Chapter 6

A Model for Assessing Lead Exposure during Pregnancy and After Delivery

6.1 Abstract

This study identifies characteristics of pregnant women that can be used to predict blood lead levels ≥2µg/dL in order to develop a clinical assessment tool that will be used by health workers to screen lead exposure levels during pregnancy and after delivery. Blood lead levels of 63 pregnant women living in the Serowe Palapye Administrative District were analysed three times from week 8 to week 36 and again six weeks after delivery. The enrolled women were only those with uneventful pregnancies, and had normal babies. Blood lead levels were dichotomized into <2µg/dL and ≥2µg/dL. A logistic regression analysis was conducted to examine the association of the characteristics of pregnant women with blood lead levels≥2µg/dL using blood lead levels collected from the first to the third trimester and six weeks after delivery (n=63, total 252 repeated measures). The following variables were associated with increased risk of blood lead levels ≥2µg/dL, defined in this study as elevated: engaging in pica behaviour (OR, 6.7, CI,1.34-34.5); Using an outdoor drinking water tap (OR,4.4, CI,1.6-12.0); Trimester of pregnancy (OR 8.6, CI,1.4-52.4) and engaging in multiple risk behaviours during pregnancy such as traditional medicine use in combination with smoking, alcohol use, and so forth; (OR, 20.9,CI,4.5-95.8). Consumption of citrus fruits (OR 0.07, CI,0.01,CI,0.41-0.01) and supplements in the combination of calcium, folic acid and iron (OR 0.02,CI, 0.01-0.11) reduced the risk of elevated blood lead levels. These predictor variables can be used to identify women with blood lead levels ≥2µg/dL This data demonstrated that understanding the behaviours, practices, social and environmental characteristics of a population can be used to develop screening tools for lead exposure, and thus prevent lead poisoning from occurring.

Key words: Blood-lead levels; pregnant women; trimester; delivery, Botswana

6.2 INTRODUCTION

Lead is a recognised and well known neurotoxin that has been associated with adverse multiple health effects ranging from impaired cognitive behaviour to death. The most recent concerns raised by researchers is that the lowest blood lead concentrations associated with deficits in cognitive functioning as well as academic achievement is poorly defined.[1] Since the 1980's blood lead levels as low as 10µg/dL were associated with adverse effects on cognitive development, growth and behaviour among childen.[2-5]Recent research has revealed that the lead affects intelligence quotient (IQ) score at blood lead levels below 10µg/dL and that no single study has been able to identify a safe level of lead.[6] Bellinger (2008) states that "…. 10µg/dL has no special biological significance with regard to neurodevelopment…..the current screening guideline is best interpreted as a risk management tool".[7] These conclusions are based on cohort studies that have reported significant inverse relationships on most or all children with blood lead levels below 10µg/dL[8-10] including cohorts with mean blood lead levels as low as 1-2µg/dL.[11]

Another concern is that lead adversely impacts offspring development at maternal blood lead concentrations that do not in fact produce maternal clinical toxicity.[12] Some of the key reproductive effects observed in females associated with low- level exposure to lead include delays in sexual maturation, the risk of spontaneous abortion, effects on birth weight and pre-term birth. [12] There is evidence of delayed puberty in adolescent girls and blood lead concentrations as low as 3µg/dL[13] Inverse associations between blood lead levels and length of gestation have been reported with implications on increased prematurity.[14]have been reported

Chapter 5 reported blood lead levels from the first trimester of pregnancy to the third trimester with concentrations ranging from 0.5-12.90µg/dL with an overall mean (±SEM) of 2.34(±0.098)µg/dL. The studies reporting low lead levels just summarized in this introduction documented effects at blood lead levels ranging from 1 to 10µg/dL. The effects include developmental neurotoxicity and reproductive effects. Of major concern is the strong weight of evidence for neurodevelopmental effects in infants and children. The lead levels in this study therefore present serious health implications for women of reproductive age, infants and children. Pregnant women are not only a source of exposure to the unborn infants, but are also a vulnerable group that requires attention in preventing the effects of low lead level. It is therefore logical to apply the principles of primary prevention in order to minimize the effects of lead poisoning on infants, children and pregnant women.

It is on this basis that the main objective of this study is to develop a clinical assessment tool for screening lead exposure levels during pregnancy and after delivery. The objective of this chapter is therefore to identify the characteristics of 63 pregnant women who completed the study from the first trimester (week 8-12) , second trimester (week 20-24), third trimester (week 34-36) and 6 weeks after delivery (weeks 42-44) which can predict blood lead levels ≥2µg/dL. The cut of point of ≥2µg/dL is based on the literature that has just been highlighted showing evidence that irreversible neurodevelopmental effects occur at levels lower than 2µg/dL. For our purpose an elevated blood lead level is ≥2µg/dL

6.3 PURPOSE OF THE TOOL

The tool will be used to guide health care workers in predicting whether a pregnant woman is at a greater risk of lead elevated blood lead level and therefore recommend educate, assess risks counsel and follow up. (Please see chapter 7)

6.4 METHODS

6.4.1 Data

Blood lead was analyzed from a total of 63 women living in the Central District of Botswana (Figure 1) who donated blood between weeks 08-12, 20-24 and 34-36 and again 6 weeks after delivery. The data was captured and cleaned in SPSS and converted to Stata version 12, where further data cleaning, data management and all statistical analyses were conducted.

6.4.2 Descriptive statistics

The outcome variable (lead measurement) was summarised first as a continuous variable (original data) and then as a binary variable. In the first instance, the outcome variable was summarised using numerical descriptive statistics. Prior to data description, three methods were used to determine the normality of the data:

1. Numerical - nearness of the mean to the median
2. Graphical - frequency distribution plot and
3. Statistical – statistical test for normality (Skewness-kurtosis and Shapiro-Wilk tests).

The lead measurement data was skewed. Data transformation, including log transformation, did not achieve normality. The data was therefore summarised using median and inter quartile range.

In the second instance, lead values were categorised as normal (<2ug/dL) and high (≥2ug/dL). The binary data was described using actual frequencies (numbers), proportions and 95% confidence intervals. Both sets of descriptive statistics were reported for all study participants and by key variables.

6.4.3 Explanatory variables modelling

Further analysis sought to determine the significant explanatory factors (risk factors and protective factors) of blood lead levels. The outcome variable for this analysis was the dichotomous lead levels data. Therefore logistic regression was used. The dichotomous lead variable was used for the modelling analysis because:

1. The original variable was not normally distributed
2. Transformation of the original variable did not achieve normality
3. Most explanatory variable binary or categorical
4. Categorized lead values would be easier for health professional to interpret.

Since the data contained repeated measures for each individual, classical statistical methods would not be appropriate as they would produce standard errors that are too small leading for false positive associations. Statistical methods that account for clustering were used for this analysis. Specifically, the generalised estimating equation (GEE) was used. The random effect approach was also explored but the results were very similar. Since the random effect method can be problematic for logit models, the GEE was preferred.

To fit the GEE models, the correlation between the repeated measures was first calculated. The correlation matrix was found to be an auto-regressive (order 1) correlation. This correlation (AR1) was therefore specified for the GEE models. To build the final model, univariate GEE logistic regression models were first built followed by a multivariate model.

First, the association between each exposure variable and the outcome variable was determined using univariate GEE logistic regression models. Variables were considered for inclusion in adjusted models on the basis of significant ($p<0.15$) univariate association with the outcome. A table of unadjusted odds ratios and 95% confidence intervals were presented for each univariate association.

Adjusted associations between significant exposure variables and outcome were then assessed using multivariate GEE logistic regression. The stepwise regression technique (forward then backward selection), starting with the most significant covariate, was used to determine the significant explanatory variables to be retained in the final adjusted model. The final model was selected from a family of models on the basis of parsimony and post-estimation model evaluation. The Wald test was used to determine if variables included in the model improved the model fit. Only variables which were significant at 0.05 were included in the model. Robust standard errors were also evaluated against the model standard errors. Tables of adjusted odds ratios and 95% confidence intervals were presented.

6.5 RESULTS

Table 6.1 summarizes the overall proportions of women with blood lead levels ≥2µg/dL. Overall 46% and 54% (n=252 repeated observations representing 63 pregnant women, C.I. 0.40:0.53) had blood lead levels <2µg/dL and ≥2µg/dL respectively.

Table 6.1 Blood lead levels (≥2µg/dL) of study participants by social, demographic and environmental status (n=252 observations (repeated measures), representing 63 women)

Characteristics	Median	Inter Quartile Range		Range		Blood lead ≥2µg/dL	
				Minimum	Maximum	No.	(%)
Age (years)							
18-25	2.25	1.65	3.37	0.5	6.55	71	57.26
26-33	2.19	1.42	2.9	0.5	4.43	40	50.00
34-42	2.1	0.85	3.74	0.73	11.1	24	50.00
Type of Location							
Major Village	2.05	1.125	3.0	0.5	4.83	80	51.28
Small Village	2.675	1.54	4.29	0.77	11.1	55	57.29
Current Location							
Lerala (small village)	3.5	1.925	4.43	0.8	11.1	34	65.38
Maunatlala(small)	2.63	1.05	3.35	0.77	5.45	21	47.73
Palapye(Major Village)	1.98	1.13	3.12	0.5	4.7	29	48.33
Serowe(Major Village)	2.18	1.35	2.94	0.5	4.83	51	53.13
Marital Status							
Married	1.63	1.025	2.8	0.8	2.88	10	35.71
Single	2.23	1.5	3.36	0.5	11.1	125	55.80
Parity							
Multipara	2.09	1.125	3.2	0.5	11.1	82	48.81
Primipara	2.25	1.75	3.38	0.5	5.45	53	63.10
Education							
Tertiary	2.175	1.57	2.63	1.13	4.68	31	58.49
Secondary	2.75	1.68	3.68	0.5	11.1	88	57.89
Primary	1.51	0.85	2.03	0.725	4.15	16	34.04
Income							
Lower	2.2	1.4	3.35	0.5	11.1	123	53.71
Middle	2.05	1.43	2.48	1.03	3.13	9	45.00
Upper	2.9	2.9	2.9	2.9	2.9	3	100.00
Home/ neighbour with backyard repair workshop							
No	1.6	1.025	2.23	0.5	4.9	40	28.57
Yes	3.2	2.48	4.68	1.05	11.1	95	84.82
Tobacco use or live with smoker							
No	1.4	0.88	1.88	0.5	2.73	25	20.49
Yes	3.22	2.71	4.55	1.58	11.1	110	84.62
Alcohol Consumption							
None	1.8	1.03	2.98	0.5	5.98	45	40.54
Light	1.73	1.4	2.48	0.75	4.15	23	40.35
Moderate	2.88	2.05	4.7	1.05	6.55	39	79.55
Heavy	3.63	2.65	4.68	1.93	11.1	32	80.00
Pica Behaviour							
No	1.58	1.03	2.25	0.5	3.35	30	27.78
Yes	2.94	1.95	4.29	0.73	11.1	105	72.92
Unconventional skin treatments							
No	1.78	1.13	3.13	0.5	11.1	69	42.33

Yes	2.84	2.18	3.5	0.73	5.98	66	74.16
Fuel for cooking							
Electricity	1.58	0.8	1.88	0.5	3.18	12	33.33
Gas	1.58	1.03	2.48	0.73	2.78	14	31.82
Elect-gas	2.21	1.75	3.38	1.03	4.89	34	60.71
Wood	2.96	1.89	4.29	0.75	11.1	74	66.07
Gas-wood	1.78	1.78	1.78	1.78	1.78	1	25.00
Traditional Medicine use and over the counter drugs							
No	1.75	1.05	2.78	0.5	11.1	71	40.11
Yes	3.1	2.64	3.74	1.63	5.45	64	85.33
Multiple risk behaviours/ practices							
0-1 risk behaviours	1.6	1.03	2.51	0.5	5.03	10	10.87
≥2 Risks risk behaviours	3.0	1.93	4.15	0.78	11.1	125	78.13
Water Source type							
Indoor	1.58	1.03	2.25	0.5	3.18	24	35.29
Outdoor	2.7	1.7	3.68	0.73	11.1	111	60.33
House paint type							
Water	2.3	0.83	3.2	0.5	4.83	19	47.50
Oil_h20	2.4	1.5	3.9	0.5	5.45	55	55.56
Oil	1.98	1.4	2.05	1.13	3.13	8	40.00
Pigment	2.25	1.525	3.44	0.76	11.1	53	56.99
Supplements							
Calcium	1.41	0.95	1.81	0.5	2.4	9	8.74
Other	2.56	1.35	3.19	0.78	5.01	14	50.00
None	3.35	2.78	4.68	2.05	11.1	111	92.50
Green veg consumption rate							
1-5xw	1.5	1.03	2.3	0.5	11.1	8	11.11
Weekly	1.93	1.58	2.48	0.5	4.68	42	51.85
None	3.3	2.9	4.43	0.8	6.55	85	85.86
Citrus fruit consumption							
1-5xw	1.58	0.89	1.93	0.5	5.03	11	11.96
Weekly	2.73	1.63	3.13	0.5	4.83	48	60.76
None	4.13	3.35	4.7	2.05	11.1	76	93.83
Peanut							
0	1.6	1.03	2.21	0.5	5.03	36	25.90
1	3.35	2.48	4.68	0.8	11.1	99	87.61
Milk consumption							
1-5xw	1.14	0.8	2.2	0.5	5.03	3	9.38
Weekly	1.73	1.9	2.15	0.5	5.03	26	26.80
None	3.25	2.78	4.43	0.75	11.1	106	86.18
Job or hobby involves paint							
No	1.65	1.05	2.63	0.5	6.55	54	35.76
Yes	3.19	2.2	4.15	1.025	11.1	81	80.20

The mean age (±SEM) of the women (n=63) was 27 (±0.39) years, range 18-42 years with 38% and 62% coming from small (rural) and major (semi-industrial) villages. Only 8% of the women were married. Median blood lead levels of women was 2.0µg/dL (CI;2.34-2.87) (Table 6.1). Women who lived in small villages (median 2.7 µg/dL) had higher blood lead levels compared to women who lived in major villages (median, 2.1 µg/dL). Consequently women from Lerala, a small village in the study area had a higher proportion of women with blood lead levels of 2 µg/dL or higher (n=13, 65%) compared to Serowe (n= 24, 53%), Palapye (n=15, 48%) and Maunatlala (n=11, 47%) . A higher proportion of women who had backyard car repairs or a neighbour with a backyard car repair shop (n=28, 84%), using tobacco or living with a smoker (n=32,85%), engaging in pica behaviour(n=36, 73%) and using traditional medicines (n=19, 85%) and using unconventional skin treatments (n=23,74%) had blood lead levels greater or equal to 2µg/dL.

A higher proportion of women who did not use supplements during pregnancy (n=28, 93%), citrus (n=19, 86%) had blood lead levels ≥2µ/dL.

Figure 6.1 and Table 6.2 characterizes blood lead levels by trimester. The proportion of women having blood lead levels ≥2µg/dL was significantly different between

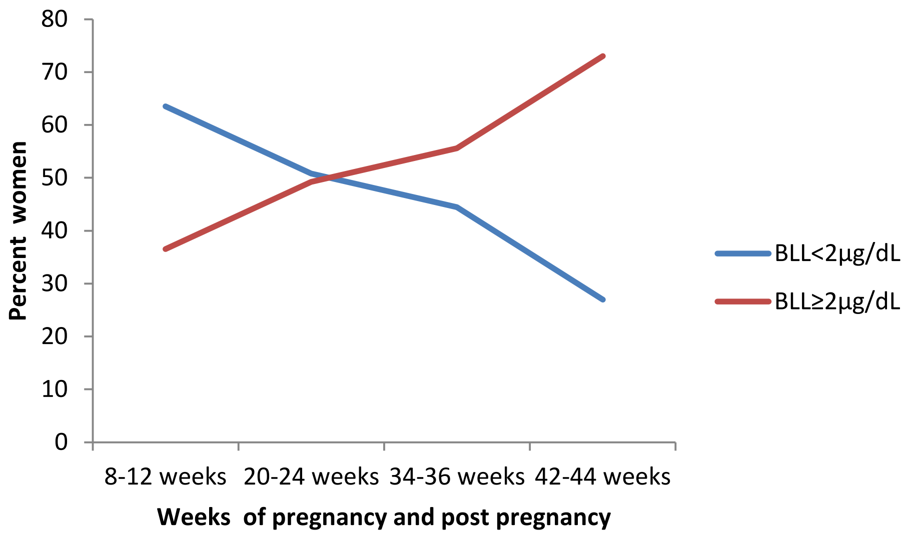

Figure 6.1 The time course of the proportion of women with blood lead levels <2µg/dL and ≥2µ/dL during pregnancy and after delivery

trimesters (between group difference p<0.01) with the first trimester (8-12 weeks) having the lowest number of women with blood lead levels ≥2µg/dL compared to post-delivery (42-44 weeks). No significant differences were observed in the proportion of women having blood lead levels ≥2µg/dL between major and small villages and the current location of residence at the time of sampling ($p>0.05$). A higher proportion of younger women (57%) had blood lead levels ≥2 μg/dL compared to older women (+34 years), however the difference was not significant ($p>0.05$). Marriage, parity and level of education had significantly different proportions of blood lead levels ($p<0.05$).

Table 6.2 Distribution of blood lead levels by trimester and socioeconomic/ demographic factors

	Trimester 1		Trimester 2		Trimester 3		Trimester 4	
Characteristics	**Median**	**IQR**	**Median**	**IQR**	**Median**	**IQR**	**Median**	**IQR**
Age (years)								
18-25	1.8	1.1-3.0	2.0	1.1-3.6	2.1	1.4-3.4	3.2	1.6-4.8
26-33	1.5	0.8-2.1	1.6	1.15-2.55	2.2	1.35-2.6	2.6	1.6-4.4
34-42	1.45	0.5-3.75	1.6	0.5-2.75	1.8	1.15-3.45	2.85	1.2-5.15
Type of Location								
Major Village	1.4	0.5-2.3	1.6	1-2.7	2.1	1.3-2.6	2.4	1.2-4.4
Small Village	1.8	1.2-3.25	2.45	1.45-3.8	2.3	1.3-4.85	3.3	1.75-5.4
Current Location								
Lerala (small village)	1.9	1.5-3.9	3.0	1.6-4.5	2.4	1.7-5.1	4.2	2.4-5.4
Maunatlala(small)	1.4	0.5-1.9	2.2	1.0-3.3	1.7	1.0-3.7	2.2	1.4-5.4
Palapye(Major Village)	1.2	0.5-2.1	1.6	1.0-2.7	1.7	1.3-2.9	3.3	1.6-4.4
Serowe(Major Village)	1.5	1.05-2.6	1.6	1.0-2.65	2.1	1.35-2.6	2.25	1.15-4
Marital Status								
Married	1.5	1.1-2.9	1.4	1.0-2.1	1.5	1.0-2.5	1.2	0.5-4.4
Single	1.6	0.5-2.45	2.0	1.05-3.15	2.1	1.35-3.4	3.25	2.0-4.9
Parity								
Multipara	1.5	0.5-2.6	1.95	1.0-3.0	1.8	1.3-3.2	2.4	1.2-4.9
Primipara	1.6	1.0-2.3	1.7	1.2-3.0	2.4	1.7-3.4	3.3	2.2-4.4
Education								
Tertiary	1.3	0.5-2.3	1.7	1.2-2.9	2.1	1.4-2.5	2.4	2.1-3.2
Secondary	1.8	1.3-3.1	2.15	1.1-3.3	2.5	1.2-3.6	4.1	1.5-5.4
Primary	0.5	0.5-1.8	1.15	0.5-2.4	1.5	1.15-2.05	2.0	1.2-3.3
Income								
Lower	1.5	0.5-2.6	2.0	1.0-3.0	2.1	1.3-3.4	3.2	1.6-4.9
Middle	1.9	1.6-2.1	1.6	1.4-1.6	2.1	1.0-2.2	2.4	1.2-4.4
Upper			2.5	2.5-2.5	2.2	2.2-2.2	2.4	2.4-2.4
Home/ neighbour with backyard repair workshop								
No	1.2	0.5-1.8	1.2	1.0-1.95	1.4	1.0-2.1	2.0	0.5-3.3
Yes	2.45	1.55-4.05	3.0	2.4-4.8	2.6	2.2-4.75	4.4	2.6-5.4
Tobacco use or live with smoker								
No	1.0	0.5-1.5	1.1	0.5-1.6	1.3	1.0-1.7	1.5	0.5-2.4
Yes	2.25	1.8-4.05	2.8	2.25-4.45	3.3	2.2-4.6	4.4	2.6-5.4
Alcohol Consumption								
None	1.2	0.5-1.8	1.4	1.0-2.5	1.65	1.15-2.45	2.05	1.15-4.3
Light	1.5	0.5-2.0	1.45	1.0-2.2	1.5	1.0-2.6	2.85	1.4-4.4
Moderate	2.9	2.0-4.2	2.7	1.6-3.6	2.5	2.1-4.9	2.4	2.2-5.4
Heavy	2	1.5-4.5	3.15	2.1-4.8	3.3	2.4-5.1	4.6	3.6-5.4
Pica Behaviour								
No	1.1	0.5-1.55	1.1	1.0-1.6	1.4	1.0-1.7	2.15	1.2-4.8
Yes	2.1	1.3-3.9	2.65	2.0-4.1	2.55	2.05-3.95	3.3	2.4-4.8
Unconventional skin treatments								
No	1.4	0.5-2.1	1.6	1.0-3.15	1.6	1.0-2.6	2.4	1.2-4.4
Yes	1.9	1.2-4.2	2.5	1.0-4.3	2.6	2.15-3.4	3.4	2.2-4.9
Fuel for cooking								
Electricity	1.2	0.5-1.9	1.6	0.5-2.4	1.5	1.0-2.1	1.2	0.5-2.1
Gas	1.5	0.5-2.1	1.1	1.0-1.6	1.4	1.0-2.6	2.0	1.1-3.6

Elect-gas	1.75	1.1-3.1	1.85	1.1-2.9	2.25	1.3-3.2	3.7	2.4-4.9
Wood	1.8	0.8-3.75	2.8	1.35-4.45	2.45	1.7-4.6	3.75	2.15-5.4
Gas-wood	1.9	1.9-1.9	2.2	20.2-2.2	1.6	1.6-1.6	1.4	1.4-1.4
Traditional Medicine use and over the counter drugs								
No	1.25	0.5-2.05	1.45	1.0-2.5	1.6	1.0-2.4	2.2	1.2-4.3
Yes	2.3	1.8-4.4	2.7	2.1-4.4	3.05	2.4-3.7	4.4	2.6-5.4
Multiple risk behaviours/ practices								
0-1 risk behaviours	1.1	0.5-1.4	1.1	0.75-1.6	1.3	1.0-1.5	1.2	0.5-2.0
≥2 Risks risk behaviours	2.2	1.5-3.9	2.7	2.0-4.4	2.55	2.1-3.7	3.35	2.4-4.9
Water Source type								
Indoor	1.2	1-2	1.1	1.0-1.7	1.5	1.0-2.1	1.6	0.5-2.4
Outdoor	1.8	0.5-3.1	2.4	1.2-3.6	2.4	1.4-3.5	3.35	2.0-5.0
House paint type								
Water	1.65	0.5-3.6	1.75	1.0-2.6	1.8	1.2-3.4	2.0	0.5-4.9
Oil_h20	1.6	1.2-2.6	2.0	1.2-3.0	2.2	1.3-3.2	2.6	1.2-4.4
Oil	0.5	0.5-1.1	1.0	0.5-1.6	1.4	1.3-2.1	3.3	2.4-4.4
Pigment	1.7	0.5-2.5	2.4	1.0-3.3	2.4	1.5-3.5	3.3	2.0-5.4
Supplements								
Calcium	0.75	0.5-1.3	1.0	0.5-1.55	1.3	1.0-1.5	1.2	0.5-2.0
Other	1.6	1.4-2.2	1.8	1.5-3.15	1.5	0.5-2.1	2.2	0.5-2.4
None	3.0	2-4.5	3.0	2.5-4.5	2.9	2.4-4.6	4.4	3.3-5.4
Green veg consumption rate								
1-5xw	1.2	0.5-1.6	1.1	0.5-1.5	1.35	1.0-1.55	0.85	0.5-2.0
Weekly	1.35	0.5-2.2	1.6	1.1-2.4	2.0	1.3-2.75	2.4	1.5-3.6
None	2.75	1.8-4.4	3.0	2.5-4.5	2.6	2.2-4.6	4.9	3.3-5.4
Citrus fruit consumption								
1-5xw	1.1	0.5-1.6	1.1	0.5-1.5	1.1	1.0-1.6	1.2	0.5-2.0
Weekly	1.7	1.1-2.3	2.4	1.2-2.9	2.2	1.4-2.6	2.5	2.0-4.4
None	3.9	2.2-5.2	3.3	2.6-4.8	3.45	2.5-5.1	4.85	3.3-5.4
Peanut								
0	1.2	0.5-1.6	1.1	1.0-1.9	1.4	1.0-1.9	2.0	0.5-3.3
1	3.6	2.1-5.0	2.95	2.4-4.45	2.9	2.1-4.6	4.4	2.4-5.4
Milk consumption								
1-5xw	1.1	0.5-1.3	1.25	0.75-1.6	0.75	0.5-1.65	1.2	0.5-1.4
Weekly	1.35	0.5-1.6	1.1	1.0-1.9	1.3	1.0-1.7	2.0	1.2-3.2
None	3.05	1.95-4.45	2.95	2.4-4.5	2.9	2.2-4.6	4.4	2.6-5.4
Job or hobby involves paint								
No	1.2	0.5-2.1	1.35	1.0-2.2	1.45	1.0-2.2	2.0	1.1-4
Yes	1.85	1.3-3.6	2.7	2.0-4.4	2.6	2.2-4.2	4.4	2.6-5.4

Table 6.3: Univariate logistic regression using generalized estimating equation to adjust for intra-class correlation within repeated measures. Outcome variable is binary blood lead levels .

Sociodemographic Characteristic	Proportion (n=252 Observations)		Adjusted Odds Ration	95% Confidence Interval		*P* Value
	<2µg/dL (%)	≥2µg/dL %				
Age(years)						
18-25	(43)	(57)	1			
26-33	(50)	(50)	1	0.34	2.93	1.00
34-42	(50)	(50)	1.3	0.49	3.65	0.57
Marital Status						
Married	(64)	(36)	1			
Single	(55)	(57)	2.2	0.67	7.70	0.19
Parity						
Multipara	(51)	(49)	1			
Primipara	(37)	(63)	1.7	0.80	3.9	0.15
Education						
Tertiary	(42)	(58)	1			
Secondary	(42)	(58)	1.16	0.46	2.91	0.75
Primary	(65)	(34)	0.54	0.17	1.67	0.28
Income						
Upper Middle	46	53	1			
Middle	55	45	1.22	0.34	4.40	0.76
Lower	0	100	7.01			
Painting hobby or job						
No	64	36	1			
Yes	20	80	6.94	3.22	14.99	**<0.001**
Backyard repair workshop						
No	71	28	1			
Yes	15	85	15.72	6.96	35.50	**<0.001**
Live smoke						
No	80	20	1			
Yes	15	85	21.48	10.74	42.96	**<0.001**
Alcohol						
None	59	41	1			
Light	60	40	0.99	0.41	2.42	0.99
Moderate	20	80	5.70	1.80	18.03	**<0.0001**
Heavy	20	80	5.87	1.76	19.55	**<0.001**
Pica Behavior						
No	72	28	1			
Yes	27	53	4.40	2.52	7.70	**<0.001**
Skin applications						
No	58	42	1			
Yes	26	74	3.15	1.50	6.65	**<0.001**
Cooking						
Electricity	67	33	1			
Gas	68	32	0.93	0.24	3.60	0.92
Gas+electricity	39	61	3.1	0.88	10.90	0.08

Wood	34	66	3.90	1.24	12.22	**<0.05**
Gas-wood	75	25	0.67	0.02	20.02	0.82
Traditional Medicine Use						
No	60	40	1			
Yes	15	85	8.27	3.46	19.77	**<0.001**
Multiple Risk Behavior						
0-1 risk behaviors	89	11	1			
≥2 risks risk behaviors	22	78	29.59	12.76	68.60	**<0.001**
H20 sour						
No	65	35	1			
Yes	40	60	2.79	1.19	6.54	<0.05
House paint						
Water	53	48	1			
Oil and water	44	56	1.38	0.46	4.15	0.56
Oil	60	40	0.73	0.14	3.76	0.71
Pigment	43	57	1.46	0.48	4.44	0.50
Supplement						
Calcium +iron	91	9	1			
Other	50	50	10.30	3.64	29.13	**<0.001**
None	8	92	130.68	48.37	353.07	**<0.001**
Eat green Veggies						
1-5xweek	89	11	1			
Weekly	48	52	9.80	3.39	28.29	**<0.001**
None	14	86	67.08	20.80	216.36	**<0.001**
Eat citrus fruits						
1-5xweek	88	12	1			
Weekly	39	61	13.05	5.18	32.86	**<0.001**
None	6.7	94	152.89	39.43	592.87	**<0.001**
Peanut						
Yes	74	26	1			
None	12	88	25.93	10.92	61.60	**<0.001**
Drinking milk						
1-5xweek	91	9	1			
Weekly	73	27	3.94	0.91	17.16	0.1
None	14	86	64.95	0.03	298.1	**<0.00**

Table 6.4 shows characteristics of pregnant women that are associated with blood lead levels ≥2µg/dL. Having a job or hobby that involves paint (OR,6.7, CI,3.22-14.99); engaging in pica behaviour (OR, 4.4,CI,2.52-7.70), traditional medicine (OR, 8,(3.46-19.77); using unconventional skin products (OR, 3.1, CI,1.5-6.7); source of drinking water supply (OR, 3.0,CI,1.2-6.54) were independently associated with an increased risk of blood lead levels exceeding 2µg/dL. Additionally, living with a smoker and drinking moderately-heavy were risk factors for increased lead levels.

An intake of a combination of supplements which include calcium, multivitamins, folic acid and iron as well as frequent and regular consumption of citrus fruit had a protective effect on lead exposure risk (OR, 0.02, CI, 0.01-0.17).

Table 6.4. Multivariate semirobust regression model for blood lead levels during pregnancy and after delivery

Predictors	**Adjusted Odds Ratio**	**Standard Error**	**Lower 95% Limit**	**Upper 95% limit**	**P Value**
Water source	4.4	2.3	1.6	12.0	0.004
Pica behaviour	6.8	5.5	1.4	33.51	0.019
Multiple risk behaviours	20.0	15.1	4.5	88.32	<0.000 1
Trimester 2	12.1	12.2	1.7	87.12	0.013
Trimester 3	8.6	8.0	1.4	52.41	0.020
Post delivery	129.7	131.5	17.8	946.25	<0.0001
Citrus fruits ingestion	0.07	0.6	0.01	0.41	0.003
Calcium and multivitamin supplements	0.023	0.02	0.01	0.17	<0.0001

Table 6.5: Correlation among repeated lead (Pb) measurements

	Pb1	Pb2	Pb3	P4
Pb1	1.0000			
Pb2	0.7008	1.0000		
Pb3	0.5447	0.7914	1.0000	
Pb4	0.4385	0.6875	0.8890	1.0006

The final multivariate model for blood lead level prediction is shown in Table 6.4 and the correlations among repeated measures are presented on Table 6.5. The strongest significant predictors of blood lead levels ≥2µg/dL were multiple risk factors (engaging in two or more risks) stage of pregnancy and an intake of calcium in combination with other supplements such as folic acid and multivitamins (p<0.001). Ingesting non-food items, pica and using an outdoor source of drinking water could be used to predict increased lead exposure levels during pregnancy ($p<0.01$ and $p<0.05$ respectively)

A dose response relationship was observed between lead exposure and ingestion of supplements and citrus fruits. Consuming more of vitamin supplements and citrus fruits had an effect on blood lead levels ≥2µg/dL.

6.6 DISCUSSION

This project has demonstrated that the behaviour, lifestyle, practices and environmental factors can be used to predict blood lead levels ≥2µg/dL in pregnant women and after delivery. This is an important undertaking in light of the mounting evidence that the toxic effects of lead occur at very low levels of lead. More and more researchers continue to prove that there is no level of lead that is safe. There is compelling evidence that low blood lead levels cause negative effects such as IQ deficits, attention-related behaviours, and poor academic achievement. A major concern among researchers is that the absence of an identified blood lead level without deleterious effects, combined with the evidence that these effects appear to be irreversible, provide good justification for the importance and critical role of primary prevention. This research was conducted in recognition of the lack of capacity for a country such as Botswana and many more countries to have the capacity for universal testing of pregnant women for lead exposure. Additionally, even if screening could be afforded by any country, the signs and symptoms of lead would usually show when detrimental effects have already occurred. Primary prevention of lead therefore aims at preventing lead exposure rather than responding after the exposure has taken place.

In this chapter, the behaviours and practices of pregnant women that have a potential to predict blood lead levels have been identified. These include pica, multiple risk behaviours, diet and nutrition. Two other predictors of blood lead levels are environmental factors (water source) and trimester of pregnancy.

6.6.1 Pica as a predictor of blood lead levels

Pregnant women in the study area ingest non-food items such as soil, bone meal, matchsticks and many other items. Women who engaged in pica were 7 times more likely to have increased lead levels that are equal to or greater than 2µg/dL (OR,6.9,CI, 1.3-34.5). Pica during pregnancy has been associated with severe lead poisoning which is not only detrimental to the mother, but to the infant.[15-17] The most important aspect in these studies however is that advising women to stop the behaviour (removal of the source) was the most important undertaking as it immediately reduced the lead load. In addition, improvements in nutrition contributed to the reduction on the lead load in the woman.[17] Multiple risk behaviours such as engaging in two or more lead exposure behaviours is yet another important predictor of lead exposure level risk. These behaviours, as discussed in chapter three include a combination of risk behaviours such as the use of traditional medicines, alcohol consumption, tobacco use as well as pica and are preventable. Education and awareness of the pregnant is an important approach in preventing lead exposure during pregnancy. It must however be noted that pica behaviour, the use of tobacco or alcohol could be difficult to stop immediately. Counselling and advise would therefore be necessary. Health workers /clinicians may therefore need to be sensitised

6.6.2 Diet and Nutrition as a predictor of lead exposure

Diet and nutrition are important strategies for preventing lead exposure and poisoning. Dietary calcium is for example known to lower lead levels in pregnancy and lactation[18]. Women who regularly consumed citrus fruits (OR, CI,0.07,CI,0.04-0.01) and supplements in the combination of calcium, folic acid and iron (OR,0.02,CI, 0.02-0.01) had lower levels of lead compared to women who did not consume these products on a regular basis. A promising hope in Botswana is that currently the Government provides supplements in the form of calcium, iron and vitamin C to pregnant women as soon as they register for prenatal care. Dietary deficiencies of calcium, iron, and zinc enhance the effects of lead on cognitive and behavioral development.[19] This good development requires strengthening to prevent lead exposure in pregnant women. It is however unfortunate as indicated in the previous chapter, that pregnant women do not consume these supplements because of several reasons which include among others the strong smell of the supplements, the taste of the supplements and the lack of awareness on the importance of consuming such supplements. These are discussed further in chapter 7. It is imperative that awareness campaigns are initiated to ensure that pregnant women utilize the supplements provided in order to prevent lead exposure.

6.6.3 Trimester or stage of pregnancy as a predictor of blood lead levels

Trimester of pregnancy is another important predictor of blood lead levels in this study. In this research there was a corresponding increase in blood lead levels by trimester. The increase may suggest implications maternal of bone lead due to the increased need for calcium in the last half of pregnancy. Prior research has shown a significant increase in maternal blood lead during periods corresponding to 20-36 weeks.[20,21]. An increase of PbB concentrations in the last half of pregnancy is reported to coincide with an increased foetal need for calcium as well as an increased maternal provision of calcium. The resultant effect is that if the needed supply of calcium is supplied from the expectant woman's bone, then women with high loads of bone lead may transfer more lead to the bloodstream with calcium.[20,21]

6.6.4 Water source as a predictor of lead level:

Women who got their drinking water from an outdoor tap were 4 times as likely to be at risk of blood lead levels >2µg/dL than women who got their water from an indoor water tap (OR, 4.3, CI, 1.6-12.03). In chapter 5 water lead levels were 19 times higher than the recommended World Health Organisation standard of 0.01ppm. About 60% of the water was from outdoor water taps. We apportioned the high lead level in water to plumbing equipment,[22-24] and water temperature which increases leachability of lead from lead soldered materials, particularly during day.[25] Lead in water has been implicated in increased maternal blood lead levels[26,27]

6.7 LIMITATIONS

The sample size of 63 women presented challenges in presenting this model. Future research is necessary to compare these results. Many women were lost to follow up. However the results are useful in knowing trends in lead exposure during pregnancy and after delivery.

6.8 CONCLUSION

Research has shown that behaviours and practices of women such as pica, intake of alcohol and tobacco smoke as well socioeconomic status may contribute to increased blood lead.[28,29]. This study has identified behaviours, practices and environmental factors of pregnant women that can be used to predict blood lead levels during pregnancy and after delivery. The data can therefore can be used to develop lead screening strategies to prevent exposure to elevated blood lead levels.

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