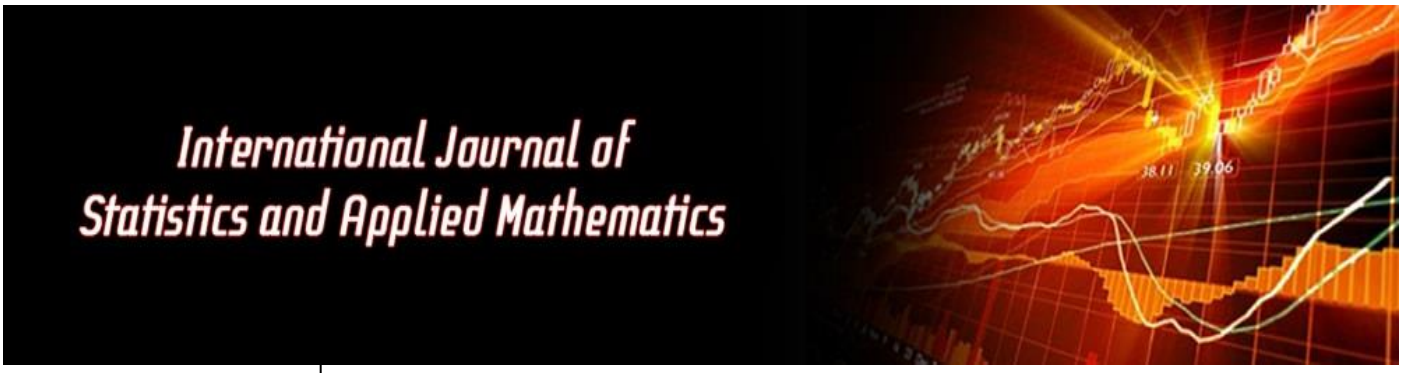

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Logistic regression methodology for assessing the contributing factors of low birth weight

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Abstract
The objective of this study was to inspect elements which impact the low birth weight in new-born babies. Low birth weight can be quantified over the maternal, nutritional and socio-economic factors, taking important properties on Low birth weight as it can lead to largest new-born sicknesses. Logistic regression model was utilized in this study to identify the influential variables in predicting Low birth weight and used babies' histories in the Medical Officer of Health office Akkaraipattu. Medical records of 410 babies accessible over the period from January 2016 to December 2016, were used for the examination. Obligatory data analysis was completed using Minitab, Excel and SPSS software.
Based on this study, it was invented that the occurrence of Low birth weight in the designated region is 17.81% with a mean Low birth weight of 2193.01 g for the year 2016. Mothers' weight increase throughout gestation, educational position, parity, birth intermission, hypertension, preceding Low birth weight history, history of miscarriage and passive smoking were considerably accompanying (positively / negatively) with Low birth weight (p<0.05). The fitted logistic regression model shows that the passive smoking has the uppermost odd ratio compared to other monitoring variables. Study consequences endorse that there is a vital requirement to develop health literateness of females on numerous features of pregnancy and extra training essentials to be connected to field level health employees to upsurge their communication skills as well as their competence to classify and manage high risk pregnancies.

Keywords: Logistic regression, low birth weight, maternal factors, pregnancy, health, morbidity

1. Introduction
Birth weight is a potent predictor and indicator of infant growth and existence. Infants born with LBW always deal with detriments from the commencement of their life and face extremely poor survival, which can cause neonatal mortalities. In Sri Lanka, it is always considered to be a middle income country that has effectively reduced maternal, infant and child mortality toward levels comparable with those of developed countries. According to the World Health Organization (WHO), 31% of neonatal deaths could be accredited to pre-term birth (PTB) and LBW (WHO Technical Consultation, 2004) [9] and LBW has been defined by the WHO as weight at birth of less than 2,500 grams (5 pounds, 8 ounces) (UNICEF/WHO, 2000) [8]. Even though the LBW is a major health issue in developing countries, mandatory and satisfied actions have not been taken yet to completely overcome this issue. The determinants associated with this foremost problem are such as maternal age, maternal engagement weight, height and body mass index (BMI), ethnicity, equality, history of LBW infants, birth interval, recorder haemoglobin levels, hypertension, diabetes, anaemia, mode of delivery and some other factors. The primary reason of low birth weight is premature birth (birth before 37 weeks gestation). Being born early means a baby will be in the mother's uterus for a short period of time than usual deliveries. So, baby has a fewer period to grow and gain weight as considerable amount of a baby's weight is gained during the ultimate portion of pregnancy. Socioeconomic conditions, poverty, education level, violence during pregnancy, and early marriages are also essential contributing factor for low birth weight infants (Khan, M. W., Arbab, M., Murad, M., Khan, M. B., & Abdullah, S., 2014) [3]. Within the districts of Sri Lanka, Nuwara Eliya district has the highest percentage of LBW recorded as 20.6%, Polonnaruwa district has 15.3% and Ampara district has the percentage of 15.8% of LBW

infants (Annual Report Family Health Programme – 2013) (Ministry of Health, Sri Lanka, 2013) [4].
There are eight divisions of MOH Health Care Centers (Clinic Center) is located under Akkaraipattu Divisional Secretariat Division. MOH office is functioning in a building which has been situated near the base hospital, Akkaraipattu. MOH office mainly carries the services to protect the people from epidemic diseases such Dengue, Malaria, HIV aids etc. and improve the maternal health and to reduce child mortality.

2. Methodology

2.1 Objective

This study has been carried out to examine the characteristics and factors that highly associated with LBW, to bring out the awareness about the LBW among the pregnant mothers as well as the whole population.

2.2 Data collection method, study area and sample size

Cross-sectional data collection method was used for this study, conducted in Medical Officer in Health (MOH) Office of Akkaraipattu Divisional Secretariat (DS) Division. The medical history of mothers of 410 babies, recorded and maintained at the Akkaraipattu MOH, the residents of that DS Division were eligible for the study to analyse the maternal, socio-economical and dietary factors impacts the LBW. Singleton LBW babies among them (73), born over a period of 12 months from January 2016 to December 2016 have been obtained. The control was the group of 337 mothers of normal weight babies with singleton delivery during the same period yielding for the study. They were randomly chosen and accumulated into this study based on the data necessity to analyse the factors.

2.3 Study variables

The outcome variable y was defined as a binary response variable conforming to the risk of an infant born with LBW. That is,

$$Y = \begin{cases} 1, \text{ if an infant is LBW} \\ 0, \text{ Otherwise} \end{cases}$$

The recognized explanatory variables X include maternal age, level of education, initial weight, weight gain, BMI range, hypertension, parity, birth interval, HB range, previous LBW history, miscarriage history and passive smoking.
Thus, this was a descriptive prevalence study to inspect the characteristics and factors that highly related with LBW, a Likert scale statement was used to categorise the level of education of pregnant mothers rated as illiterate = 1, primary = 2, junior secondary = 3, senior secondary = 4, collegiate = 5 and degree = 6 and furthermore four binary response variables (history of miscarriages, previous delivery of LBW, passive smoking and hypertension) have been analysed and the significant factors were identified. A logistic regression model consisting of those significant variables also has been fitted to identify the probability of high risk group of pregnant mothers who could give a LBW delivery to reduce the neonatal mortality and morbidity.

2.4 Models and techniques

Logistic Regression model was used to identify the significant factors which contributes for LBW by assessing the odds ratios (OR) and their 95% confidence interval (CI). Logistic Regression is a very general systematic implement that is operated in many epidemiological studies to forecast a binary response variable through predictor variables. Logistic regression model with the probability of occurrences of LBW can be presented as follows:

$$P\,(\,y_i) = \frac{\exp(\sum_i \beta_i x_{ik})}{1+\exp(\sum_i \beta_i x_{ik})'} \quad (1)$$

where, i= 1,2,3,……,n denotes the predictors and k = 1,2,3,… denotes the number of subjects.
A measure of association between an exposure and an outcome is called an odd ratio (OR). The OR represents the probabilities that an outcome will occur given a particular exposure, compared to the probabilities of the outcome occurring in the non-appearance of that exposure.

$$\text{OR} = \frac{\text{P}\,(\,\text{y}_\text{i})}{1-\text{P}\,(\,\text{y}_\text{i})} \quad (2)$$

When a logistic regression is designed, the regression coefficient (β_i) is the estimated increase in that log odds of the outcome per unit increase in the value of the exposure. In supplementary arguments, the exponential function of the regression coefficient (e^{β_i}) is the odds ratio related with a one-unit increase in that exposure.

$$\log(OR) = \log\frac{P\,(\,y_i)}{1-P\,(\,y_i)} = \sum_i \beta_i x_{ik} \quad (3)$$

If; OR=1 then, exposure does not affect odds of outcome
OR>1 then, exposure associated with higher odds of outcome
OR<1 then, exposure associated with lower odds of outcome
To estimate the precision of the OR, the 95% confidence interval (CI) is used. A low level of precision of the OR, is indicated by a large CI whereas a higher precision of the OR is indicated by a small CI (Szumilas, 2010) [7].
All the specified determinants of LBW available in the MOH records were characterized and essential measurements were gathered. Under 5% significance level, the Minitab 16 statistical package, SPSS and Excel software were used for data analysis.

3. Results & discussion

From Figure 1, it is illustrated that for the age interval of 15-19 the delivery of LBW is nearly 2.84 times greater than that of normal birth weight. For the age interval from 20-24 the delivery of normal birth weight babies is 2.26 times high compare to LBW. Also it reveals clearly that the majority of mothers of LBW (62.9%) have been identified in both the groups belonged to age group of 25 -34 years.

Table 1 shows mean and standard deviation of the selected variables associated with the babies born in 2016 in the Akkaraipattu MOH division. 18% of mothers had children with low birth weight, which shows that the odds of a LBW baby are 0.18/0.82 = 0.22, meaning that having a LBW baby is less likely than having a baby of normal weight (because the odds are less than 1). This study enclosed 410 mothers, and the mean age was 28.64 (±5.624) years. Teenage mothers founded to be 5.12%, whiles mothers above 35 years old founded to be 16.1% of the 410 mothers examined.

Table 1: Descriptive Statistics of the factors Influencing LBW

Variables	Mean	Standard Deviation
LBW	0.18	0.383
Age (in years)	28.64	5.624
Initial Weight (in kg)	57.248	12.5269
Weight Gain (in kg)	9.815	7.1179
BMI	23.666	4.6089
HB (mg/dl %)	11.570	1.3150
Hypertension	0.37	0.482
Parity	2.28	1.487
Birth Interval	1.2647	1.68507

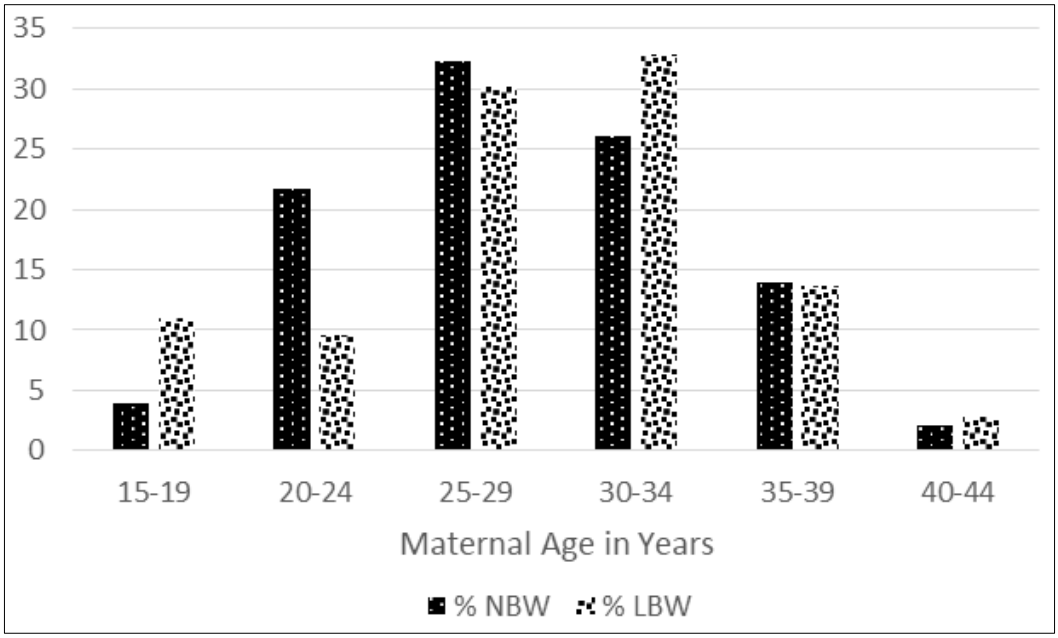

Fig 1: Distribution of Maternal Age and Normal Birth Weight & Low Birth Weight in 2016

In the study sample mean birth weight of LBW babies was 2.19 kg with SD of 0.399 kg and of normal birth weight babies was 3.11 kg with SD of 0.353kg.

The results of Table 2 show that, there was a significant association between maternal age and birth weight (p-value =0.041) also there was a significant association (p-value =0.001) between education level of the mothers and LBW, explains that about 30.14% of mothers of low birth weight babies were junior secondary, 63.01% had an education of senior secondary and above. From the previous studies similar findings were suggested that maternal age, education and socioeconomic status were found to be significant factors associated with the birth weight of the new-born (Roy, S., Motghare, D. D., Ferreira, A. M., Vaz, F. S., & Kulkarni, M. S., 2009) [6].

There was a significant difference perceived between the two groups with regards to initial weight of the mother (p-value=0.039) and weight gain during pregnancy (p-value = 0.000), thus 65.75% mothers of LBW baby gained less than 8kg during pregnancy as compared to77.45% mothers of normal birth weight babies covers the group of weight gain from 4kg to 16kg based on their nutrition intake during the pregnancy. However no difference was observed with regards to the Body Mass Index (BMI) (p-value=0.093). A significant difference was realized between the two groups with regards to hypertension during pregnancy (p-value=0.000), parity (p-value=0.013), birth interval (p-value=0.000).

Table 2: Association of Variables and Birth Weight

Variables	Normal Birth Weight (NBW)	Low Birth Weight (LBW)	P – value
Maternal Age (in years)			
15 – 19	22	8	Chi-Sq = 11.609 P-Value = 0.041
20 – 24	80	7	
25 – 29	131	22	
30 – 34	111	24	
35 – 39	57	10	
40 – 44	9	2	
Level of Education			
Illiterate	25	0	Chi-Sq = 20.345 P-Value = 0.001
Primary	61	5	
Junior Secondary	46	22	
Senior Secondary	89	18	
Collegiate	85	20	
Degree	31	8	
Initial Weight(in kg)			
≤ 35	4	5	Chi-Sq = 11.681 Value = 0.039
> 35 - ≤ 45	54	7	
> 45 - ≤ 55	100	20	
> 55 - ≤ 65	95	25	
> 65 - ≤ 75	52	9	
> 75	32	7	
Weight Gain (in kg)			
≤ 4	39	27	Chi-Sq = 34.773 P-Value = 0.000
> 4 - ≤ 8	83	21	
> 8 - ≤ 12	100	15	
> 12- ≤ 16	78	7	
> 16 - ≤ 20	21	1	
> 20	16	2	
BMI Range			
< 18.5	37	6	Chi-Sq = 6.424 P-Value = 0.093
18.5 ≤ — ≤ 24.9	172	31	
25 ≤ — ≤ 29.9	105	25	
≥ 30	23	11	
Hypertension			
No	232	28	Chi-Sq = 24.037 P-Value = 0.000
Yes	105	45	
Parity			
1	143	26	Chi-Sq = 14.542 P -Value = 0.013
2	85	15	
3	42	22	
4	34	5	
5	17	3	
> 5	16	2	
Birth Interval (in years)			
< 2	242	41	Chi-Sq = 27.990 P-Value = 0.000
2 ≤ — ≤ 3	77	14	
> 3	18	18	
HB Range (gm/dL%)			
< 12	160	40	Chi-Sq = 1.286 P-Value = 0.257
12 ≤ — ≤ 16	177	33	
Previous LBW History			
No	326	52	Chi-Sq = 54.235 P-Value = 0.000
Yes	11	21	
Miscarriages History			
No	305	35	Chi-Sq = 76.762 P-Value = 0.000
Yes	32	38	
Passive Smoking			
No	305	13	Chi-Sq = 182.199 P-Value = 0.000
Yes	32	60	

The variables showing the history of previous LBW, passive smoking and history of miscarriages had significant effect on the prevalence of LBW (p-value=0.000) while the level of haemoglobin was not statistically associated with the prevalence of LBW (p-value=0.257).

By considering some remarkable observations, it has been noticed that 57.5% of the LBW babies are of male and the rest is females. Also the mother of negative blood groups have some high occurrence of LBW (63.01%) compared to positive groups of blood as it was mentioned in the records of pregnant mothers with negative blood groups as “Risk Group”.

Outcomes of Table 3 show that educational level of the mothers was a significant factor for LBW (p-value = 0.000). The odds ratio 2.283 (> 1) is the statistical evidence supporting the relationship. Weight gain also showed significance (p-value = 0.008, OR = 0.872), and a one-unit increase in weight decreased the odds that a mother would give birth to a LBW baby by 12.8%. Controlling for the other variables, weight gain and parity are negatively related to the log odds of having a low birth weight baby. The parity of birth also played an important role in clarifying reasons for variation in birth weight outcomes (p-value = 0.001, OR = 0.402). Specifically, for every additional order of parity the log odds of having a low birth weight baby decreases by 91.1%.

Table 3: Multiple Logistic Regression Analysis of Effect of selected Variables on Birth Weight

	B = log(OR)	**S.E.**	**Wald**	**df**	**P-value**	**OR**	**95% C.I for OR (LCL UCL)**	
Age (in years)	-0.070	0.048	2.088	1	0.148	0.932	-2.2436	2.1036
Education Level	0.825	0.230	12.905	1	0.000	2.283	-0.7058	2.3558
Initial Weight (in kg)	-0.048	0.025	3.749	1	0.053	0.953	-2.034	1.938
Weight Gain (in kg)	-0.137	0.052	7.041	1	0.008	0.872	-2.885	2.611
Hypertension	2.286	0.572	15.949	1	0.000	9.831	1.761	2.811
Parity	-0.911	0.266	11.715	1	0.001	0.402	-3.212	1.390
Birth Interval (in years)	0.658	0.224	8.652	1	0.003	1.931	-0.269	1.585
Miscarriage	2.579	0.621	17.232	1	0.000	13.185	1.993	3.165
Previous LBW	2.202	0.977	5.083	1	0.024	9.043	1.416	2.988
Passive Smoking	4.698	0.623	56.841	1	0.000	109.741	3.996	5.3997
Constant	-1.910	2.090	0.835	1	0.361	*****	*****	*****

It was also observed from Table 3 that maternal history of mean health including hypertension (p-value = 0.000, OR = 9.831), history of miscarriages (p-value = 0.000, OR = 13.185) and other pregnancy-related medical complications such previous history of LBW (p-value = 0.024, OR = 9.043), increased the risk of giving birth to a LBW infant by the percentage of their odd ratio values. These verdicts were authenticated since the previous history of LBW and hypertension were found to be significant factors in a study conducted earlier (Yadav, H., & Lee, N., 2013) [10]. The birth interval also found to be significant (p-value = 0.003, OR = 1.931), which indicates that birth interval positively related to the log odds of having a LBW baby. For the increment of every additional year the odd ratio of having a low birth weight baby increases by 93.1%.

Finally, exposure to passive smoking during pregnancy was also found as a risk factor for LBW (p-value =0.000, OR = 109.741), with the high occurrence of LBW due to the highest odd ratio. That is, mothers who supposed to expose to passive smoking have high probability of deliver a LBW baby. However, the age coefficient and initial weight are not statistically significant (p-value = 0.148 and 0.053 respectively) whereas the others are. Controlling for the other variables, age and initial weight do not appear to be much related to the log odds of having a low birth weight baby.

Since the p-values for these two independent variables were greater than level of significance $\alpha = 0.05$, it was concluded to be excluded from the model. Further, Nagelkerke R Square is 0.772 suggests that about 77.2% of the variation in LBW can be explained by the predictor variables. So this model could be considered as a suitable predicting tool for LBW, with the selective characteristics and factors influencing the deliveries of LBW that could lead to neonatal deaths and morbidities. Therefore the finalized multiple logistic regression model is:

$$logodd(LBW = 1) = -1.91 + 0.825_{\boldsymbol{EL}} - 0.137_{\boldsymbol{WG}} - 0.911_{\boldsymbol{P}} + 0.658_{\boldsymbol{BI}} + 2.286_{\boldsymbol{HT}} + 2.579_{\boldsymbol{M}} + 2.202_{\boldsymbol{PLBW}} + 4.698_{\boldsymbol{PS}}$$

Where;

EL=Education Level — **WG**= Weight Gain
P=Parity — **BI**=Birth Interval
HT=Hypertension — **M**=History of Miscarriage
PLBW=Previous History of LBW — **PS**=Passive Smoking

This study evaluated the assistance of several risk factors to the occurrence of LBW in the Akkaraipattu MOH Division. Among the risk factors, initial weight, weight gain during pregnancy, parity, and age of the pregnant mothers were scored negative by higher proportions of mothers. However, age and initial weight of the pregnant mothers have no significant effect on low birth weight. Logistic regression analysis has been used to construct a predictive model, the outcome confirms well recognised findings which determined that education level, weight gain, parity, birth interval, hypertension, previous history of miscarriages, previous history of low birth weight and passive smoking were detrimental to neonatal weight-gain and so influences babies to LBW.

Other influential predictor for LBW in the selected MOH division was maternal health, especially among mothers who suffered hypertension during pregnancy. Known research (Raghunath, D., Kujur, A., Dixit, S., Sabnani, S., Yadav, S., & Saroshe, S., 2016) [5] has established that maternal sicknesses increase the risk of delivering LBW babies. Improving the health of a pregnant mother will always improve the health of neonate security and subsequently excludes or diminishes the occurrence of low birth weight.

One more risk factor is the passive smoking that reported in this study, the pregnant mothers having partners or people in their environment who smoke cigarettes. Consequences of Table 3 show that all pregnant mothers exposed to passive smoking has the highest odd ratio thus has a high chance of delivering low weight babies. It also shows that mothers who exposed to passive smoking during pregnancy were found to be 82.2% among the population of total low birth weight babies. That is approximately 4.6 times as possible to give birth of a LBW baby compared with non-passive smoking mothers.

Food intake during pregnancy plays a vital role in determining birth weight of an infant. That has been shown to be a key measurement in birth-weight analysis. A well-adjusted nourishment should be taken to improve maternal health as well as to minimise the delivery of low birth delivery.

A further risk contributing factor that has been identified is the birth interval. It was considered into three groups of time periods in year (less than two years, between two and three years and more than three years). Almost 56.2% of the low birth weight deliveries were occurred due to the birth interval less than two years, consequently there is a high risk of delivering a baby with low weight.

Concerning the level of education of the pregnant mothers, no one was illiterate among the mothers of those low birth weight babies and junior secondary mothers have the highest percentage of low birth occurrences (30.14%) among them. Some well-known studies (Anuranga, C., Wickramasinghe, R., Rannan-Eliya, R., Hossain, S. M. M., & Abeykoon, A. T. P. L., 2012) [1] indicate that pregnant mothers with lowest level of education has the high occurrence of low birth weight deliveries.

Consanguineous Marriages also are considered as a risk factor in this study but only very few parents have got consanguineous marriage relationship. Thus this factor was not analysed and based on the earliest histories available at the MOH Akkaraipattu it could be suggested that these consanguineous marriages can lead to delivery of low birth weight babies and that should be decreased in order to avoid such scientifically proven non fit issues.

Although there is no proven evidence for the blood groups that have some significant effects on low birth weight deliveries, it was remarked that the negative blood group has some high risk of getting adverse impacts on pregnancy as well as delivery. Based on their records it was observed that the percentage of miscarriages in pregnant mothers due to these negative blood groups are fairly high compared to the percentage of miscarriages in pregnant mothers with positive groups of blood.

Therefore the established logistic regression model can be used to predict the high risk group of pregnant mothers will have a high risk probability of delivering a LBW baby. That probability of risk was found to be 0.9999, having hypertension, previous history of LBW, history of miscarriages and exposure to passive smoking. Deprived of these four conditions the probability of having a LBW will be 0.2009.

4. Conclusion

According to the results obtained in this study in the year 2016, the prevalence of LBW in the MOH division Akkaraipattu has been found to be 17.81% by considering the selected population within that particular area, inferring that nearly one in every five births brings about in a LBW infant. No relationship has been observed between BMI and prevalence of LBW while level of Haemoglobin also has no association.

The active factors of the prevalence of LBW babies in the chosen metropolis are education level of the pregnant mothers, weight gain during pregnancy, parity of pregnancy, birth interval, hypertension, history of miscarriages, previous history of miscarriages and passive smoking. Even though the percentage of male LBW babies is high compared to female LBW babies, it cannot be concluded that an infant born with a LBW depends on its sex.

Granting the overall LBW prevalence of 17.81% in the region was moderate; the mean birth weight of 2.65kg is creditable. Findings of this study demonstrate that the pregnant mothers are misguided and have to bring more concern on their maternal history of mean health issues such as hypertension, miscarriages, and other pregnancy-related medical complications such previous history of LBW, diabetic, cholesterol, rheumatic heart disease, varicose, etc. pregnant women have to pay much attention on their health related judgments, such as exposure to smoking, dietary intakes during pregnancy, doing exercises and to be aware about the effects of these factors on their future born child.

There are several international research findings elaborate that, the prevalence of LBW due to diabetic during pregnancy is very rare in practice and they have the significant proofs. It can be monitored that the occurrence of LBW by managing the identified significant factors with in the certain levels. Therefore some important trainings and vital assortment should be carried out for the pregnant women during pregnancy to prevent and reduce preterm deliveries and births of LBW. The fitted logistic regression model could be implied to categorise the high risk group of pregnant mothers in the future aspects and some strategies and effective efforts can be emphasize to control the percentage of delivery of LBW.

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