher economic status as compared to that of women of lower economic status. If the index pregnancy is desired, then the reported prevalence of complications declines by one-third than that of the undesired pregnancies. The prevalence of complications found to be decreased steadily with educational level. It is noteworthy that the reports of complications decreased significantly (one-fifth) for those whose age at marriage was 15 years or higher. It is also worth mentioning that the prevalence of complications is reportedly higher during the initial stage of pregnancy and decreases significantly at the advanced stage.

Table 3 shows that all covariates but the first pregnancy are significant under the exchangeable correlation assumption. In addition to positive association between economic status and prevalence of complications as observed for independence assumption, we find that gainful employment exerts positive effect as well. There is a 13% increase in the odds of suffering from complications among those who are engaged in gainful employment as compared to those who are not engaged in gainful employment. Unlike the results presented for independence, the exchangeable correlation assumption reveals that 5 or more previous pregnancies can decrease the prevalence of complications.

The GEE for autoregressive structure shows that all covariates except gainful employment and first pregnancy are significantly associated with the prevalence of complications during pregnancy. For all other variables, the effects are similar to those reported independence and exchangeable.

Finally the pairwise correlation structure indicates the significance of economic status, wanted pregnancy, primary education, secondary education, age at marriage and duration of pregnancy. Again the results are similar to the estimates based on working independence correlation structure.

We estimated the parameters and their respective standard errors assuming independence, exchangeable, autoregressive and pairwise correlation structures within the repeated measures of the outcome variable at different follow-ups. We found that the estimated standard errors of different parameters are not very similar. We observed estimates obtained under the assumption of pairwise correlation within the responses having greater standard errors than the others. Table 4 compares the relative efficiencies of the parameters obtained from different methods with respect to parameters obtained under the assumption of independence correlation structure.

It is shown that for almost all variables the estimates obtained under exchangeable correlation are more efficient estimators as compared to the others. The relative efficiency of the estimated coefficient of duration of pregnancy is 1.045 under exchangeable correlation structure. Only pairwise correlation structure displays a lower relative efficiency compared to independence correlation structure for all the variables except duration of study.

Table 4: Relative efficiencies of the coefficients under different correlation models

Variable	Pairw.	Exch.	AR
Constant	0.715	1.225	1.089
Economic Status	0.684	1.319	1.096
Wanted Preg.	0.667	1.355	1.095
Gainful Empl.	0.667	1.357	1.086
Prim. Education	0.669	1.350	1.094
Sec. Education	0.687	1.294	1.089
#(Preg's) = 0	0.677	1.323	1.088
#(Preg's)$\geq$ 5	0.673	1.346	1.094
Age at Marriage	0.681	1.351	1.100
Duration	1.095	1.045	1.045

5 Discussion

Pregnancy related complications are very common in the rural areas of Bangladesh. This paper makes an attempt to identify the factors associated with some life threatening and high-risk complications commonly confronted by the rural women during childbearing. The generalized estimating equations approach is employed in order to analyze the repeated observations during pregnancy emerging from a follow-up study. The logistic regression model based on exchangeable correlation structure for the repeated observations appears to be the best.

For all correlation structures considered in this study, only economic status and in some cases gainful employment have demonstrated positive association and all other variables showed negative association with the prevalence of complications during pregnancy.

Although it is surprising that respondents belonging to higher socio-economic status have reported more complications than their counterparts during pregnancy, there might be some explanations. Economic status and lifestyle are more or less related to one another. Women from lower socio-economic status are exposed to more physical labor during pregnancy that might help them to avoid some of the complications.

The findings indicate that the risk of suffering from complications is higher if the pregnancy is unwanted. It is clearly evident from all the models that the prevalence of complications decreases steadily with the level of education. This may be because the educated patients are well informed about the pregnancy related complications and the health care activities such as nutritional foods, light physical work, timely medical checkup etc., which help them avoiding some complications during pregnancy as compared to their counterparts. It is demonstrated in the model that the risk is significantly higher among the respondents who reported their age at marriage lower than 15 years. In other words, lower age at marriage has an accumulated effect in the subsequent pregnancies as well. This shows the health problems associated with marriage at very young ages in the rural areas of Bangladesh. Those who reported their age at marriage more than fifteen years are less likely to suffer from severe complications during index pregnancy. The results confirmed the belief that marriage of girls at a very young age can result in

long term complications even at an older stage of childbearing. Similarly, the results show that the risk of suffering from complications decreases with an increase in the duration of pregnancy. This might be attributable to the psychological factors associated with every pregnancy. At the initial stage of pregnancy, the women feel various problems due to their psychological as well as physical changes and once they become used to the pregnancy, the false reporting of complications decreases to some extent.

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