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Fitting GEE Models and Goodness-of-Fit Tests for Delivery Complications 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 Generalized Estimating Equations (GEE) models with different correlation structures are used and tested for the maternal morbidity data by kappa-like statistic. 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 and kappa-like statistic shows that GEE model with exchangeable correlation structure fitted the data well.

Keywords: Repeated Observations, GEE, Goodness-of-Fit, Antenatal Morbidity, Correlation Structures, Logistic Regression.

INTRODUCTION

There are strong relationships between various maternal morbidities and maternal mortality and, in addition, various socio-economic factors are also found to be associated with both maternal morbidity and maternal mortality (Fortney & Smith, 1999; Jejeebhoy, 1997; Okolocha *et al.,* 1998. However, there is little information on the extent and determinants of such morbidity and mortality in developing countries like Bangladesh (BRAC, 1994). Rochat *et al.,* (1981) showed that a substantial share, (26 %) of all pregnancy-related deaths was attributed to induced abortion. In Bangladesh, the most important causes of maternal deaths are eclampsia, septic abortion, postpartum sepsis, obstructed labour and antepartum and postpartum hemorrhage (Chen *et al.,* 1974; Rochat *et al.,* 1981; Khan *et al.* 1986; Koenig *et al.,* 1988; Fauveau *et al.,* 1989). It is observed that prior to deaths, most of the pregnancies are attended either by traditional practitioners or are not attended at all (Fauveau *et al.,* 1989; Goodburn *et al.,* 1995). These are only reflections of the poor healthcare facilities during the pregnancy as well as at the time of delivery. It is evident that in India 18 % of the women reported problems during antenatal period and an equal proportion during delivery (Bhatia, 1995). In another study, Bhatia (1993) also indicates that most common problems in a south Indian community include weakness, anemia, and lower abdominal pain. It is noteworthy that maternal health is greatly affected by a lack of adequate nutritional intake. It is found that nutritional interventions during pregnancy such as calcium supplementation reduces the risk of high blood pressure and pre-eclampsia (Kulier *et al.,* 1998). In other words, a properly monitored antenatal care services can reduce the incidence of pregnancy related complications for both short and long terms.

For women in the developing countries, with the present high level of fertility, the life time risk of deaths related to pregnancy and childbirth is estimated by WHO to be 4-5 hundred times as high as those in the privileged societies (Ray, 1995). The causes of this problem are deeply rooted in the adverse social, cultural, political and economic environment of societies and especially the environment that societies create for women. In spite of all medical advancement, women are sinking towards death every minute due to complications of pregnancy.

Community level data on maternal morbidity in developing countries are inadequate. Most studies on this subject are clinic or hospitals based, but as a huge segment of women usually do not visit such facilities, available figures do not represent the actual enormity of the problem.

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Pregnancy anemia is emerging as a most important cause of maternal morbidity and mortality in all developing countries. It results in various pregnancies related complications. Bhatt (1995) presented the condition of the Indian women showing surprisingly that many pregnant women with anemia many have no symptoms because the body system has adjusted to reduced hemoglobin mass. There may be vague complaints such as ill health, fatigue, loss of appetite, exertional dyspnoea, palpitation. None of these are specific for anemia and may be present in many other conditions.

According to Haththotuwa *et al.,* (1995), maternal deaths and morbidity due to postpartum hemorrhage are 50 times commoner in developing countries than in England and Wales. Primary postpartum hemorrhage is defined as the loss of 500 ml or more of blood per vagina during the first 24 hours after delivery of the baby. But in most Asian countries, the lower value is taken because the Asian women are unable to cope with a larger amount of blood loss as they are of smaller built and, therefore, have less blood volume, less well nourished and tend to have a lower antenatal hemoglobin value than their Western counterparts. (Ratnam and Mary, 1989).

Bhargava *et al.,* (1991) observed in their study that income, type of housing, type of family, age at marriage, maternal education have a direct bearing on pregnancy and its outcome. The women's health and well being are most influenced by unwanted pregnancies, multi parities which lead to greater harm than the occasional side effects of some of the contraceptives (Ray, 1995). Gainful Employment is another important factor. Working and earning women in Bangladesh have no liberty to spend what they earn. Manual work and poor nutrition is certainly associated with the risk of prematurity and even some of the medical complications of pregnancy.

In the Special issue on Safe Motherhood of the Journal of Indian Medical Association, almost all the authors suggested to advise the women to avoid pregnancy too early, too late, too frequently and too close and emphasized on raising the educational status of women. According to Choolani and Ratnam (1995), if one were to identify one strategy that would change tide of maternal death, it would be female literacy. Education allows the women to take better charge of themselves; it improves their economic power and better social and legal status.

Akanda *et al.,* (2005a) reported that the estimator of the correlation based on conditional residuals was nearly efficient when compared with maximum likelihood. This estimator also yielded more efficient estimates of the correlation than the usual GEE estimator that was based on unconditional residuals. For the diabetes mellitus study, Akanda *et al.,* (2005b) would recommend that the kappa value for the GEE model with quadratic terms indicated better prediction than the GEE models without quadratic terms. That is, the GEE models with quadratic terms was fitter well. In another study the goodness-of-fit tests suggest that the model with only main effects did not fit the data well. The parameter estimates and the goodness-of-fit tests obtained here were very similar to the results obtained by using a weighted least squares approach (Akanda *et al.,* 2005c).

The Bangladesh Institute of Research for Promotion of Essential and Reproductive Health and Technologies (BIRPERHT) conducted a study on maternal morbidity in rural Bangladesh 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 a report (Akhter *et al.,* 1996). We analyzed the data from the prospective survey for this paper.

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 during pregnancy. This study is based on a follow-up study and repeated measures were considered for the outcome variable of interest.

Data:

In this study, 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 was used in the present 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 from each selected district was chosen randomly. At the end, two unions from each selected thana were considered as study area. 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.

For this analysis we selected 993 pregnant women out of 1020 who had at least one antenatal follow-up. To avoid complications arising from the association among repeated observations on the same individual, we considered only first occurrence of specific disease conditions in any follow-up. Among the selected pregnant women, progressively large proportions were lost to follow-up at each subsequent interview. Table 1 shows the exact number of respondents interviewed during each follow-up.

Table 1: The number of respondents interviewed during each follow-up period (n=993)

Follow-up	Frequency	Percentage
1	992	97.3
2	917	89.9
3	771	75.6
4	594	58.2
5	369	36.2
6	145	14.2
7	34	3.3
8	1	0.1

Respondents entered into the study at different times in their pregnancies; hence we observe that after the first two follow-ups the number of respondents decreased sharply. Information on treatment corresponding to specific disease condition at follow-up was considered to examine differentials in the use of maternal health services. The data were collected through participant interview of the selected pregnant women during each 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.

Variables:

The factors that contribute to maternal morbidity are too numerous to enumerate. The causes are multiple, interrelated and tiered. Some of the major ones include malnutrition and anemia, infections, hemorrhage, fits, convulsion, vesico vaginal fistula, recto-vaginal fistula, prolapse, 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 they may have serious social and physical consequences for women. The main medical causes include anemia, septic abortion, hemorrhage, eclampsia etc. Though there are numerous factors, we considered only a few selected variables in our study due to unavailability of data on those factors.

Response Variables:

Presence of complications such as hemorrhage, fits, convulsion, cough or fever for more than 3 days or Edema are considered as disease 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 in this study are food supplied, 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 with two categories 0 and 1 where, 0: Age at marriage ≤ 15, and 1: Age at marriage > 15. In food supplement we consider normal food as the reference group. We have introduced two design variables for education. These are primary education and secondary education. The respondents without having any formal schooling are the reference category. There are two more design variables included in this study for number of pregnancies prior to the index pregnancy and these are (i) number of prior pregnancies 0, and (ii) number of prior pregnancies 5 or more. In this case, the number of prior pregnancies 1-4 is considered as the reference category.

Table 2: Percent distribution of respondents by complications during pregnancy and by selected characteristics

Variable	Category	Complications	
		No	Yes
Food supplied	Diet	62.4	37.6
	Normal	51.3	48.7
Economic Status	Low	66.9	33.1
	High	59.6	40.4
Wanted Pregnancy	No	60.2	39.8
	Yes	68.3	31.7
Gainful Employment	Unemployed	65.9	34.1
	Employed	64.8	35.2
Education	Primary	69.9	30.1
	Secondary	71.1	28.9
No. of Pregnancy	0	61.8	38.2
	5 +	62.8	37.2
	1 – 4	65.6	34.4
Age at Marriage	≤ 15	63.8	36.2
	15 +	69.0	31.0

Table 3: Number and Percentage of Respondents at Different Follow-ups by Complication Status

Follow Up	Complications				Total
	No		Yes		
	N	%	N	%	N
1	565	57.0	427	43.0	992
2	623	67.9	294	32.1	917
3	534	69.3	237	30.7	771
4	418	70.4	176	29.6	594
5	245	66.2	125	33.8	370
6	101	68.2	47	31.8	148
7	23	67.6	11	32.4	34
8	0	0..0	1	100.0	1

Table 2 represents percent distribution of respondents by complications during pregnancy and by selected characteristics. Data show that 33 percent of the respondents of low economic status suffer from one of the conditions as compared to that of 40.4 percent of the respondents of high economic status. Although it is surprising that respondents belonging to higher socio-economic status have reported higher percentage with complications during pregnancy, there might be some explanations. Women from lower socio-economic status are exposed to more physical labor during pregnancy that might help them to avoid some of the complications. Economic status and lifestyle are more or less related to one another. Respondents from low economic status are supposed to do their usual household works while the women from high economic status remain less exposed to physical work that might lead to complications.

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 %). The proportion of respondents reported to have complications during pregnancy does not show any difference by their employment status.

The table also shows that the proportion of respondents with complications decreases with level of education. Among the respondents who do not have any formal education, 38.2 percent reported complications during pregnancy, whereas 30.1 percent of the respondent having primary education and 28.9 percent with secondary education reported complications. This may be considered as the reflector of the fact that women having some education are well informed about the pregnancy- related complications and the health care activities such as nutritional foods, light physical work, timely medical checkup etc. That is why, they can avoid some complications during pregnancy as compared to that of the respondents with no formal 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 four 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. Thirty eight percent of the women with first pregnancy and 37 percent of the women with fifth or higher pregnancies reported to have complications as compared to that of 34 percent among those who have had 1-4 previous pregnancies.

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 (Table 2). 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. At that time, physically as well as mentally they are unfit to become a mother.

Table 3 represents the follow-up distribution of respondents with or without complications. We observe that the number of respondents decreases rapidly as number of follow up increases. We started with 992 respondents and gradually we found only one respondent at the last follow-up. However, the distribution of available respondents shows that at the first follow up, more than 40 percent had one or more complications. This number is around 30 percent at the second to seventh follow-ups. But at the last follow up, we had only one respondent and she had some complications.

Generalized Estimating Equations:

In this study, the Generalized Estimating Equation (Zeger & Liang, 1986; Liang & Zeger, 1986) is applied to observe how the certain covariates are associated with repeated observations on status of complications at different follow-ups. Here, the GEE has been applied to the data of one to eight repeated binary observations of the registered patients at BIRPERHT. We applied the GEE method for unequal number of follow-ups.

Let us consider that i-th individual is observed for T_i occasions. Thus, we have a T_i X 1 random vector of responses for the ith individual where the response variable is binary.

Notationally, $Y_i = [Y_{i1}, Y_{i2},\ldots,Y_{iTi}]$ $\quad i = 1, 2, \ldots, N$

Here the response variable is dichotomous. We took k independent variables, so for ith individual we have a T_i X k matrix of covariates.

$X_i = (X_{i1}\ X_{i2,}\ \ldots,X_{iTi})^T$

where,

$X_{ij} = (X_{ij1}\ \ X_{ij2,}\ldots,X_{ijk})$; $\quad j = 1, 2, \ldots, T_i$.

The mean vector is $\mu_i = [\mu_{i1}, \mu_{i2}, \ldots, \mu_{iTi}] = p_i$;

where, $\mu_{ij} = p_{ij} = Pr(y_{ij} = 1| X_{ij})$ $\quad j =1,2,\ldots,T;$ $\quad i =1,2,\ldots,N.$

The probability of not developing the disease for i-th individual at j-th occasion is

$1 - p_{ij} = 1 - \mu_{ij}$.

So the variance of y_{ij} is

$p_{ij}(1 - p_{ij}) = \mu_{ij}(1 - \mu_{ij})$

Following the quasi-likelihood approach, Liang and Zeger expressed the GEE for β of the form

$$U(\beta)=\sum_{i=1}^{N} D_i^T V_i^{-1}(y_i-\mu_i)=0 \qquad (1)$$

where,

$$D_i=\frac{\delta\mu_i}{\delta\beta^T}$$

and V_i is a working or approximate covariance matrix of Y_i, chosen by the investigator. This working covariance matrix can be expressed in the following form:

$$V_i=A_i^{\frac{1}{2}} R_i(\alpha) A_i^{\frac{1}{2}}$$

where, $A_i = \text{diag}[\text{var}(Y_{i1}),\ldots, \text{var}(Y_{iTi})]$, is a T_i X T_i diagonal matrix

α represents a vector of parameters associated with a specified model for corr (Y_i). Here the form of the estimating equation is similar to the quasi-likelihood estimating equations described in McCullagh and Nelder

(1989, ch.9). With a binary response vector, these equations simply generalize the ordinary logistic regression estimating equations by introducing a working or approximate correlation matrix, $R_i(\alpha)$.

This leads to estimating equations of the form

$$U(\beta) = \sum_{i=1}^{N} X_i^T A_i V_i^{-1} (y_i - \mu_i) = 0 \qquad (2)$$

In addition to the mean and covariance of the vector of responses Liang and Zeger (1986) suggested to take a T X T working correlation matrix for each Y_i. The correlation matrix [denoted by $R_i(\alpha)$] is working in the sense that it is an approximation to the actual correlation matrix of Y_i. It is assumed that $R_i(\alpha)$ is fully specified by the vectors of unknown parameters α that is same for all subjects.

The GEE approach allows the time dependence to be specified in a variety of ways. The followings are some common specifications for corr (Y_i).

- Identity matrix: $R_i(\alpha) = I$,
- Exchangeable correlation: corr $(Y_{is}, Y_{it}) = \alpha$; $s \neq t$.
  So that the correlation matrix for ith individual is defined as
  $R_i(\alpha) = \text{corr}(Y_{is}, Y_{it}) = \alpha$; $s \neq t$.
- Autoregressive correlation: $\text{corr}(Y_{is}, Y_{it}) = \alpha^{|s-t|}$; $s \neq t$. Here, a is a correlation value and thus a fraction. So, in this types of correlation, we consider that for all $t > k$, $\alpha^{|s-t|} > \alpha^{|s-k|}$
  Then the correlation matrix can be defined as
  $(R_i(\alpha))_{st} = \text{corr}(Y_{is}, Y_{it}) = \alpha^{|s-t|}$; $s \neq t$.
- Unstructured or Pairwise Correlation: corr $(Y_{is}, Yit) = \alpha_{st}$; $s \neq t$.
  The correlation matrix can be written as
  $(R_i(\alpha))_{st} = \text{corr}(Y_{is}, Yit) = \alpha_{st}$; $s \neq t$
  where, $\alpha_{s,s+1} = \alpha_{s+1,s}$; $s = 1, 2, \ldots, T$;

Kappa-like Statistic:

We used a kappa-like statistic to assess model fit for GEE categorical response models. Historically, the kappa coefficient has been used to determine the agreement of binary and categorical outcomes between raters. We described details in the previous paper Akanda et. al. (2005b). The kappa-like statistic takes on a value of 0.0 for the intercept-only model and a value of 1.0 for the saturated model. An advantage of the statistic is that no decisions need be made when calculating it, unlike methods based on covariate partitioning (where to partition, how many partitioned categories), Hosmer and Lemeshow's approach, rank correlation methods and classification tables. Interpretation of the kappa statistic is not always straightforward; see Fleiss (1971) and Landis (1977) for details. Similar to Landis's (1977) labeling of kappa values, Williamson *et al.,* (2003) suggest interpreting the values of kappa for this classification index as follows:

Kappa-like Statistic	Fit of Model
0.00-0.20	Poor
0.21-0.40	Fair
0.41-0.60	Good
0.61-1.00	Excellent

We fit a GEE logistic regression model with main effects terms only.

RESULTS AND DISCUSSIONS

In this section, we present the resulting estimates of the co-efficients of the covariates obtained under the assumption of different correlation structures. The following tables provide the estimates of the parameters of the link function along with their estimated standard error, associated Wald test and the Odds ratio.

Under the independence assumption (Table 4), we observe that economic status, wanted pregnancy, primary education, secondary education, age at marriage, and duration of pregnancy are significant at 1% 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 63 percent 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 declined by one-third than that of

Table 4: GEE Estimates for Maternal Morbidity under the Assumption of Working Independence within the Responses

Variable	Estimated Coefficient	Estimated Standard Error	Wald Statistic	Odds Ratio
Constant	- 0. 0199	0. 0981	- 0. 2035	0. 9802
Food supplied	-0.1667	0.1034	-1.6122	0.8465
Economic Status	0. 4927	0. 0909	5. 4208**	1. 6368
Wanted Pregnancy	- 0. 4041	0. 0798	- 5. 0663**	0. 6676
Gainful Employment	0. 0640	0. 0761	0. 8417	1. 0661
Primary Education	- 0. 3934	0. 0813	- 4. 8376**	0. 6748
Secondary Education	- 0. 4825	0. 1102	- 4. 3790**	0. 6172
No. of Pregnancy 0	0. 0343	0. 0862	0. 3976	1. 0349
No. of Pregnancy ≥ 5	- 0. 1699	0. 1049	- 1. 6192	0. 8438
Age at Marriage	- 0. 2202	0. 0765	- 2. 8787**	0. 8023
Duration of Study	- 0. 1146	0. 0229	- 5. 0074**	0. 8917
Chi-square Value = 436.02869	P - Value = 0. 00			
Kappa-like statistic(k)=0.51				

** Significant at 1 % level; * significant at 5 % level

Table 5: GEE Estimates for Maternal Morbidity under the assumption of Exchangeable Correlation within the responses

Variable	Estimated Coefficient	Estimated Standard Error	Wald Statistic	Odds Ratio
Constant	- 0. 0247	0. 0796	- 0. 3103	0. 9756
Food supplied	-0.1713	0.0754	2.2719*	0.8426
Economic Status	0. 4497	0. 0687	6. 5458**	1. 5679
Wanted Pregnancy	- 0. 4816	0. 0587	- 8. 2044**	0. 6178
Gainful Employment	0. 1219	0. 0564	2. 1613*	1. 1297
Primary Education	- 0. 3543	0. 0596	- 5. 9446**	0. 7016
Secondary Education	- 0. 5208	0. 0847	- 6. 1488**	0. 5940
No. of Pregnancy 0	0. 1007	0. 0646	1. 5588	1. 1059
No. of Pregnancy ≥ 5	- 0. 1745	0. 0783	- 2. 2286*	0. 8398
Age at Marriage	- 0. 1394	0. 0570	- 2. 4456*	0. 8699
Duration of Study	- 0. 1190	0. 0221	- 5. 3846**	0. 8878
Chi-square Value = 810. 0466	P - Value = 0. 00			
Kappa-like statistic(k)=0.63				

** Significant at 1 % level; * significant at 5 % level

Table 6: GEE Estimates for Maternal Morbidity under the assumption of Autoregressive Correlation within the responses

Variable	Estimated Coefficient	Estimated Standard Error	Wald Statistic	Odds Ratio
Constant	- 0. 0389	0. 0904	- 0. 4305	0. 9618
Food supplied	-0.1702	0.0941	-1.8087	0.8435
Economic Status	0. 4945	0. 0832	5. 9411**	1. 6397
Wanted Pregnancy	- 0. 3984	0. 0729	- 5. 4671**	0. 6714
Gainful Employment	0. 0704	0. 0695	1. 0126	1. 0729
Primary Education	- 0. 3985	0. 0744	- 5. 3574**	0. 6714
Secondary Education	- 0. 4935	0. 1011	- 4. 8817**	0. 6105
No. of Pregnancy 0	0. 0389	0. 0789	0. 4928	1. 0396
No. of Pregnancy ≥ 5	- 0. 1718	0. 0959	- 1. 7908	0. 8421
Age at Marriage	- 0. 2180	0. 0700	- 3. 1132**	0. 8042
Duration of Study	- 0. 1118	0. 0217	- 5. 1613**	0. 8943
Chi-square Value = 531. 89183	P - Value = 0. 00			
Kappa-like statistic(k)=0.56				

** Significant at 1 % level; * significant at 5 % level

the undesired pregnancies. As compared to the respondents with no formal education, the prevalence of complications decreases substantially for both respondents with primary education (33 %) and secondary education (38 %). In other words, the prevalence of complications decreases steadily with level of education. It is noteworthy that the prevalence of complications decreases significantly (one-fifth) if the age at marriage is 15 years or higher. It is surprising that the prevalence of complications is reportedly higher during the initial stage of pregnancy and decreases significantly at the advanced stage. The kappa-like statistic is good for GEE model of independence correlation structure.

Table 5 shows that all the covariates used in this study except the first pregnancy are significant under the exchangeable correlation assumption. In addition to positive association between economic status and prevalence of complications as observed from Table 4, we find that gainful employment exerts positive effect and food supplement negative effect as well. There is 13 percent 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. There are 16% decreases in the risk of suffering from these complications among the women who take diet food as compared to that of women who take normal food. Unlike the results presented in Table 4, the exchangeable correlation assumption reveals that 5 or more previous pregnancies can decrease the prevalence of complications. In this case the kappa-like statistic respond excellent for GEE model of exchangeable correlation structure.

The GEE for autoregressive structure (Table 6), represents 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 in Tables 4 or 5 and the kappa-like statistic is good for GEE model of autoregressive correlation structure.

Table 7: GEE Estimates for Maternal Morbidity under the assumption of Pairwise Correlation within the responses

Variable	Estimated Coefficient	Estimated Standard Error	Wald Statistic	Odds Ratio
Constant	0. 0130	0. 1370	0. 0946	1. 0130
Food supplied	-0.1467	0.1531	-0.9582	0.8636
Economic Status	0. 4621	0. 1334	3. 4641**	1. 5873
Wanted Pregnancy	- 0. 3860	0. 1197	- 3. 2255**	0. 6798
Gainful Employment	0. 0327	0. 1135	0. 2878	1. 0332
Primary Education	- 0. 3827	0. 1213	- 3. 1561**	0. 6820
Secondary Education	- 0. 4204	0. 1601	- 2. 6265**	0. 6568
No. of Pregnancy 0	0. 0251	0. 1269	0. 1978	1. 0254
No. of Pregnancy ≥ 5	- 0. 1473	0. 1560	- 0. 9439	0. 8630
Age at Marriage	- 0. 2500	0. 1133	- 2. 2060*	0. 7788
Duration of Study	- 0. 1124	0. 0205	- 5. 4879**	0. 8937
Chi-square Value = 194.40	P - Value = 0. 00			
Kappa-like statistic(k)=0.38				

** Significant at 1 % level; * significant at 5 % level

Table 8: Relative Efficiencies of the Estimates Obtained by GEE Assuming Independence, Exchangeable and Autoregressive Correlation

Variable	Independence	ExchangeableCorrelation	Autoregressivecorrelation
Constant	1.397	1.721	1.516
Food supplied	1.481	2.031	1.627
Economic Status	1.468	1.942	1.603
Wanted Pregnancy	1.500	2.039	1.642
Gainful Employment	1.492	2.012	1.633
Primary Education	1.492	2.035	1.630
Secondary Education	1.453	1.890	1.584
No. of Pregnancy 0	1.472	1.964	1.608
No. of Pregnancy ≥ 5	1.487	1.992	1.627
Age at Marriage	1.481	1.988	1.619
Duration of Study	0.895	0.928	0.945

Finally the pairwise correlation structure (Table 6), 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 presented in Table 4 and the kappa-like statistic is fair predictor for GEE model of pairwise correlation structure.

In all cases, only economic status and in some cases gainful employment have demonstrated positive association and all other variables show negative association with the prevalence of complications during pregnancy. This has been displayed in the bivariate analysis as well. On the other hand, respondents who wanted the index pregnancy are less likely to suffer from complications than those who did not want the index pregnancy.

It is clearly evident from all the models that the prevalence of complications decreases steadily with the level of education. Also the education plays an important role to decrease the rate of disease. This may be because the educated patients are well informed about the complications and know how to avoid these complications.

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. Those who reported their age at marriage more than fifteen years are less likely to suffer from severe complications during index pregnancy.

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.

Comparison of Estimates Obtained from Different Methods:

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 8 compares the relative efficiencies of the parameters obtained from different methods with respect to parameters obtained under the assumption of pairwise correlation.

The table represents that for almost all the variables, the estimates obtained under the assumption of exchangeable correlation provide much more efficient estimators as compared to the others. The relative efficiency of the estimates under exchangeable correlation versus the pairwise correlation is 1.94 for economic status, 2.04 for wanted pregnancy, 2 for gainful employment, 2.04 for primary education, 1.9 for secondary education, 2 for both first pregnancy and 5 or more pregnancies prior to the index pregnancy, and 2 for age at first marriage as well. The relative efficiency of the estimated coefficient of duration of pregnancy is almost 93 percent under exchangeable correlation structure.

Conclusion:

The 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. In this paper, 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. The findings indicate that the risk of suffering from complications is higher if the pregnancy is unwanted. However, there is a negative association between level of education and prevalence of complications. 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.

For his study, we would recommend that the kappa-value for the GEE model with exchangeable correlation structure indicated better predictor than the GEE model with other correlation structures. That is, the GEE models with exchangeable correlation structure are fitted well.

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