UNIVERSITY FOR DEVELOPMENT STUDIES

DETERMINANTS OF MATERNAL WEIGHTS DURING PREGNANCY AND BIRTH WEIGHT IN THE NORTHERN REGION OF GHANA

ABUKARI KADIRI (BSc. STATISTICS)

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DECLARATION

Student

I hereby declare that this thesis is the result of my own original work and that no part of it has been presented for another degree in this university or elsewhere:

Candidate's Signature:…………………………….. Date:…………….

Name:…………………………………………………………………………….

Supervisor

I hereby declare that the preparation and presentation of the thesis was supervised in accordance with the guidelines on supervision of thesis laid down by the University for Development Studies:

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Name:…………………………………………………………………………….

ABSTRACT

We obtained secondary data from the Tamale Teaching hospital, in the labour ward at Tamale Metropolitan Assembly. Twins and those mothers who do not attend antenatal for at least three months were excluded. The study was to investigate whether maternal weight gain during pregnancy and socio-economic factors of the mother affect birth weight of the new born baby. Profile analysis (both graphical and MANOVA) was used to study the pattern of maternal weights during pregnancy. Mixed effects modeling approach was used to model maternal weights gain and the generalized linear modeling was used to model birth weight and to describe the relationship between maternal weights, birth weight and the socio –economic factors of the mother. The results show that, maternal weights together with the number of antenatal visit, Gestation age, fundal height, parity and maternal education are all significant determinants of birth weight. The trend model of maternal weight was quadratic indicating that, the maternal weight gain doubled with time and the weight gain for term pregnancy is 9.04kg. The study found BMI, gestation age, fundal height, parity, number of antenatal visits and husband occupation to be the best determinants of birth weight. The study also estimated low birth weight prevalence rate in the region to be 10.60% and normal birth weight rate to be 89.40%.

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DEDICATION

This work is dedicated to my beloved mother, Mrs Abukari Amina.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS AND ACRONYMS

AIC	Akaike's Information Criterion
BIC	Bayesian Information Criterion
BMI	Body Mass Index
BW	Birth Weight
FH	Fundal Height
GA	Gestation Age
LBW	Low Birth Weight
HBW	High Birth Weight
NBW	Normal Birth Weight
LOC	Location
SB	Sex of Baby
MO	Maternal Occupation
HO	Husband Occupation
NAV	Number of Antenatal Visit
WHO	World Health Organization
MW	Maternal Weight (Gestational Age)
IUGR	Intrauterine Growth Retardation
SGA	Small for Gestational Age
GSS	Ghana Statistical Service
IOM	Institute of Medicine
GLSS	Ghana Living Standard Survey

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

1.1.1 Maternal Weight Gain during Pregnancy

Gestational weight gain, often referred to as maternal weight gain, is motivated by several trends in perinatal health that are of great public health concern. The increase in body mass index (BMI) among pregnant women worldwide has become one of the most significant public health concerns (Yazdani et al., 2012).Women are increasingly gaining weight during pregnancy beyond the thresholds set forth by the Institute of Medicine (IOM, 2009). Gestational (formerly maternal) weight gain includes the products of conception, which include the fetus and placenta, and increases in maternal fat stores, plasma volume, and uterine and breast tissue. Because pregnancy is the only common clinical situation when the provider has at least two patients, the mother and the fetus(es), balancing the amount of weight gain needed to optimize the size of the baby without jeopardizing the health of the mother both in the short and long term is essential l(Viswanathan et al., 2008).

Pregnancy is without any doubt a time for weight gain, which is essential for un-disturbed fetal growth and development and maternal health. Consequently gestational weight gain is a major determinant of reproductive success and an important factor in human reproductive ecology. It is well known that inadequate weight gain as well as excessive weight during pregnancy has a profound negative impact on maternal and newborn health (Crane et al., 2009). It has been nearly two decades since guidelines for how much weight a woman should gain during pregnancy were issued by the Institute of Medicine (IOM, 2009). In that time, more research has been conducted on the effects of weight gain in pregnancy on the health of both the mother and the baby. There have also been dramatic changes in the population of women having babies. Women today are also heavier; a greater percentage of them are entering pregnancy overweight or obese, and many are gaining too much weight during pregnancy. Many of these changes carry the added burden of chronic disease, which can put the mother and her baby's health at risk (IOM, 2009).

Obesity during pregnancy has been shown to carry significant risk to both the mother and the child. The role of uncontrolled weight gain during pregnancy has not been fully elucidated. (Savona-Ventura et al., 2008) study analysed the incidence of gestational hypertension and fetal macrosomia in various groups of mothers according to their BMI and antenatal weight gain. A definite statistically significant increased risk of both gestational hypertension and infant macrosomia was demonstrated with increasing BMI. This was compounded by increases in antenatal birth weight in all ranges of maternal BMI suggesting that adverse maternal metabolic parameters may contribute towards promoting the development of maternal and fetal complications. A restricted calorific intake in obese individuals during pregnancy may contribute towards decreasing the relative risks to both the mother and the child (Savona-Ventura et al., 2008).

1.1.2 Birth Weight

Birth weight is the weight of a newborn baby, measured immediately at the time of its birth. A baby's birth weight is an important indicator of overall health as well as a way to measure development and growth. Therefore, it is important that health professionals and parents understand the average birth weight expected of a full-term baby. However, there are global differences in average birth weights with significant discrepancies between developing and developed countries. Average birth weights in developing countries are significantly lower than in other countries, due to a variety of differences, including nutrition (UNICEF, 2005). Birth weight is the primary measure of a baby’s health in most analyses of infant health and welfare in economic research. In some contexts, birth weight is viewed as the “output” in the study of infant health production functions and the maternal behaviors that impact infant well-being (Currie and Moretti, 2003).

According to WHO, babies born with a weight less than 2.5kg are referred to as low birth weight (LBW). Those with birth weight less than 1.5kg are described as 'very low birth weight' (VLBW), and a birth weight less than 1.0kg is recognized as 'extremely low birth weight' (ELBW). Birth weight between 2.5kg – 4.2kg is considered as the normal weight for a newborn baby, for a full term delivery. Low birth weight risks include poor growth of the child, leading to both physical and psychiatric problems.

Research conducted in collaboration between the World Health Organization and the United Nations Children's Fund in 2004 (WHO and UNICEF, 2005) showed that in the least developed countries in the world 18% of babies are considered to be low birth weight in comparison to only 7% in the most developed countries. Asia is the worst affected continent with 18.3% of babies weighing less than 2.5kg, followed by Africa with a figure of 14.3%. South-central Asia is the most significantly affected area with an estimated 27.1%. Countries with the highest percentages of low birth weights include Sudan at 31.0%, India with 30.0%, Pakistan at 19.0% and Nigeria with 14.0% (WHO, 2004).

Research conducted by UNICEF and WHO also identified several causes of low birth weights in developing countries: poor diet and nutrition, genetic factors and poor general health of the mother. These negative factors are all more likely to be experienced by women who live in poor socio-economic conditions, such as those found in developing countries. Other women who are at increased risk of having a low birth weight baby are shorter women, younger women and those who live at high altitudes (WHO, 2013 and UNICEF, 2005).

LBW is not only a sensitive indicator for predicting the chances of both infant survival and healthy childhood growth and development, but is also a reflector of the present and past health status of the mother. LBW is a leading cause of prenatal and neonatal deaths, and as such it remains a worldwide issue and one of the most important public health problems, particularly in developing countries.

Birth weight is a major factor in determining child survival, future physical growth, and mental development. It is also sensitive to changes in the physical and socio-demographic status of the mother. In addition, the incidence of LBW babies is linked to maternal nutritional status. The quality of the maternal diet is related to the level of education and income, and affects the health status of the mother. Moreover, the fear of experiencing a difficult labor and birth prompts some pregnant women to restrict their food intake during the third trimester. Also, some of the pregnant women do not take the drugs given to them during antenatal. There are other cases in which low income expectant mothers seem to be significant factors that result in LBW babies. LBW occurred in 60.0% of prenatal deaths, and in those deaths occurring within the first week of life, the incidence of LBW was 71.0%. As a rule, LBW might constitute the single most important factor affecting neonatal mortality and morbidity, as evidenced by the fact that LBW babies are 40 times greater contributors to neonatal mortality and morbidity. Even if a LBW baby survives, it is likely to suffer a high incidence of malnutrition, diarrhea, acute respiratory infection, infectious disease, neurodevelopment problems such as cerebral palsy, and physical defects. In addition, LBW also determines the postnatal mental, physical, and neurological development of children (Louangpradith *et al.*, 2010).

Infant health problems are not only related to low birth weight but high birth weight has its own effects. A high birth weight baby has a birth weight more than 4.5kg. For mothers, higher birth weight has been linked to gestational diabetes and maternal obesity or weight gain during pregnancy (Gunn, 2005).

1.2 Problem Statement

The increase in BMI among pregnant women worldwide has become one of the most significant public health concerns (Yazdani et al., 2012).

During the 20th century, recommendations for appropriate weight gain in pregnancy changed dramatically, ranging from rigid restriction in the first half of the century to substantial gain in the 1970s and1980s. In 1990, the Institute of Medicine (IOM, 1990) recommended weight gain ranges with the primary goal of improving infant birth weight. Based on pre-pregnancy BMI categorizations, the recommended weight gain ranges were: 12.5 – 18.0kgfor underweight women, 11.5-16.0kg for normal weight women, 7.0-11.5kg for overweight women and at least 7.0kg for obese women. The recommendation for obese women was modified in 2009 to 5.1-9.3kg.

The Global Safe Motherhood Initiative, launched in 1987, was designed to improve antenatal care and counseling throughout the world. Nutrient intake and weight gain during pregnancy are the two main modifiable factors influencing maternal and infant outcomes. Indeed, a low body mass index (BMI) and suboptimal weight gain during pregnancy are long-recognized risk factors for the delivery of infants too small for gestational age. Being born small for gestational age is a major predictor of neonatal mortality and morbidity, failure to grow, slow cognitive development and chronic diseases in adulthood.

The maternal characteristics have been considered an important indicator of pregnancy prognosis, of birth conditions, especially those related to birth weight and perinatal mortality. Birth weight plays an important role in infant mortality and morbidity, child development, and adult metabolic diseases. Birth weight is divided into three main categories including, low birth weight (LBW), normal birth weight (NBW) and the high birth weight (HBW). In all the three categories, there is an associated health implication including child mortality and morbidity in the latter life conditions and child development.

It is against this background that the current study is important, in which determinants of birth weight and maternal weight during pregnancy in Northern Region is investigated. The need to find the determinants and to predict the average birth weight and maternal weight gain in the area would be the focus of the study.

1.3 Research Questions

The research objectives will be achieved if these questions are properly answered.

i. What is the gestational weight gain for a term pregnancy?

ii. What is the relationship between birth weight and the other factors of the mother?

iii. Does sex of the baby, mother's age and BMI affect birth weight?

iv. What is the prevalence of low birth weight and high birth weight in Northern Region?

1.4 Objectives of the study

General objective

The general objective of the study is to analyze longitudinal data from the Northern Region of maternal weight gains and predict birth weight using the prevailing factors of the mother using the mixed effects model.

Specific Objectives

i. To estimate the prevalence of low and high birth weight in the Northern Region of Ghana.

ii. To determine the average maternal weight gain during pregnancy in the Northern Region of Ghana.

iii. To determine the factors that significantly affects birth weight in the Northern Region.

iv. To find predictive models for both birth weight and maternal weights during pregnancy.

1.5 Significant of the Study

The study found a best model that will predict both birth weight and maternal weight during pregnancy based on some covariates. Stakeholders would find it useful in planning interventions and strategies for addressing the health problem of maternal and newborn babies in the area.

OUTLINE OF THESIS

The thesis followed the following outline to achieve its study objectives.

Chapter One contain Background of the study, Problem Statement, Objectives and the Significance of the study. Literature review on maternal weights and birth weight are contained in Chapter two, while chapter three contained the methodology of the study. Results and discussion are contained in chapter four and the thesis made conclusion and recommendations in chapter Five.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, we will review literature of both maternal weight gain and birth weight across the world and in Ghana.

2.2 BIRTH WEIGHT

Birth weight is the first weight of the foetus or newborn baby measured immediately after birth. For live births, birth weight should be measured within the first hour of life before significant postnatal weight loss has taken place. Birth weight is a major factor in determining child survival, future physical growth, and mental Development. It is also sensitive to changes in the physical and socio-demographic status of the mother (Louangpradith et al., 2010.).

Birth weight is one of the most commonly studied variables in epidemiology. It is associated with health risks ranging from infant mortality to cardiovascular disease. (Allen, 2001).

Sanderson et al.(1996), reported a positive association between birth weight and the risk of breast cancer in premenopausal women in the USA, but not in postmenopausal women; they interpreted their findings as compatible with the hypothesis that links pregnancy oestrogens to risk of breast cancer.

A research by Arnaud and Vincent (2007), revealed that, on average, educated mothers have heavier babies. Mothers who exited at age 17 have the lightest babies. Also, maternal health, as measured by haemoglobin level and blood pressure has no substantial effect on birth weight. After controlling for pre-pregnancy smoking intensity, smoking during pregnancy reduces birth weight by 0.16kg. The main non-genetic factors affecting birth weight are: gestation length, smoking, pre-natal health care, maternal nutrition (including alcohol and coffee consumption) and maternal stress. Maternal education can potentially affect all these inputs, and a correlation between birth weight and maternal education is a robust finding (Behrman and Wolfe, 1989; World Bank, 1993). Additionally, maternal education improves the financial resources available to the child directly and indirectly through the choice of partner, timing of fertility, and number of offspring.

Maternal education can have a causal effect on birth weight. This is identified by Currie and Moretti (2003) in the United States with a policy increasing the supply of colleges when the mother was a teenager. The rationale is that the opening of a college reduces the cost of higher education in a way that is uncorrelated with the unobservable term correlating both education and health.

2.3 HISTORY OF LOW BRTHWEIGHT

For many years, the presumed reason for babies to be born at low birth weight (LBW) was their preterm delivery. Indeed, the terms "LBW" and "premature" were used interchangeably in the scientific literature from the 1920s to the 1960s (Wilcox, 1993). However, not all small babies are premature, and not all premature babies are small. An accumulation of epidemiologic data during the

1950s and 1960s finally made this distinction clear. In 1961, the World Health Organization recommended that the term LBW should no longer be used as an official definition of prematurity. By the 1970s, most researchers had complied and by 1977 a book written on LBW as titled

The Epidemiology of Prematurity.

Perinatal epidemiologists (Wilcox 1993) avoided the use of the word "premature", instead it used the label "preterm" to signify a baby born so early.

Popular Assumptions about LBW

The dichotomization of birth weight is deeply entrenched in public health research. This practice rests on several assumptions about LBW.

1. **LBW causes infant mortality.**

In the first year of life, LBW babies are typically 20 or more times more likely to die than heavier babies. The sheer strength of this association with mortality is regarded as evidence of its causality.

2. **The percent LBW in a population is an indicator of infant risk.**

Infant death is rare (at least in developed countries), so researchers need a more prevalent surrogate indicator of perinatal risk. LBW serves this purpose nicely. This assumption, causes of LBW themselves become topics of investigation.

3. **LBW is preventable.**

If LBW is caused by either preterm delivery or fetal growth retardation, then LBW is presumably preventable. Thus, LBW provides a target for interventions to improve infant survival.

While these assumptions about LBW are generally accepted, not all aspects of LBW neatly fit into them (Allen, 2001).

2.4 HIGH BIRTH WEIGHT

High Birth Weight is defined as a baby born weighing more than 4.5kg. For mothers, higher birth weight has been linked to gestational diabetes and maternal obesity or weight gain during pregnancy (Gunn, 2005). Kirkegaard et al. (2006,) found out that children with a birth weight of 2.5 to 2.999kg had nearly twice the risk of reading difficulties than children with a birth weight of 3500 to 3999 grams. The association between birth weight and reading difficulties seemed to have a U-shaped pattern with a decreasing risk with increasing birth weight until 3500 grams and an increasing risk of having reading difficulties above this weight. They found no association between gestational age and arithmetic difficulties.

Nutrition during pregnancy and fetal development

It is well recognized that pregnancy is a critical period during which good maternal nutrition is a key factor influencing the health of both the child and the mother. Maternal weight gain during pregnancy is an important determinant of fetal growth and mother's health. Normal fetal growth is a positive function of the weight gained during pregnancy modified by pre-pregnancy nutritional status. There is some evidence that low maternal weight gain is associated with increased risk of pre-term delivery. On the other hand, excessive maternal weight is associated with macrosomia (babies with birth weight greater than 4.0kg or above the 90^{th} percentile of reference weight for a given gestational age).

Abrams , Altman and Pickets (2000), found in healthy, well- nourished U.S. women that maternal weight change in the first trimester of pregnancy had a greater influence on newborn size than weight change in the second or third trimester. Maternal weight gain in the first and second trimesters predicted newborn size (1.0 kg gestational weight gain in the first trimester predicted a 0.31kg increase in newborn weight, and 1.0 kg maternal weight gain in the second trimester predicted a 0.26kg increase in birth weight). Net maternal weight gain (gross maternal weight gain minus birth weight) in the third trimester did not predict birth weight.

2.5 STATE OF LOW BIRTH WEIGHT IN GHANA

According to world health organization (WHO), low birth weight in Ghana was 13.4 percent. The most recent evidence on Ghana Statistical Service shows that approximately 10% of all births are LBW (GSS, 2009). A survey conducted in 2011 estimated the low birth weight in Ghana to be 32 percent. A study by Edward *et al* (2012) study also estimated LBW prevalence in Northern Region to be 5.26% which is lower than the national average (Ghana) of 13.4%.

According to the latest WHO data published in April 2011 Low Birth Weight Deaths in Ghana reached 6,056 or 3.23% of total deaths. The age adjusted Death Rate was 16.06 per 100,000 of population ranked, Ghana number 52 in the world.

Many infants in developing countries are not weighed at birth. In sub-Saharan Africa for example, it is estimated that nearly 75% of newborns are not weighed. In other regions, the percentages range from 20% to 82%. Much of the available data on low birth weight are, therefore, not representative of the general population and are often underestimated.

2.6 REVIEWS ON MATERNAL WEIGHT

Erika et al.(2010), quantify the prevalence of small and large size for gestational age and the risk factors involved in Viet Nam using univariate and multivariate logistic regression method. The study also estimates the optimal weight gain during pregnancy as a function of maternal BMI.

The RTI International–University of North Carolina at Chapel Hill Evidence-based Practice Center (RTI-UNC EPC) systematically reviewed evidence on outcomes of gestational weight gains, their confounders and effect modifiers, outcomes of weight gain within or outside the 1990 Institute of Medicine (IOM, 1990) guidelines, risks and benefits of weight gain recommendations, and anthropometric measures of weight gain.

The study by Padilha et al. (2009), aimed to identify birth weight variation according to maternal characteristics and gestational weight gain..The study found the predictor variables of birth weight to be the total gestational weight gain, pre-gestational BMI, maternal age and number of perinatal care appointments. Socio-demographic obstetric and perinatal care characteristics were controlled using linear regression model.

Ahmadu et al. (2012), studied the effect of maternal pregnancy body mass index as a measure of pregnancy weight gain on neonatal birth weight outcome in the labor ward of the University of Maiduguri Teaching Hospital. The study used Chi- Square test of association to investigate the effect of maternal pregnancy BMI on neonatal birth weights. The study showed that, maternal BMI did not significantly contribute to the birth weight of neonates.

The impact of maternal somatic factors, first of all maternal stature height, on gestational weight gain was studied by Sylvia et al. (2013), using multiple regression method. Additionally the effect of gestational weight gain and other maternal somatic factors on size of newborn was tested. Their study concluded that gestational weight gain is influenced by several maternal somatic factors.

Phaneendra et al. (2001), studied the effect of pre-pregnancy weight, maternal height and weight gain during pregnancy on birth weight. One way Analysis of variance (ANOVA), multiple range test, correlation and stepwise multiple regression analysis were the different statistical methods applied for analyzing the data Their study pointed out that, as the pre-pregnancy weight increased there was a corresponding increase in the mean birth weight and this relationship was statistically significant.

Chrishantha and Pushpa (2010), used Multiple logistic regression to determine the effect of maternal and social factors for excessive gestational weight gain. They concluded that, being overweight, maternal complications, passive smoking, low educational level and high income were the determinants of excessive weight gain during pregnancy.

Savona-Ventura et al. (2008), analyzed the incidence of gestational hypertension and fetal macrosomia in various groups of mothers according to their BMI and antenatal weight gain. Chi square and the student t tests were the statistical method used. A definite statistically significant increased risk of both gestational hypertension and infant macrosomia was demonstrated with increasing BMI.

Abdulai et al. (2015), studied the maternal determinants of birth weight in Northern Ghana, using multiple and univariate regression method. Their study shows that pre-pregnancy body mass index and weight gain during pregnancy influence birth weight.

Addo (2010), studied the effects of pregnancy weight gain in different body mass index groups on maternal and neonatal outcomes in women delivering singleton at term. Chi square test and student T- test were the statistical methods used for the data analysis. This study was conducted in Bomso Specialist Hospital in Kumasi, Ghana**.** Most deliveries in the two BMI groups resulted in normal weight babies. The study observed that, Overweight and Obesity is associated with significantly increased incidence of adverse maternal and neonatal outcomes.

Gloria (2002), studied the impact of frequent reproductive cycle on pregnancy outcomes and maternal nutritional status. Multiple stepwise regression analysis was used to determine factors associated with birth weight. The study was conducted in Accra, the capital of Ghana. The study found a mean birth weight for the two groups to be 3.05±0.49kg and 3.11±0.36kg for mothers with 1-2 births and the multiparous mothers.

A research conducted in the urban area of Bangladesh shows that low birth weight incidences in the area was 23.2% and 51.1% of the LBW came from mothers of the <20years of age group, 50% of mothers of LBW were found illiterate, socioeconomic status was significantly more poor, maternal anaemia was found significantly more common in LBW and iron & vitamin supplementation during pregnancy were found significantly less among the mothers of LBW babies in comparison to Normal birth weight (NBW). Significant relationship was found between early maternal age, poor educational and socioeconomic status, anaemia, iron & vitamin supplementation during pregnancy with LBW. No relationship was found between LBW and maternal height but significant relationship was found with maternal weight and BMI (Matin et al., 2008).

A research conducted at four central hospitals in Vientiane, Lao PDR (Louangpradith et al.,2010) show that, almost 96% of the mothers belonged to the Laolum ethnic group, and were mostly Buddhist in religion had babies with low birth weight. Most mothers of LBW babies (88.9%) belonged to the hard physical labour group, and 68.9% of them had incomes of less than one million Kips (US$120.00) per month.

It also reveals that, most first-born children were LBW (60.9%), whereas 39.1% of second children were LBW. LBW prevalence was 6.8% among those mothers who had a family history of LBW babies, while it was 93.2%of those mothers who never had such a family history. They determined the level of knowledge and practice on different issues involving LBW babies, their causes and nutritional roles using a set of questions for each component. The knowledge ability of mothers having scores of 75% or more for giving the correct answers to knowledge related questions was ranked as 'adequate', while below 75% were regarded as 'inadequate'. Accordingly, the researchers also found out that only 27.2% of all mothers had adequate knowledge. As for the level of practicing healthy behavior during pregnancy was concerned, they determined that only 48.9% of mothers with LBW babies had adequate practice, in contrast to 89.4% of mothers of NBW babies. Indeed, few mothers of LBW babies were in good health (69.8%) in comparison to mothers of NBW babies (88.7%). They also show the different factors affecting the outcome of LBW babies. As expected, mothers below 18 years of age were eight times more prone to deliver LBW babies (95% CI=2.4–30.7). Mothers engaging in strenuous physical labor were also at high risk of giving birth to LBW babies with confidence interval of 5.0 (95% CI=3.1–8.1). Knowledge about the details of a healthy pregnancy is an important contributor to giving birth to a healthy baby. The results further showed that a lack of such knowledge played a significant role in delivering LBW babies (OR=10.1 95%CI=6.7–15.2). Similarly, mothers in poor health were at three times the risk of having LBW babies (95% CI=2.1–5.4). Family incomes of mothers were one of the most reliable indicators in the analyses, which was reflected by the fact that low-group mothers were as much as 13.9 times at higher risk of having LBW babies (95% CI=8.8–21.9). Overall, the study discovered significant ($p < 0.01$) contributions of several studied factors to the development of LBW babies (Louangpradith *et al.*, 2010).

2.7 LONGITUDINAL STUDY

A longitudinal study refers to an investigation where participant outcomes and possible treatments or exposures are collected at multiple follow-up times. A longitudinal study generally yields multiple or repeated" measurements on each subject. For example, a monthly weight of the mother is taken from the time of conception to birth day. Both the within and between variations of the subjects are studied. Another important outcome of longitudinal study that is commonly measured is the time until a key clinical event such as disease recurrence or death occurred. Longitudinal studies play a key role in epidemiology, clinical research, and therapeutic evaluation. Longitudinal studies are used to characterize normal growth and aging, to assess the effect of risk factors on human health, and to evaluate the effectiveness of treatments. Longitudinal studies involve a great deal of effort but offer several benefits. These benefits include:

- *Incident events are recorded*. A prospective longitudinal study measures the new occurrence of disease. The timing of disease onset can be correlated with recent changes in patient exposure and/or with chronic exposure.
- *Prospective ascertainment of exposure*. In a prospective study participants can have their exposure status recorded at multiple follow-up visits. This can alleviate recall bias where subjects who subsequently experience disease are more likely to recall their exposure (a form of measurement error). In addition the temporal order of exposures and outcomes is observed.

- *Measurement of individual change in outcomes*. A key strength of a longitudinal study is the ability to measure change in outcomes and/or exposure at the individual level. Longitudinal studies provide the opportunity to observe individual patterns of change.
- *Separation of time effects: Cohort, Period, Age*. When studying changes over time there are many time scales to consider. The cohort scale is the time of birth such as 1946 or 1964, period is the current time such as 2003, and age is (period - cohort), for example 58 = 1945-1945, and 40 =1963-2003. A longitudinal study with measurements at times$t_{1,}t_2,\ t_3,..t_n$can simultaneously characterize multiple time scales such as age and cohort effects using covariates derived from the calendar time of visit and the participant's birth year: the age of subject i at time t_j is
- $age_{ij} = (t_i -$ birth); and their cohort is simply $cohort_{ij} - birth_i$. Lebowitz [1996] discusses age, period, and cohort effects in the analysis of pulmonary function data.
- *Control for cohort effects*. In a cross-sectional study the comparison of subgroups of different ages combines the effects of aging and the effects of different cohorts. For instance, comparison of outcomes measured in 2003 among 58 year old subjects and among 40 years old subjects reflects both the fact that the groups differ by 18 years and the fact that the subjects were born in different eras. For example, the public health interventions such as vaccinations available for children under ten years of age may differ during the years 1945-1955 as compared to the preventive

interventions experienced in 1963-1973. In a longitudinal study the cohort under study is fixed and thus changes in time are not confounded by cohort differences.

2.7.1 Challenges of longitudinal studies:

- *Participant follow-up*. There is the risk of bias due to incomplete follow up, or drop-out of study participants. If subjects that are followed up to the planned end of a study differ from subjects who discontinue follow-up then a naive analysis may provide summaries that are not representative of the original target population.
- *Analysis of correlated data.* Statistical analysis of longitudinal data requires methods that can properly account for the intra-subject correlation of response measurements. If such correlation is ignored then inferences such as statistical tests or confidence intervals can be grossly invalid.
- *Time-varying covariates*. Although longitudinal designs offer the opportunity to associate changes in exposure with changes in the outcome of interest, the direction of causality can be complicated by feedback between the outcome and the exposure.

2.7.2 Characteristic of Longitudinal Data

- Individuals are measured repeatedly over time
- When the measurements are taken is not of primary interest and is considered fixed by design.

The fact that people have different number of observations and at different times is often ignored under certain assumptions such as:

- Small number of observations per subject but relatively large number of subjects.
- The variability can be divided into three components:
    1. Heterogeneity between individuals.
    2. Serial correlation, measurements closely spaced are more similar.
    3. Measurement error.

Conclusion

Chapter two above therefore provided literature review on maternal weights, birth weight and also explained longitudinal data analysis.

CHAPTER THREE

METHODOLOGY

3.1 INTRODUCTION

In this chapter, we explained the methodology that was used in the entire study. The chapter consists of discussions of study area, target and study populations, research instruments, data collection, modeling approach, model evaluation and profile analysis and statistical analysis.

3.2 Background of study area

We extracted secondary data from the antenatal cards in the Labour ward of Tamale Teaching Hospital in the Tamale Metropolitan Assembly. The Tamale Metropolitan Assembly (TaMA) was elevated to the status of Metropolis in 2004. The Metropolis is one of the six Metropolitan Assemblies in the country and the only Metropolis in the three Northern Regions of Ghana namely; Upper East, Upper West and Northern Regions. The capital of the Metropolis is the capital of the Northern Region and the seat of the Northern Regional Minister. It lies between latitude 9.16° and 9.34° north and longitudes 00.36°and 00.57^0.Tamale Metropolitan Assembly is located approximately 180 meters above sea level. The topography is generally rolling with some shallow valleys which serve as stream courses.

There are also some isolated hills but these do not inhibit physical development. The Tamale Metropolis is one of the 26 demarcated districts in the Northern Region. It has a population of over 370 000 people (GSS, 2010 population census). The Metropolis is located in the central part of the Northern Region and shares boundaries with five other districts namely the Savelugu- Nanton to the North, Yendi Municipal Assembly to the East, Tolon-Kumbungu to the West, Central Gonja to the South West and East Ganja to the South. The metropolis is recently divided into two: Tamale Metropolitan Assembly and Sagnarigu District.

3.3 Study population

The study population comprises of pregnant women who gave birth to a singleton babies in the Tamale Teaching Hospital.

3.4 Target Population

The target population included all women who delivered in the hospital and whose babies were alive excluding twins and those women who did not attend antenatal for at least three months. There were 247 participants who delivered in the Tamale Teaching Hospital during the period of our visit. Eighty seven of these participants were dropped as a result of twins, and those women who do not attend antenatal for at least three times (3 months). Only one hundred and sixty participants were used for the analysis.

3.5 Source of Data and Data Collection

We extracted secondary data from the antenatal cards in the labour ward of Tamale Teaching Hospital. Those women who had stillbirth, those who had less than three antenatal visit and those with twins were not included in the study. The secondary data consists of birth weight, gestational age, sex of the baby, fundal height, maternal height, marital status, number of antenatal visits to hospital during pregnancy, maternal weights, age and parity, educational status, occupation of the mother and the husband and location.

3.6 Statistical Analysis

The data was sorted, edited, coded and entered in Ms Excel sheet. Statistical software's like SAS vision 9.2, SPSS and STATA (small) was used for the data analysis. Information from the data were presented in graphs, tables and charts. Descriptive statistics such as frequencies, means, median, standard deviation and percentages were presented as preliminary analysis. The appropriate model was subsquently fitted for the prediction of both maternal weight and birth weight.

3.7.0 Modelling Approach

Linear mixed effects model was used, adjusted for potential explanatory variables, including time to treatment, mother's age, height, occupation, fundal height, gestation age, marital status, parity, educational status and husband occupation and parity. Linear mixed-effects model was used because it takes into account inter- and intra pregnant sources of variation. They are flexible enough to account for the natural heterogeneity in the population, and they can handle any degree of imbalance in the longitudinal data. In the first stage of a linear mixed-effects model, the general structure for the mean response model is

$$\mathbf{y_i} = \mathbf{X_i}\boldsymbol{\beta} + \mathbf{Z_i}\mathbf{b_i} + \boldsymbol{\varepsilon_i},\ \boldsymbol{i} = \mathbf{1}, \ldots, \boldsymbol{n}. \quad 3.1$$

where

$$\mathrm{y_i} = (\mathrm{y_{i1}}, \mathrm{y_{i2}}, \ldots \mathrm{y_{ini}})^{\mathrm{T}}, \quad \mathrm{b_i} \sim \mathrm{N_q}(0, \psi) \quad \varepsilon_{\mathrm{i}} \sim \mathrm{N_{ni}}(0, \sigma^2 I)$$

Where β = fixed effects, b_i = Random effect for unit i

ψ =Between-unit covariance matrix

$\sigma^2 I$ =Within-unit covariance matrix

Averaging over the distribution of the latent random effects b_i, the marginal (population-average) distribution of y_i is

$$y_i \sim N(X_i\beta, \Sigma_i),$$

$$\Sigma_i = Z_i\psi Z_i^T + \sigma^2 I \qquad 3.2$$

If we take $Z_i = (1, 1, \ldots, 1)^T$ that is random intercepts then Σ has compound symmetry. The elements of β represent the effects of the variance in X_i on the mean response, both for a single subject and on average for the population

Therefore the initial full model is as follows

$$Y_i = \beta_0 + \beta_1 GA_i + \beta_2 age_i + \beta_3 edu_i + \beta_4 m.status_i + \beta_5 FH_i + \beta_6 ANV_{it} + \beta hi + \cdots + \beta parity + \varepsilon_i \qquad 3.3$$

where β_0 is a random-effect intercept that varies according to i, which is the pregnant woman index, *t* is the time and has the value 1 (1 month) to 2(2 months), 3 (3 months), 4 (4 months), 5 (5 months), 6 (6 months), 7 (7 months), 8 (8 months) and 9 (9 months) and ***b₁….bₖ*** are fixed-effect parameters associated with the nonrandom predictors. The resulting estimated ***b*** , the fixed-effect parameter for each predictor in these models, represents the average maternal weight for a unit increase in that predictor. We will then estimate a co-variance and correlation matrix to determine which particular covariance model will fit the data.

3.7.1 Correlation and Covariance Structure

Correlation and Covariance Matrix

In characterizing the correlation, we looked at the component of variance that can enable us to identify a variance or correlation model for regression in our mixed-fixed model. One way to do this is to estimate the covariance matrix which is defined as

$Cov(Y_{ijk}, Yijl)=$

$$\begin{pmatrix} E[(Y_{i1}-\mu_{i1})^2] & E[(Y_{i1}-\mu_{i1})]E[(Y_{i2}-\mu_{i2})] & \cdots & E[(Y_{i1}-\mu_{i1})]E[(Y_{in}-\mu_{in})] \\ E[(Y_{i2}-\mu_{i2})]E[(Y_{i1}-\mu_{i1})] & E[(Y_{i2}-\mu_{i2})^2] & \cdots & E[(Y_{i2}-\mu_{i2})]E[(Y_{in}-\mu_{in})] \\ \vdots & \vdots & \ddots & \vdots \\ E[(Y_{i2}-\mu_{i2})]E[(Y_{i1}-\mu_{i1})] & E[(Y_{i2}-\mu_{i2})]E[(Y_{i1}-\mu_{i1})] & \cdots & E[(Y_{i2}-\mu_{i2})^2] \end{pmatrix} \quad 3.4$$

The covariance can be written in terms of σ_j^2 and the correlation ρ_{jk};

$$Cov(Y_i)=\begin{bmatrix} \sigma_1^2 & \sigma_1\sigma_2\rho_{12} \ldots\ldots\ldots\ldots & \sigma_1\sigma_n\rho_{1n} \\ \sigma_2\sigma_1\rho_{21} & \sigma_2^2 \ldots\ldots\ldots\ldots & \sigma_2\sigma_n\rho_{2n} \\ . & . & . \\ . & . & . \\ . & . & . \\ \sigma_n\sigma_1\rho_{n1} & \sigma_n\sigma_2\rho_{n2} \ldots\ldots\ldots\ldots\ldots & \sigma_n^2 \end{bmatrix} \quad 3.5$$

$$Corr(Y_i) = \begin{bmatrix} 1 & \rho_{12} \ldots\ldots & \rho_{1n} \\ \rho_{21} & 1\ldots\ldots & \rho_{2n} \\ . & . & . \\ . & . & . \\ . & . & . \\ \rho_{n1} & \rho_{n2}\ldots\ldots & 1 \end{bmatrix} \quad 3.6$$

Which is useful for comparing the strength of association between pair of outcomes particularly when the variance is not constant.

3.7.2 Model for Covariance Structure

Depending on the pattern in the variance and correlation, one of the following four covariance models will be used:

Unstructured covariance structure

The unstructured is the most "liberal" of all allowing every term to be different. It requires fitting the most parameters of any structure, t(t+1)/2. Where t is the time interval between parameters

$$\text{Corr}(Y_i) = \begin{bmatrix} \sigma_1^2 & \sigma_{12} & \sigma_{13}\ldots\ldots & \sigma_{1n} \\ \sigma_{12} & \sigma_2^2 & \sigma_{23}\ \ldots . & \sigma_{2n} \\ & \vdots & \vdots & \vdots \\ \sigma_{1n} & \sigma_{23} & \sigma_3^2\ \ldots & \sigma_{3n} \end{bmatrix} \qquad 3.7$$

Variance Components

The variance covariance structure is the standard variance components, where there is no correlation between any pair of observation. The covariance structure is given as;

$$Corr(Y_i) = \begin{pmatrix} \sigma_A^2 & 0 & 0 & 0 \\ 0 & \sigma_B^2 & 0 & 0 \\ 0 & 0 & \sigma_{AB}^2 & 0 \\ 0 & 0 & 0 & \sigma_{AB}^2 \end{pmatrix} \qquad 3.8$$

Compound Symmetry

Compound symmetry has a correlation between two separate measurements and the variances are homogeneous, but it is assume that, the correlation is constant regardless of how far apart the measurements are.

$$Corr(Y_i) = \begin{pmatrix} \sigma^2+\sigma_1^2 & \sigma_1^2 & \sigma_1^2 & \sigma_1^2 \\ \sigma_1^2 & \sigma^2+\sigma_1^2 & \sigma_1^2 & \sigma_1^2 \\ \sigma_1^2 & \sigma_1^2 & \sigma^2+\sigma_1^2 & \sigma_1^2 \\ \sigma_1^2 & \sigma_1^2 & \sigma_1^2 & \sigma^2+\sigma_1^2 \end{pmatrix}. \quad 3.9$$

First-Order Autoregressive covariance structure:

The AR(1) structure has homogeneous variances and correlations that decline exponentially with distance. It means that two measurements that are right next to each other in time are going to be pretty correlated (depending on the value of ρ), but as measurements get farther and farther apart they are less correlated.

$$Corr(Y_i) = \begin{bmatrix} 1 & \rho & \rho^2 & \cdots & \rho^n \\ \rho & 1 & \rho & \cdots & \rho^2 \\ \cdots & \cdots & \cdots & \cdots & \rho \\ \rho^n & \cdots & \rho^2 & \rho & 1 \end{bmatrix} \quad 3.10$$

First-Order Autoregressive Moving Average, ARMA(1,1)

The measurements are repeated across time, then the time variable will be prominent in this distance function. If measurements are repeated across location, then the distance function will involve some spatial metric reflecting the experimental design's geometry.

$$Corr(Y_i) = \begin{pmatrix} \sigma^2 & \sigma^2\lambda & \sigma^2\lambda\rho & \sigma^2\lambda\rho^2 \\ \sigma^2\lambda & \sigma^2 & \sigma^2\lambda & \sigma^2\lambda\rho \\ \sigma^2\lambda\rho & \sigma^2\lambda & \sigma^2 & \sigma^2\lambda \\ \sigma^2\lambda\rho^n & \sigma^2\lambda\rho & \sigma^2\lambda & \sigma^2 \end{pmatrix} \quad 3.11$$

3.7.3 Estimating $\boldsymbol{\beta}$

The regression parameter β and the covariance parameters will be obtained by maximizing the likelihood function;

$$L \propto (\sigma^2)^{-N/2} \prod_i |W_i|^{1/2} \times \exp\left\{\sum_i \frac{-1}{2\sigma^2}(y_i - X_i\beta)^T W_i (y_i - X_i\beta)\right\} \qquad 3.11$$

Where

$$W_i = (\sigma^{-2} Z_i \psi Z_i^T + I)^{-1},$$

given the covariance parameters, L is maximized at Generalized Least Square estimate

$$\widehat{\beta} = \left(\sum_{i=1}^{m} X_i^T W_i X_i\right)^{-1} \left(\sum_{i=1}^{m} X_i^T W_i y_i\right) \qquad 3.12$$

3.8 PROFILE ANALYSIS

The pattern of maternal weight during pregnancy is assessed through the profile analysis. We performed profile plot to observe the pattern of change in maternal weight during pregnancy over time. The factors used for the plot were maternal education, maternal occupation, sex of baby, marital status, location and husband occupation.

A quadratic scatter plot of the means of maternal weight over time was plotted. A linear trend model was then fitted for the pattern. We checked the model accuracy by performing the following tests.

Shapiro-wilks Test

The purpose of this test is to test normality of the residuals. Given a set of observations $\overline{x_1}$, $\overline{x_2}, \overline{x_3}$, …, $\overline{x_n}$ sorted in either descending or ascending order. The test statistics of Shapiro-Wilks is

$$W=\frac{\left(\sum_i^n a_i x_i\right)^2}{\sum_{i=1}^n (x1-\bar{x})^2} \qquad (3.13)$$

Where

$\bar{x} = 1/n \sum_{i=1}^n x_i$

is the sample mean and a_i for i= 1, 2, 3,…, n are the set of weight whose values depend only on the sample size n.

3.9 MANOVA

Multivariate Analysis of Variance was performed to complement and confirm the profile analysis. The MANOVA test is based on the matrices:

$$\text{Wilks'Lamda}(\Lambda) = \frac{|W|}{|B+W|} \qquad 3.14$$

$$\text{Lawley-Hoteling Trace} = \text{tr}[BW^{-1}] \qquad 3.15$$

$$\text{Pillai trace} = \text{tr}[(B+W)^{-1}] \qquad 3.16$$

$$\text{Roy's largest root} = \text{maximum eigenvalue of } B(B+W)^{-1} \qquad 3.17$$

3.10 Test of Parallelism

Profiles are said to be parallel when the group differences are constant across variables. We conducted parallelism test for the significant variables in the model.

$H_o: C\vec{\mu}=C\vec{\mu}$ vs $H_a: C\vec{\mu} += C\vec{\mu}$

3.11 Model Selection Criteria

Akaike information criterion (AIC) and Bayesian information criterion (BIC) was used to compare the goodness-of-fit between models. These models are based on the log-likelihood *l(b)*, the number of parameters in the distribution, *p*, and the total number of observations, *n*. Where $\hat{b}$ denotes the MLE of all the parameters in the distribution. Models with smaller AIC or BIC values show a better fit. However, the BIC is preferred if the distribution has a sufficiently large sample size because it penalizes models more severely than the AIC does.

$$BIC = l(\hat{b}) - \frac{p}{2}\log n \qquad 3.18$$

$$AIC = l(\hat{b}) - 2p \qquad 3.19$$

3.12 Model Evaluation

Likelihood Ratio Test, Wald Test and Lagrange Multiplier (Score) Test

The model would be evaluated by linear mixed effects model by the following three tests to check which of them best fit our model.

The Likelihood Ratio (LR) Test

This test will be performed by estimating two models and compare the fitness of one of them to the other. If the difference is significant, the one with more variables will fit the data significantly better than the more restrictive model. Thus the formula for the LR test statistic is

$$T_{LRT} = -2\left(\log\hat{L}_{reduced} - \log\hat{L}_{full}\right) = 2\log\hat{L}_{full} - 2\log\hat{L}_{reduced} \qquad 3.20$$

The test statistic has chi-square distribution, with degree of freedom equal to the number of parameters.

The Wald Test

Wald test is used to test the null hypothesis that a set of two parameters are simultaneously equal to zero. If the test fails to reject the null hypothesis, it will suggest that removing the variables from the model will not substantially affect the model fitted, since a predictor with a coefficient that is very small relative to its standard error generally does not help to predict the dependent variable.

Lagrange Multiplier (Score) Test

This test requires estimating only one model. This test is used in testing whether adding another variable to a model will result in a significant improvement in the model fit, for instance if we run a model with only two predictor variables. The test statistic is calculated based on the slope of the likelihood function at the observed values of the variables in the model (Bruin, 2006).

3.13 Generalized Linear Model

In a generalized linear model (GLM), each outcome of the dependent variable, **Y**, is assumed to be generated from a particular distrbution in the exponential family, which has a large range of probability distributions and includes the normal, binomial, poission and gamma distributions, among others. The mean, $\boldsymbol{\mu}$, of the distribution depends on the independent variables, **X**.

$$\mathrm{E}(\mathbf{Y}) = \boldsymbol{\mu} = g^{-1}(\mathbf{X}\boldsymbol{\beta}) \qquad 3.21$$

where E(**Y**) is the expected value of **Y**; ***Xβ*** is the linear predictor, a linear combination of unknown parameters **β**; g is the link function.

Generalized linear models are a framework for modeling this type of conditional distribution P(Y|X1, . . . , Xn) subject to four key assumptions:

1. The influences of the{Xi}variables on Y can be summarized into an intermediate form, the linear predictor η;

2 . η is a linear combination of the{Xi};

2. There is a smooth, invertible function *l* mapping η to the expected value μ of Y;

3. The distribution P(Y=y; μ) of Y around μ is a member of a certain class of noise functions

and is not otherwise sensitive to the X_i variables, Where

$$\eta=\alpha+\beta_1X_1+\cdots+\beta nXn \quad 3.22$$

$$\eta = l(\mu) \quad 3.23$$

Adding a noise function $\mathcal{E}_i$,

$$Y = \alpha + \beta_1X_1 + \ldots + \beta_nX_n + \mathcal{E}_{i}, \quad 3.24$$

Using least square estimates , and assuming normality. we have

$$\beta= (X^1X)^{-1}X^1Y \quad 3.25$$

Conclusion

The data is analysed using linear mixed effects model and generalized linear model to fit maternal weight and birth weight predictive models respectively. Profile plots and MANOVA were also used to access the pattern of change in maternal weight by groups.

CHAPTER FOUR

ANALYSIS AND DISCUSSION OF RESULTS

4.1 INTRODUCTION

This chapter presents the following findings: Descriptive Statistics of Birth weight and the Maternal weight of the pregnant women included in the study as well as preliminary analysis, profile analysis of maternal weight gain and further analysis on the mixed model.

4.2 PRELIMINARY ANALYSIS

4.2.1 Descriptive Statistics of Maternal Weight

Table 4.1: Descriptive Statistics of Maternal weight

Label	Mean	Median	StdDev	Minimum	Maximum
Age	28.0	29.0	5.8	18.0	41.0
LOCATION					
Rural	63.1	62.0	8.0	49.0	87.0
Urban	68.1	67.0	10.0	42.0	102.5
EDUCATION					
Nill	66.0	65.0	9.0	42.0	88.0
Primary	66.3	63.5	9.2	51.0	85.0
JHS	65.9	64.8	11.1	50.0	102.5
SHS	68.6	70.0	10.3	46.0	97.0
Tertiary	72.2	70.0	10.0	55.0	94.0
MSTATUS					
Single	60.5	58.5	8.2	48.0	72.0
Married	67.6	66.0	10.0	42.0	102.5
MOTHER OCC					
Unemployed(H/W)	66.6	64.0	10.8	46.0	97.0
Unskilled Lab.	68.0	68.0	9.3	47.0	102.5
Skilled/Selfemp.	62.7	62.0	7.4	42.0	85.0
Salary	73.2	70.5	10.1	55.0	94.0
HUSBAND OCC					
Unemployed	62.1	63.0	6.5	48.0	72.0
Unskilled Lab.	64.4	63.0	8.6	49.0	88.0
Skilled Lab.	67.6	67.0	9.9	42.0	102.5
Salary	69.4	69.5	10.3	46.0	97.0

Table 4.1 shows the descriptive statistics of maternal weight of mothers who delivered in the Tamale Teaching Hospital excluding those who had twins. Women in the urban areas are heavier (68.1kg) than their counterparts (63.1kg) in the rural areas. For educational level category, tertiary had the highest mean maternal weight (72.2kg), followed by SHS (68.6kg), Primary (66.3kg), No education (66.0kg) and JHS (65.9kg). The highest median maternal weight of 70.0kg was recorded by the SHS and the tertiary categories. For the marital status, the higher mean was recorded among the married women (67.6kg). The maximum maternal weight in the marital status was 102.5kg under the married categories. Women who are salary earners had the highest mean of 73.2422kg followed by the unskilled labourers category of 68.0kg and the least in the group is skilled labourers/self-employed (62.7kg). The highest maternal weight of 102.5kg was recorded in the unskilled labourers categories. For the husband occupation category, the highest maternal mean (69.4kg) was recorded among the salary earners category and the least weight of 62.1kg was recorded in the unemployed women categories. The median maternal weights of 63.0kg, 63.0kg, 67.0kg and 69.0kg were recorded for unemployed, unskilled, skilled/self employed and the salary earners categories respectively.

Table 4.2: Descriptive Statistics of birth weight

Treatment	Mean	Median	Std	Min	Max
Overall	3.1	3.1	0.5	1.2	4.2
EDUCATION					
Nill	3.1	3.1	0.5	1.3	4.0
Primary	3.2	3.5	0.5	2.1	3.7
JHS	2.8	3.0	0.5	1.2	3.5
SHS	3.3	3.4	0.5	2.3	4.2
Tertiary	3.3	3.3	0.4	2.2	4.1
LOCATION					
Rural	3.0	2.9	0.5	1.7	4.2
Urban	3.1	3.2	0.5	1.2	4.2
MSTATUS					
Single	2.6	2.5	0.5	2.1	3.3
Married	3.1	3.1	0.5	1.2	4.2
HUSBAND OCC					
Unemployed	2.7	2.6	0.3	2.3	3.3
Unskilled labour	3.0	3.0	0.5	1.2	4.0
Skilled labour	3.1	3.1	0.5	1.3	4.2
Salary	3.3	3.4	0.5	2.1	4.2
MOTHER OCC					
Unemployed(H/W)	3.0	2.9	0.5	1.7	4.1
Unskilled labour	3.1	3.1	0.5	1.2	4.2
Skilled labour	3.0	3.0	0.5	1.9	4.0
Salary	3.3	3.4	0.2	3.0	3.7
BABY SEX					
Female	3.1	3.1	0.5	1.2	4.1
Male	3.1	3.1	0.5	1.7	4.2

Table 4.2 shows the descriptive statistics of birth weight by groups. The overall mean birth weight was 3.1kg and the median was 3.1kg. The minimum birth weight was 1.2kg and the maximum was 4.2kg. For the education categories, women with Tertiary and SHS education had a maximum mean birth weight of 3.3kg followed by primary (3.2kg), No education (3.1kg) and the least was JHS (2.8kg). Rural area had a mean birth weight of 3.0kg as against the urban area which recorded an average birth weight of 3.1kg. The median birth weight for the urban and the rural categories were 3.2kg and 2.9kg respectively. For a marital status, women who are married had babies with mean birth weight of 3.1kg as

compare to 2.6kg for single mothers. The maximum birth weight under the single mothers category was 3.3kg and the highest for the married category is 4.2kg. The minimum birth weights of 2.1kg and 1.2kg were recorded among the single and the married categories respectively. For the Husband occupation category, mean birth weights of 2.7kg, 3.0kg, 3.1kg and 3.3kg were recorded for the unemployed, unskilled labourers, skilled labourers and the salary workers respectively. The maximum birth weight of 4.2kg was recorded under skilled labourers and the salary categories while the minimum birth weight of 1.2kg was recorded in the unskilled labourers category. For the Babies' sex category female babies on the average had a higher birth weight of 3.1kg as compared to the male babies who had an average birth weight of 3.1kg.

Gender Distribution of babies

Majority of the babies were females (57.8%) and the male babies accounted for 42.2% as shown in the figure 4.1 below.

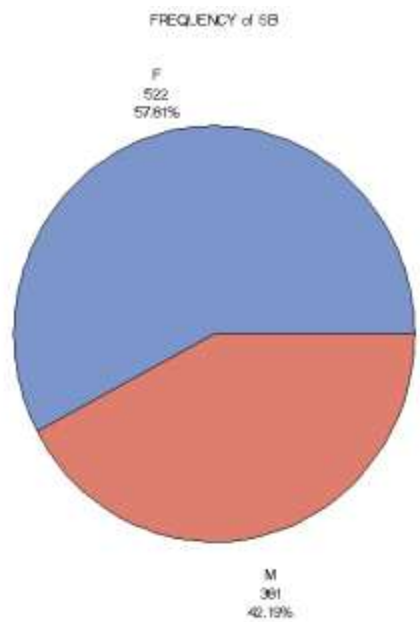

Figure 4.1: Gender distribution of babies.

Where Single = 0 and Married = 1

Distribution of Maternal age

Figure 4.2 shows the age distribution of mothers in the Northern region. About 21.5%, 18.0%, 32.5%, 18.5% and 9% belong to the age groups 17.5-22.5, 22.5-27.5, 27.5-32.5, 32.5-37.5 and 37.5-42.5 respectively. The maternal age group 37.5 to 42.5 had the least representation (9%).

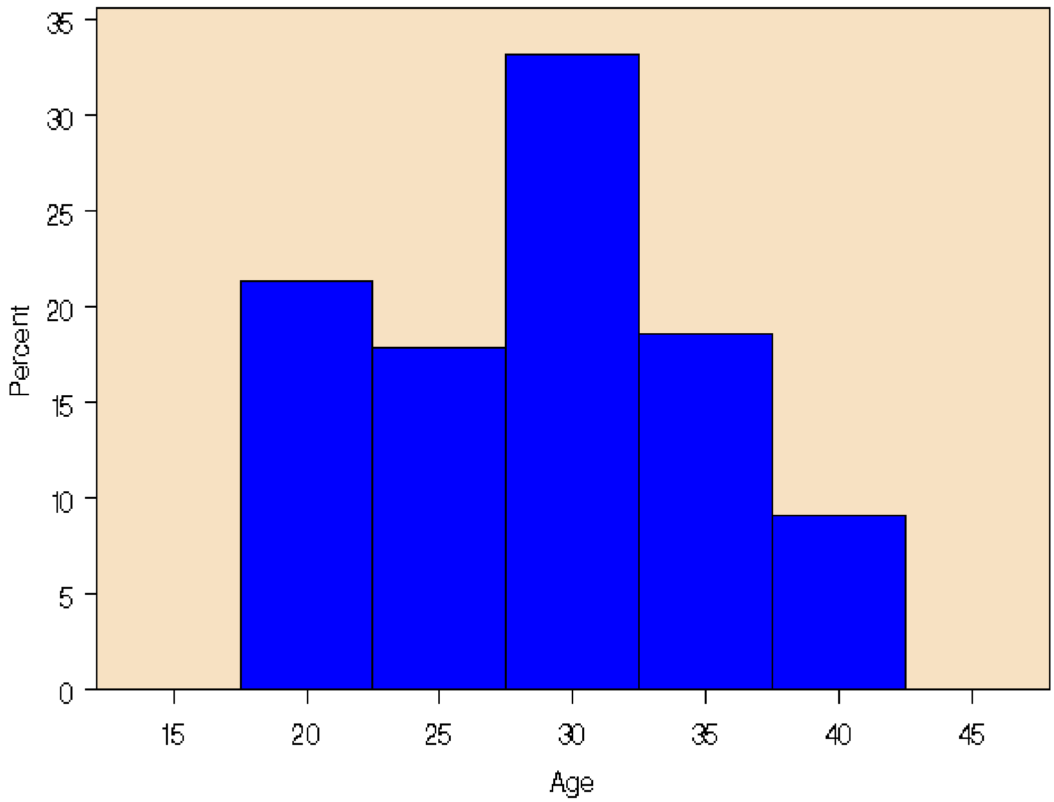

Figure 4.2 Maternal age distribution

Educational levels of mothers

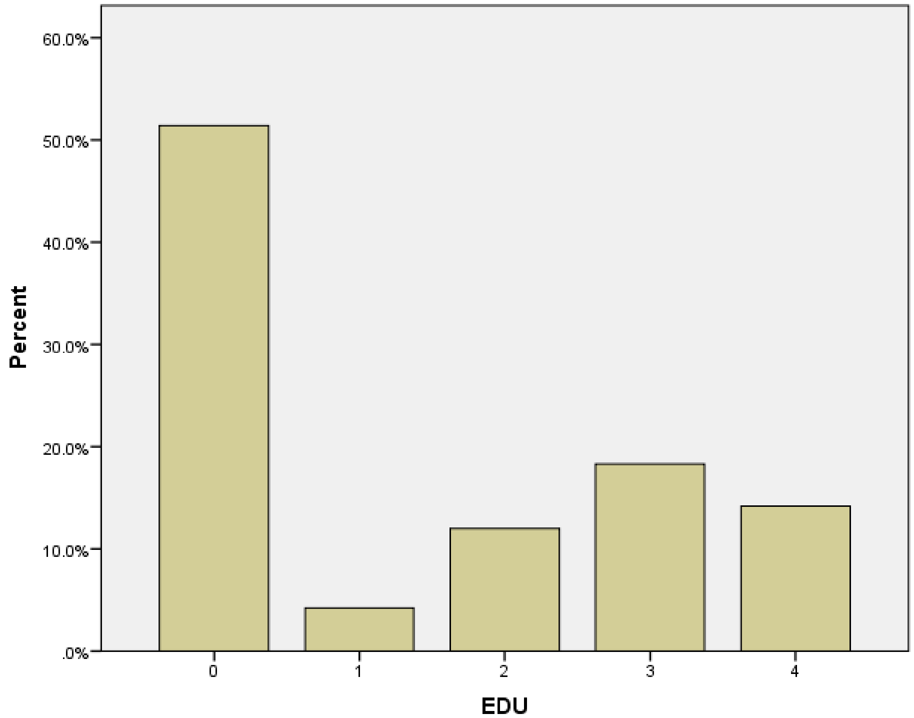

Figure 4.3: Maternal education

Where no education = 0, Primary – 1, JHS = 2, SHS = 3, and Tertiary = 4.

Figure 4.3 revealed that, majority of the mothers (51.5%) had no formal education. Those who had primary education constituted only 4.0% of the study population. Those with JHS education was 12%. Only 18.5% had SHS education and 14% had college education and above.

Distribution of mothers

Majority of the women (85.3%) were from the urban area as shown in figure 4.4 below. The remaining 14.7 % were from the rural area.

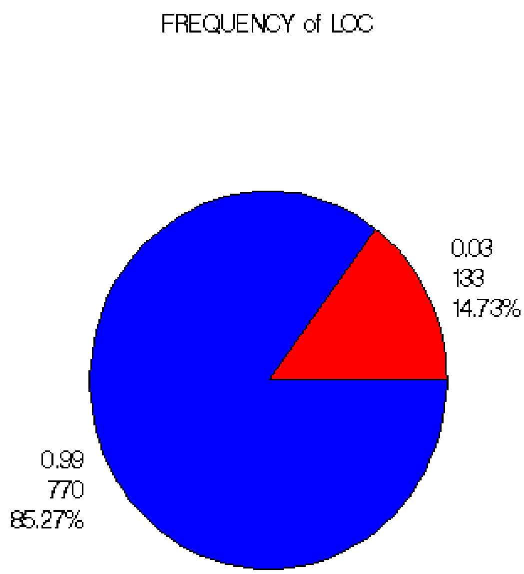

Figure 4.4 Area distribution of mothers

Husbands Occupational Distribution

From the figure 4.5, only 2.5% of husbands were not employed. About 21% of the husbands were employed as unskilled labourers. Majority of the Husbands (39.5) were employed as skilled labourers and the rest of the population (salary earners) constituted 37.0%.

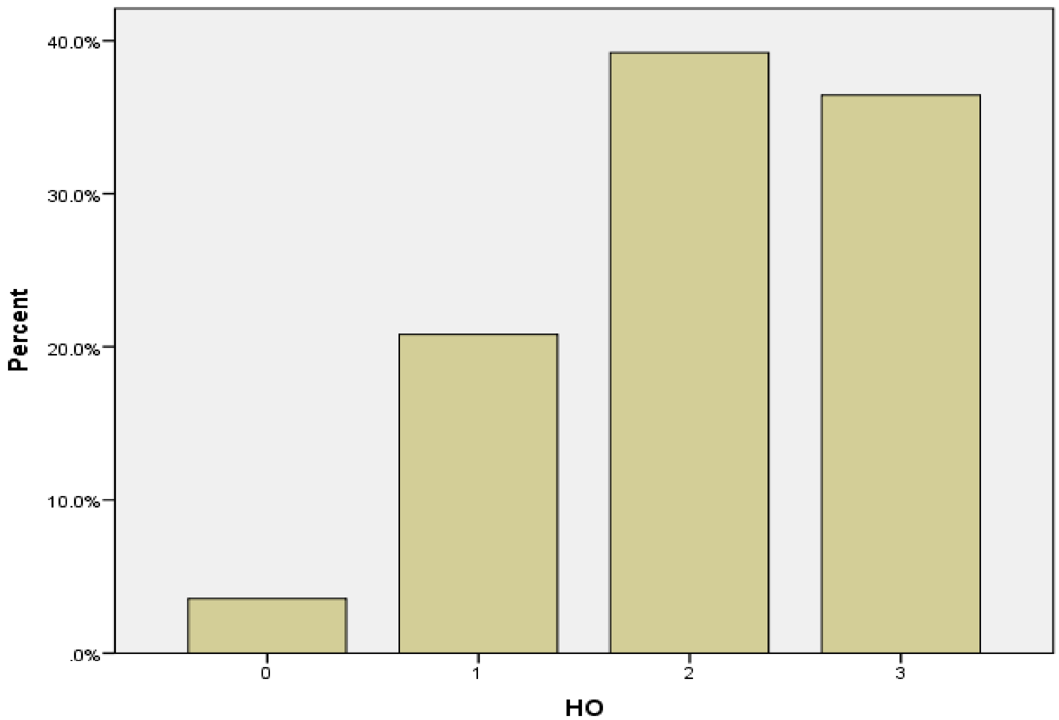

Figure 4.5:Husband Occupational Distribution

Where Unemployed =0, Unskilled labourer = 1, Skilled labourer/self-emploed = 2, and Salary earners = 3.

Occupational Distribution of Mothers

The figure 4.6 below revealed that majority of the mothers (45.5%), were employed as unskilled labourers. Those mothers who were not employed constituted 26% of the population. Mothers who were employed as skilled labourers constituted 17.5% and only 11% of the mothers were employed as salary workers.

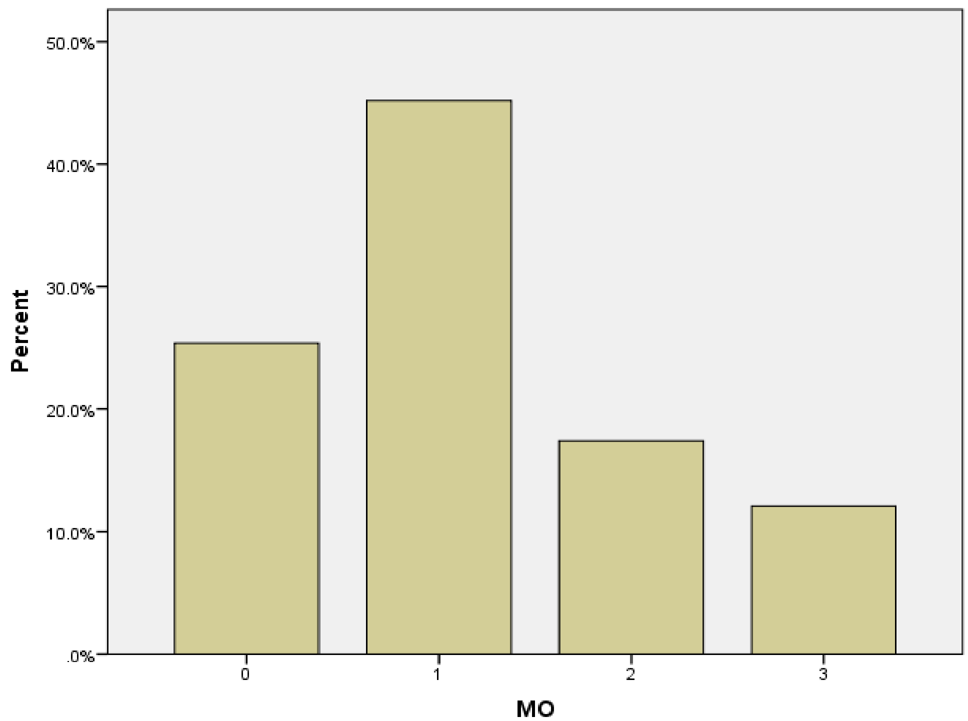

Figure 4.6. Maternal occupational distribution

Where Unemployed/HW =0, Unskilled labourer = 1, Skilled labourer/self-emploed = 2, and Salary earners = 3.

PERCENTAGES OF BIRTH WEIGHTS

Table 4.3 Birth Weight (BW) prevalence

BW	Percentage	Cummulative percentage
1.2	0.3	0.3
1.3	0.4	0.8
1.7	0.3	1.1
1.8	0.9	2.0
1.9	0.6	2.5
2.0	1.7	4.2
2.1	2.2	6.4
2.2	1.6	8.0
2.3	1.7	9.6
2.4	1.0	10.6
2.5	0.9	11.5
2.6	4.2	15.7
2.7	4.4	20.1
2.8	3.1	23.2
2.9	4.1	27.3
3.0	15.3	42.6
3.1	10.5	53.1
3.2	7.1	60.2
3.3	4.5	64.7
3.4	5.0	69.7
3.5	14.9	84.6
3.6	4.3	88.9
3.7	2.8	91.6
3.8	3.6	95.3
4 .0	2.4	97.7
4.10	1.0	98.7
4.2	1.3	100.0

Table 4.3 Birth weights prevalence

Table 4.3 revealed that, birth weights less than 2.5kg constituted only 10.6%. This implies that, the low birth weight in the northern region is 10.6% and the normal birth weight (birth weight from 2.5kg to 4.5kg) constituted 89.4%. There was no incidence of high birth weight during the period.

4.3 FURTHER ANALYSIS

4.3.1 Profile plots of Maternal Weight by Group

- **Plot by Maternal Occupation**

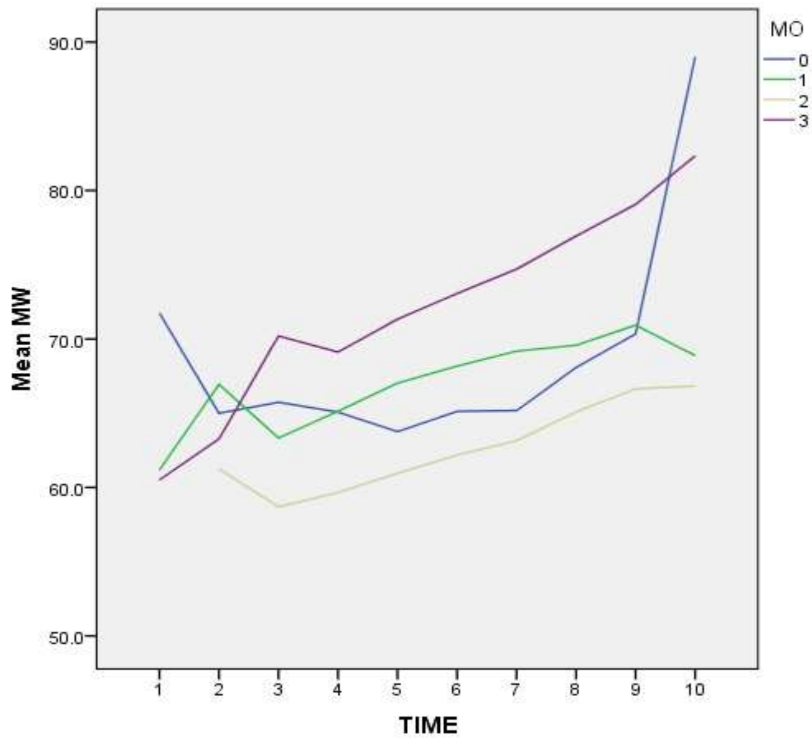

Figure 4.7 Profile plot of maternal weight by maternal occupation.

Where Unemployed/HW =0, Unskilled labourer = 1, Skilled labourer/self-emploed = 2, and Salary earners = 3.

The profile plot of maternal weight during pregnancy by maternal occupation suggests a change in maternal weight over time. Women whose occupational status is self employed and skilled labourers (SL) had a lower profile plot. In general all the profiles look different in terms of increasing time. This dissimilarity in the plots suggests that, the average change in maternal weight within the group may not be parallel.

- **Profile Plot of Maternal Weight by HO**

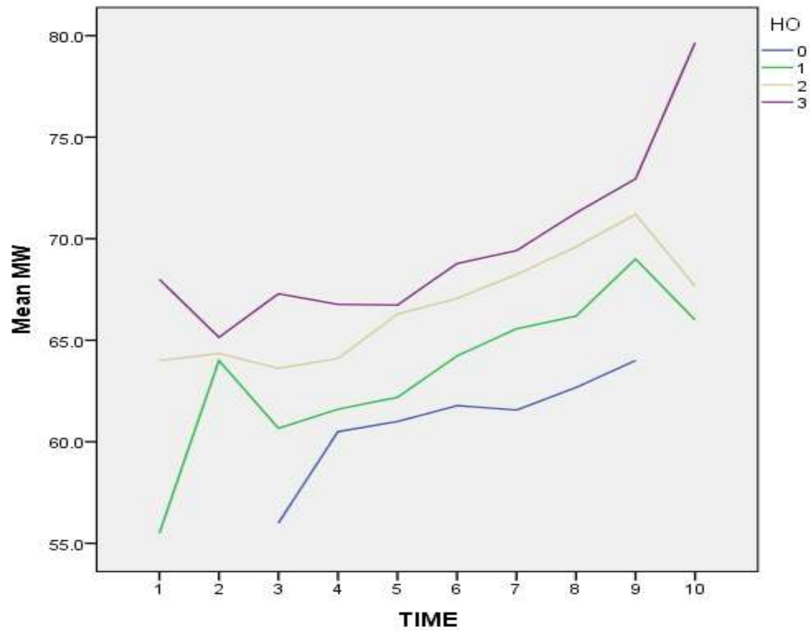

Figure 4.8 Profile plot of maternal weight by Husband Occupation.

Where Unemployed =0, Unskilled labourer = 1, Skilled labourer/self-emploed = 2, and Salary earners = 3.

Figure 4.8 shows the average change of maternal weight during pregnancy by the group is changing over time and the pattern of change looks similar. The pattern of change for the self employed and the salary group looks similar and above the unemployed and the unskilled labourers but the change over time is not similar. This suggests that, the profiles may not be parallel.

- **Profile Plot of Maternal Weight by Location**

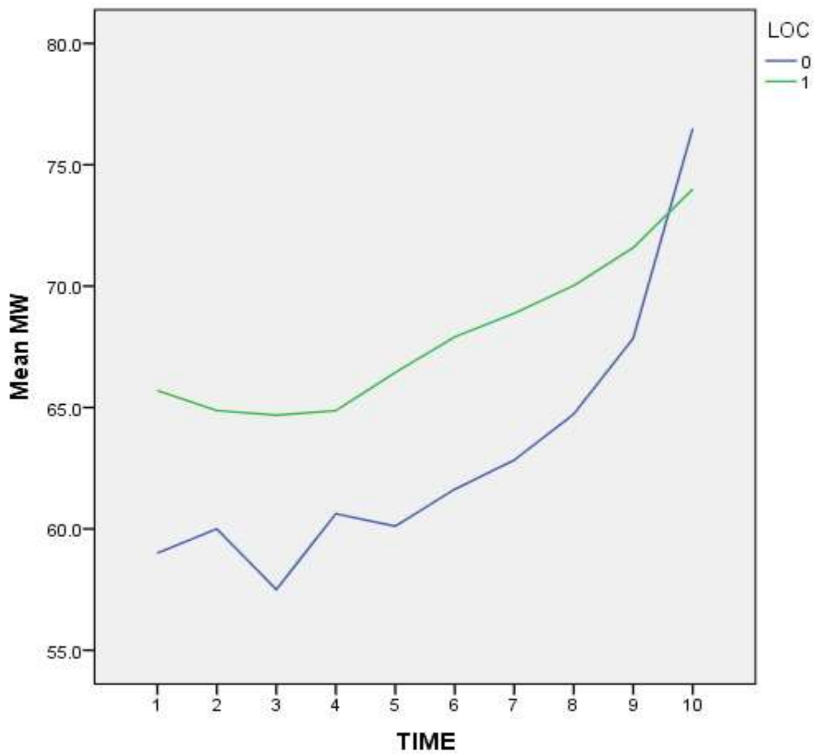

Figure 4.9 Profile plot of maternal weight by location

Where Rural = 0 and Urban = 1

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The figure 4.9 above shows the mean plot of location and the profile shows the average change of maternal weight during pregnancy by the group is changing over time and the pattern of change looks different. The pattern of change for the urban is above that of the rural and some kind of interaction. The rural maternal weight increases faster than that of the urban maternal weight. This suggests that the profile may not be parallel.

- **Profile Plot of Maternal weight by Marital status**

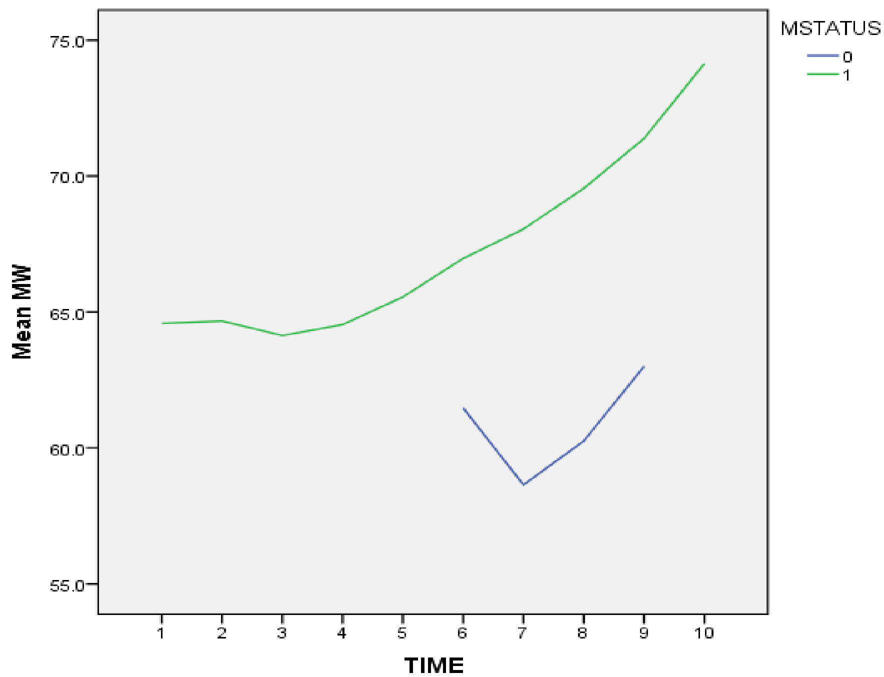

Figure 4.10 Profile plot of maternal weight by marital status

Where Single = 0 and Married = 1

Figure 4.10 shows the average change in maternal weight in the group are changing over time and the pattern of change seems to differ. This suggests that the profiles may not be parallel. The profile shows that, Women who are single start weighing in the sixth to seventh month.

- **Profile Plot of Maternal Weight by Educational Status**

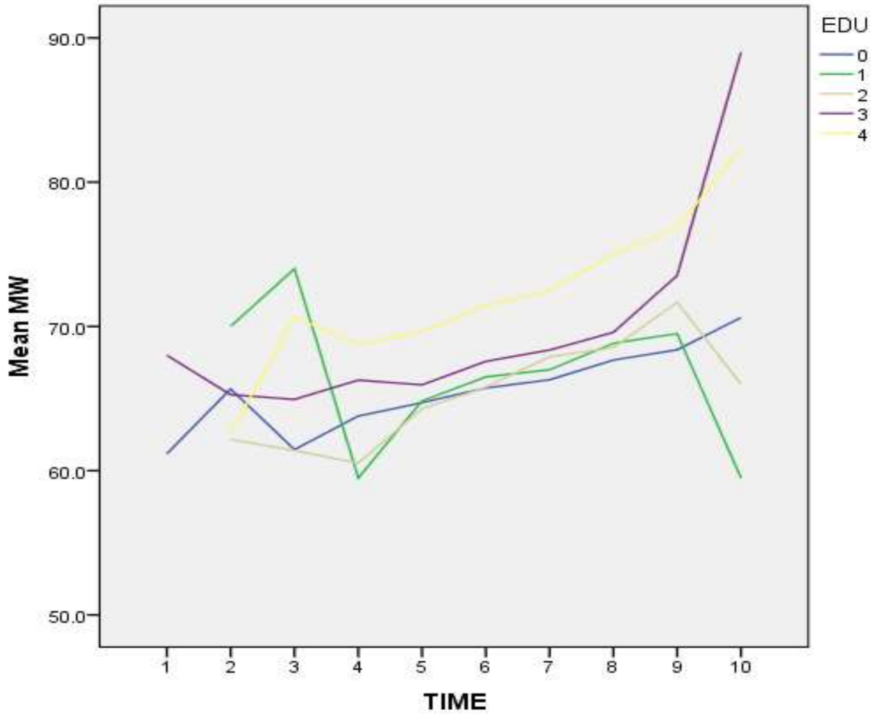

Figure 4.11: Profile plot of maternal weight by educational status

Where no education = 0, Primary – 1, JHS = 2, SHS = 3, and Tertiary = 4.

The profile plot of maternal education during pregnancy revealed an increasing change in maternal weight over time. Women with tertiary education seams to have higher maternal weight as compare to the rest of the educational categories. In general all the profiles looks different and the average change may not be parallel.

- **The Pattern of Maternal Weight**

Table 4.4 Trend model

Model	Parameter	R^2 value
Linear	α= 1.056	0.881
	β= 61.228	
Logarithmic	α= 3.737	0.647
	β= 61.391	
Exponential	α= 0.016	0.891
	β= 61.474	
Quadratic	α_1= -0.586	
	α_2=0.149	0.993*
	β= 64.512	
Power	α= 0.055	0.661
	β= 61.597	.

Where α=scale and β=slope
*Mean highest variability

Table 4.4 shows the model parameter and R^2 estimates of the trend of maternal weights during pregnancy and delivered in the Tamale Teaching hospital. The model with the highest variability is selected and trend of the maternal weight was fitted. Quadratic model was selected since it has the highest R^2 value of 0.993.

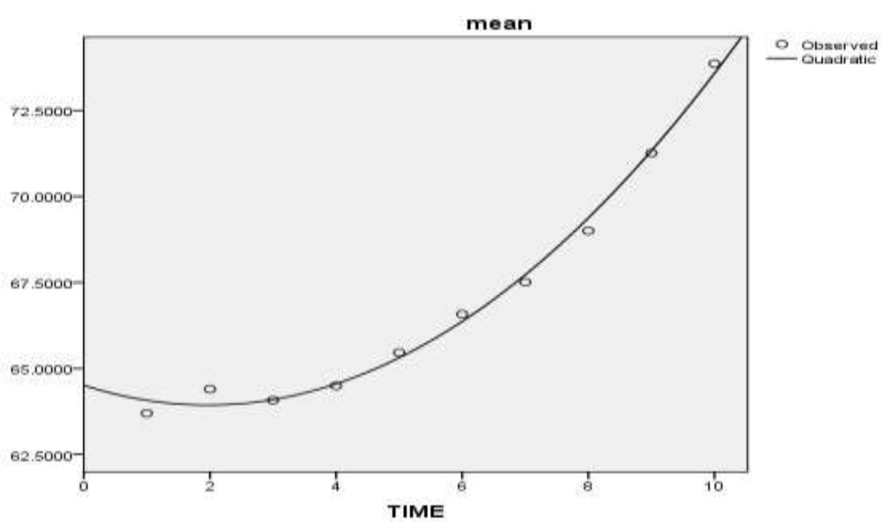

Figure 4.12 The pattern of maternal weight during pregnancy

Figure 4.12 shows that, a general pattern of change of maternal weight during pregnancy increases over time. A quadratic function is shown to be a better fit of the change in maternal weight gain during pregnancy over time. The model for the quadratic function is given by:

$$MW = a - \beta t + \alpha t^2 \quad (4.1)$$

Maternal weight (MW) = a + αt^2- βt = 64.512 -0.586t +0.149t^2.

Where t = 0, 1, 2, …,t_n

The rate of change of the maternal weight during pregnancy is given by

$$\frac{\partial mw}{\partial t} MW = -\beta + \alpha t \quad (4.2)$$

d/dt(MW)=d/dt(64.512 -0.586t +0.149$t^{2)}$ = -0.586+ 0.298t.

at t= 1, 9

-0.586 + 0.298t = -0.586 +0.298(1) = -0.288kg

-0.586 + 0.298t =-0.586 + 0.298(9) = 2.096kg

This function indicates an increasing rate. The model accounts for 99.3% of the variability in the data.

4.3.2 Analysis of Variance of the Quadratic Trend Model

Table 4.5 Analysis of Variance

Source	DF	SS	F	P-Value
Regression	2	103.733	51.867	0.000
Residual Error	7	0.696	0.099	
Total	9	104.429		.

The regression analysis of variance for the quadratic trend model shown in the Table 4.5 shows that, the trend model is significant (P-Value = 0.000).

4.3.3 Trend Model Diagnoses

Table 4.6 Trend Model Diagnoses

			P Value
Wald Test	H_0 : Time = TimeSq	W=16624.700	0<0.0001
Wald Test	H_0 :Intercept = Time +TimeSq	W=19.100	0<0.0001
Durbin-Watson		DW= 2.0750	0.8135
GARCH		Normality=1.1682	0.5576
Shapiro-Wilks		W = 0.8809	0.1338

The trend model was diagnosed to check for its adequacy. The Wald Test of parameter reject the two null hypotheses in the Table 4.6 above (P-Value <0.0001). This implies that, removing any of the parameters in the trend model would significantly harm the fit of the model. Durbin-Watson test shows that the model up to lag 2 is free from serial correlation (P-Value = 0.8135). Both GARCH test and the Shapiro-Wilks test indicated that, the residuals of the model were distributed normally (P-Value=0.5576 and 0.1338 respectively). Hence the diagnostic test revealed that the model is adequate for prediction of mean maternal weight during pregnancy.

4.3.4 MANOVA Test For Groups

Table 4.7 MANOVA Test for Groups

	Statistic	value	Df	Df1	df2	F	Proc>F
EDU	W	0.9908	4	4	891	2.0700	0.0829
	P	0.0092		4	891	2.0700	0.0829
	L	0.0093		4	891	2.0700	0.0829
	R	0.0093		4	891	2.0700	0.0829
MO	W	0.9407	3	3	891	18.7200	0.0000
	P	0.0593		3	891	18.7200	0.0000
	L	0.0630		3	891	18.7200	0.0000
	R	0.0630		3	891	18.7200	0.0000
HO	W	0.9881	3	3	891	3.5700	0.0138
	P	0.0119		3	891	3.5700	0.0138
	L	0.0120		3	891	3.5700	0.0138
	R	0.0120		3	891	3.5700	0.0138
LOC	W	0.9780	1	1	891	20.0400	0.0000
	P	0.0220		1	891	20.0400	0.0000
	L	0.0225		1	891	20.0400	0.0000
	R	0.0225		1	891	20.0400	0.0000
MSTATUS	W	0.9931		1	891	6.2100	0.0129
	P	0.0069		1	891	6.2100	0.0129
	L	0.0070		1	891	6.2100	0.0129
	R	0.0070		1	891	6.2100	0.0129

The multivariate analysis of variance tests for groups in Table 4.7 shows that the profiles for the different levels of location, marital status, Husband occupation and the maternal occupation show a significant difference and there are therefore not parallel. However maternal education shows no significant difference and hence, the profiles may be parallel.

4.3.5Test of Parallelism for Maternal Education

Table 4.8 Test of parallelism for maternal education

	Statistic	Value	df	df1	df2	F	Prob>F
EDU#TIME	W	0.8700	46	46	857	2.7800	0.0000
	P	0.1300		46	857	2.7800	0.0000
	L	0.1495		46	857	2.7800	0.0000
	R	0.1495		46	857	2.7800	0.0000

The test of parallelism for maternal education is shown in Table 4.8 above. The results show that, the profiles for the different levels of maternal education are not parallel. Therefore, the pattern of change in maternal weight varies for different levels of maternal education.

4.3.6 Statistics for covariance structure models

Table 4.9 Statistics for covariance structure models

Structure	AIC	BIC
Compound Symmetry	5542.9	5549.0
AR(1)	4934.5	4940.6
ARH(1)	4928.1	4961.8
CSH	5296.1	5329.8
ARMA(1, 1)	4927.1**	4936.3**
Variance Components	6486.5	6489.6

** mean smallest

The comparison analysis of the Akaike's Information Criterion (AIC) and the Bayesian Information Criterion (BIC) for each of the covariance models are shown in the Table 4.9 above. The results show that, the first –order Autoregressive moving Average (ARMA (1, 1)) model has the least AIC (4927.1) and the BIC (4936.3) values. Hence, the first –order Autoregressive moving

Average model is selected. This means that there is a strong correlation between maternal weight at t and t+1 and two adjacent correlations are equal.

4.3.7 Parameter Estimates of Mixed Effects Model for Maternal Weight

Table 4.10: First-order Autoregressive moving average ARMA (1, 1) covariance structure output

Effect	Estimate	Standard Err.	DF	t-Value	Pr>t
TIME	1.5163	0.1485	884	10.2100	<.0001
Age	-0.0065	0.0666	884	-0.1000	0.9229
GA	-0.6033	0.2234	884	-2.7000	0.0071
FH	0.9866	0.1836	884	5.3700	<.0001
NAV	1.2434	0.2049	884	6.0700	<.0001
PARITY	1.0326	0.3134	884	3.2900	0.0010
MATERNAL EDUCATION					
No Education	35.0584	8.3799	884	4.1800	<.0001
Primary education	35.7389	8.6179	884	4.1500	<.0001
JHS/middel	36.1050	8.3243	884	4.3400	<.0001
SHS	36.4809	8.3262	884	4.3900	<.0001
Tertiary/College	39.2867	8.3107	884	4.7300	<.0001
MATERNAL OCCUPATION COMPARED WITH SALARY EARNERS					
Unemployed/HW	-1.4797	1.4272	884	-1.0400	0.3001
Unskilled Labourer	-1.1927	1.5186	884	-0.7900	0.4324
Skilled labourer/Selfemp.	-6.3757	1.5168	884	-4.2000	<.0001
HUSBAND OCCUPATION COMPARED WITH SALARY EARNERS					
Unemployed	0.4414	2.2900	884	0.1900	0.8472
Unskilled Labourer	-1.3795	0.9806	884	-1.4100	0.1598
Skilled labourer/Selfemp.	1.0002	0.8407	884	1.1900	0.2345
MARITAL STATUS COMPARED WITH MARRIED					
Single	-6.3126	2.7433	884	-2.3000	0.0216
LOCATION COMPARED WITH URBAN					
Rural	-3.9036	0.9021	884	-4.3300	<.0001
BABY SEX COMPARED WITH MALE					
Female	-1.0964	0.5985	884	-1.8300	0.0673

We incorporated first-order Autoregressive moving average covariance structure to obtain the parameter estimates of the linear mixed effects model and their significance as shown in Table 4.10 above. The table shows that time, gestation age, fundal height, number of antenatal visit, parity, maternal education, marital status and location of the mother all show significant effects on the maternal weight during pregnancy. The non significant covariates are maternal age, sex of the baby and the husband occupation. However, maternal occupation shows differentials in the significant levels. The time of pregnancy, fundal height, number of antenatal visit, and maternal education all contributed positively to the change in maternal weight, where as the maternal age, gestation age, maternal occupation, marital status, location and sex of baby contributed negatively to the change in maternal weight gain. However, husband occupation shows differentials in the change of maternal weight. Women with tertiary education on average have, about 2.8kg more weight than the other women with lower educational background. Rural women also had on average 3.9kg lower weight than the urban pregnant women.

4.3.8 Full model for the Maternal Weight

The full model for linear mixed effects model is given by;

$$MW = 1.5163X_1 - 0.0065X_2 - 0.6033X_3 + 0.9866X4_4 + 1.2434X5_5 + 1.0326X_6 + 35.0584X_7 + 35.7389X_8 + 36.1050X_9 + 36.4809X_{10} + 39.2867X_{11} - 1.4797X_{12} - 1.1927X_{13} - 6.3757X_{14} + 0.4414X_{16} - 1.3795X_{17} + 1.0002X_{18} - 6.3126X_{19} - 3.9036X_{20} - 1.0964X_{21}. \qquad 4.3$$

Where MW =maternal weight, X_1=time, X_2= age, X_3= GA, X_4 = FH, X_5= NAV, X_6 = Parity, X_7 = no education, X_8 = primary, X_9= JHS, X_{10} =SHS, X_{11} =

Tertiary/college, X_{12}= unemployed mother, X_{13}= unskilled mother, X_{14}= Skilled mother, X_{15} = salary earner(mother), X_{16}= Unemployed husband, X_{17}= unskilled husband, X_{18}= skilled husband, X_{19}= single, X_{20}= rural, X_{21}= female.

4.3.9 Reduced Model for Mean Maternal Weight

Table 4.11: Model selection for Predicting Maternal Weight

Step	Model	AIC	BIC
1	MO	4972.8	4067.0
2	MO,TIME	4915.7	4010.2
3	MO, TIME, NAV	4851.2	3946.2
4	MO, TIME, NAV, FH	4833.4	3928.6
5	MO, TIME, NAV, FH, LOC	4815.6	3911.0
6	MO, TIME, NAV, FH, LOC, PARITY	4798.1	3893.8
7	MO, TIME, NAV, FH, LOC, PARITY, GA	4793.2*	3889.0*

*mean smallest

In fitting the reduced model for prediction, stepwise selection method was used with BIC to select the best model for prediction of maternal weight during pregnancy. The variables; sex of baby(SB), marital status, maternal age, maternal education and husband occupation were dropped leaving maternal occupation, fundal height, location, parity, number of antenatal visit during pregnancy and time to treatment as the only ones that remained significant on the maternal weight during pregnancy as shown in Table 4.12 below.

4.3.10 Estimates of Reduced Model

Table 4.12 Estimates of Reduced Model

Parameter	DF	Estimate	Standard Error	t- Value
TIME	1	1.5192	0.1497	10.1500
GA	1	-0.5848	0.2233	-2.6200
FH	1	1.0353	0.1789	5.8200
NAV	1	1.3750	0.1936	7.1000
PARITY	1	1.1362	0.2610	4.3500
MATERNAL OCCUPATION				
Unemployed/HW	1	30.1999	7.6421	3.9500
Unskilled labourer	1	29.7456	7.7081	3.8600
Skilled labourer/selfemo.	1	25.3673	7.6019	3.3400
Salary earnerd	1	34.3487	7.7653	4.4200
LOCATION COMPARED WITH URBAN				
Rural	1	-4.4493	0.8607	-5.1700

Predictive Model for Maternal Weight

$$MW = 1.5192X1 - 0.5848X3 + 1.0353X4 + 1.3750X5 + 1.1362X6 + 30.2000X12 + 29.7456X13 + 25.3674X14 + 34.3487X15 - 4.4493X20. --(4.4)$$

4.3.11 Model Diagnoses

From Figure 4.13 shows the various plots of residuals plots. The residuals verses linear predicted shows that, the residuals distributed randomly. The percent verses residual plot shows that, the residuals had a normal distribution. Also the residual verses quantile plots shows that, there is no influence of outliers.

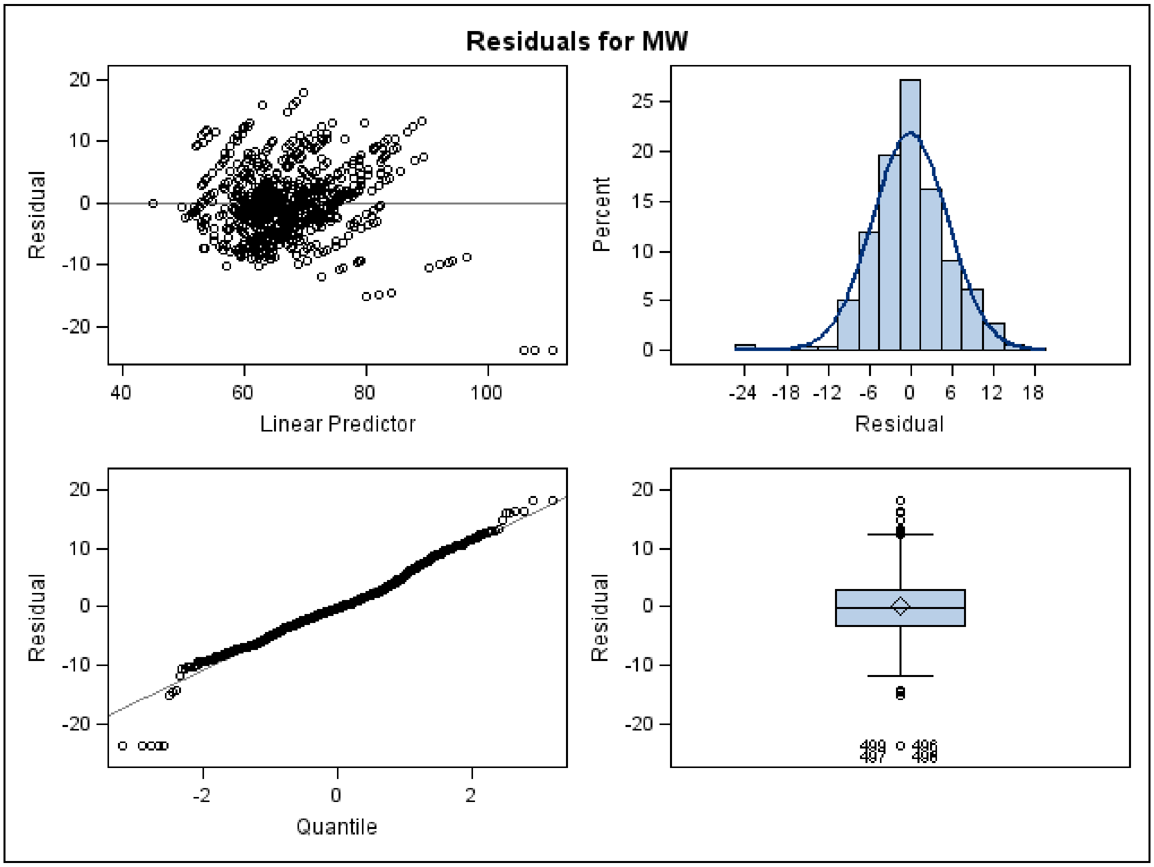

Figure 4.13 Residual plots of maternal weight during pregnancy

4.3.12 Parameter Estimates of Generalized Linear Model for Birth Weigh

Table 4.13 Parameter Estimates for Birth Weight

PARAMETER	DF	Estimate	Standard Err.	Wald 95% CL Limits		Pr>ChiSq
Intercept	1	-1.5029	0.4426	-2.3705	-0.6354	0.0007
Age	1	-0.0086	0.0035	-0.0150	-0.0018	0.0130
GA	1	0.0791	0.0116	0.0564	0.1018	<.0001
FH	1	0.0390	0.0097	0.0201	0.0580	<.0001
NAV	1	0.0254	0.0104	0.0051	0.0458	0.0143
PARITY	1	0.0625	0.0164	0.0304	0.0947	0.0001
BMI	1	0.0085	0.0030	0.0026	0.0144	0.0046
MATERNAL EDUCATION COMPARED WITH TERTIARY						
No Education	1	-0.0241	0.0753	-0.1717	0.1236	0.7493
Primary education	1	-0.0280	0.1029	-0.2297	0.01737	0.7855
JHS/middel	1	-0.1887	0.0821	-0.3496	-0.0278	0.0216
SHS	1	0.0863	0.0734	-0.0576	0.2302	0.2397
MATERNAL OCCUPATION COMPARED WITH SALARY EARNERS						
Unemployed/HW	1	-0.1150	0.0747	-0.2614	0.0314	2.3700
Unskilled Labourer	1	-0.0135	0.0795	-0.1693	0.1423	0.8655
Skilled labourer/Selfemp.	1	-0.0276	0.0800	-0.1843	0.1292	0.7305
HUSBAND OCCUPATION COMPARED WITH SALARY EARNERS						
Unemployed	1	-0.2190	0.1199	-0.4540	0.0160	0.0678
Unskilled Labourer	1	-0.1044	0.0513	-0.2049	-0.0039	0.0417
Skilled labourer/Selfemp.	1	-0.0148	0.0441	-0.1612	0.0116	0.0897
MARITAL STATUS COMPARED WITH MARRIED						
Single	1	-0.0342	0.1436	-0.3156	0.2472	0.8118
LOCATION COMPARED WITH URBAN						
Rural	1	-0.0904	0.0475	-0.1836	0.0027	0.0571
BABY SEX COMPARED WITH MALE						
Female	1	0.0317	0.0313	-0.0297	0.0931	0.3100

Table 4.13 shows the parameter estimates of generalized linear models for birth weight. Intercept, Maternal age, body mass index, fundal height, gestation age, number of antenatal visit and parity are the significant determinants of birth

weight. The non significant determinants are maternal occupation, marital status, location and sex of baby. However, maternal education and husband occupation show differentials in the significant levels. The factors that contributed positively to the birth weight are gestation age, fundal height, number of antenatal visit, parity, body mass index and sex of baby. Those factors that had negative impact on birth weight are location, husband occupation, maternal occupation, maternal education and maternal age. Female babies are expected to have higher weight than the male babies. Likewise the urban babies are expected to weigh higher than their rural counterparts. On the educational background, secondary school mothers are expected to have heavier babies than the rest in the group.

4.3.13 Full Model for Birth Weight

The full model for the generalized linear model for the birth weight is given by;

$$BW = -1.5029 - 0.0086X_1 + 0.0791X_2 + 0.0390X_3 + 0.0254X_4 + 0.0625X_5 + 0.0085X_6 - 0.0241X_7 - 0.0280X_8 - 0.1887X_9 + 0.0863X_{10} - 0.1150X_{11} - 0.0135X_{12} - 0.0276X_{13} - 0.2190X_{14} - 0.1044X_{15} - 0.0748X_{16} - 0.0342X_{17} - 0.0904X_{18} + 0.0317X_{19}. - (4.5)$$

.

BW = birth weight, X_1= age , X_2 = GA, X_3= FH, X_4= NAV, X_5 = PARITY, X_6 = BMI, X_7 = no education, X_8= primary, X_9 = JHS, X_{10}= SHS, X_{11}= unemployed mother, X_{12} = unskilled mother, X_{13}= skilled mother, X_{14}= unemployed husband, X_{15}= unskilled husband, X_{16}= skilled husband, X_{17}= single, X_{18}= rural, X_{19}= female.

4.3.14 Reduced Model of Birth Weight

Table4.14:Model Selection for prediction of Birth Weight

Step	Model	AIC	BIC
0	Intercept	-283.0	-1187.6
1	Intercept, GA	-448.9	-1353.4
2	Intercept, GA, FH	-469.8	-1374.3
3	Intercept, GA, FH, NAV	-486.3	-1390.8
4	Intercept, GA, FH, NAV, BMI	-493.8	-1398.4
5	Intercept, GA, FH, NAV, BMI, HO	-508.9	-1413.4
6	Intercept, GA, FH, NAV, BMI, HO, PARITY	-515.2*	-1419.6*

In fitting the model for selection, stepwise selection method with both AIC and BIC criterion and alpha equal to 0.05 was used. The variables; Gestation age, number of antenatal visit, fundal height, body mass index, parity and husband occupation including the intercept were selected dropping the rest of the variables that do not meet the selection entry and the stay alpha=0.05. That is the variables; maternal occupation, sex of baby, marital status, location, maternal age and maternal education were all dropped.

4.3.15 Parameter Estimates of Reduced Model for prediction of Birth weight

Table 4.15: Estimates of Reduced model of birth weight

Parameter	DF	Estimate	Standard Error	t- Value	Pr>$\|t\|$
Intercept	0	-1.9029	0.4250	-4.4800	.
GA	895	0.0846	0.0117	7.1900	<.0001
FH	895	0.0355	0.0094	3.7500	0.0002
NAV	895	0.0371	0.0096	3.8700	0.0001
PARITY	895	0.0394	0.0137	2.8700	0.0042
BMI	895	0.0095	0.0029	3.2300	0.0013
HUSBAND OCCUPATION COMPARED WITH SALARY					
Unemployed	895	-0.2932	0.0876	-3.3500	0.0009
Unskilled labourer	895	-0.1487	0.0428	-3.4700	0.0005
Skilled labourer/selfemp.	895	-0.1298	0.0369	-3.5200	0.0005

The parameter estimates of the reduced model for prediction are shown in the Table 4.15 above.

Reduced model for prediction of birth weight is given by

$$BW = -1.9029 + 0.0847X_2 + 0.0390X_3 + 0.0371X_4 + 0.0394X_5 + 0.0095X_6 - (0.2932X_{14} + 0.1487X_{15} + 0.1298X_{16}). \quad ------------- (4.6)$$

4.3.16 Model Diagnoses

The residual plots of the birth weights are shown in Figure 4.14 below. The residual vs predicted plot shows a random distribution of the residuals. The Histogram in the Figure 4.14 below also shows that the residuals are normally distributed. The residual and the Quantile plot shows that, the residuals are not influenced by outliers since the cook's distance is very close to the plot.

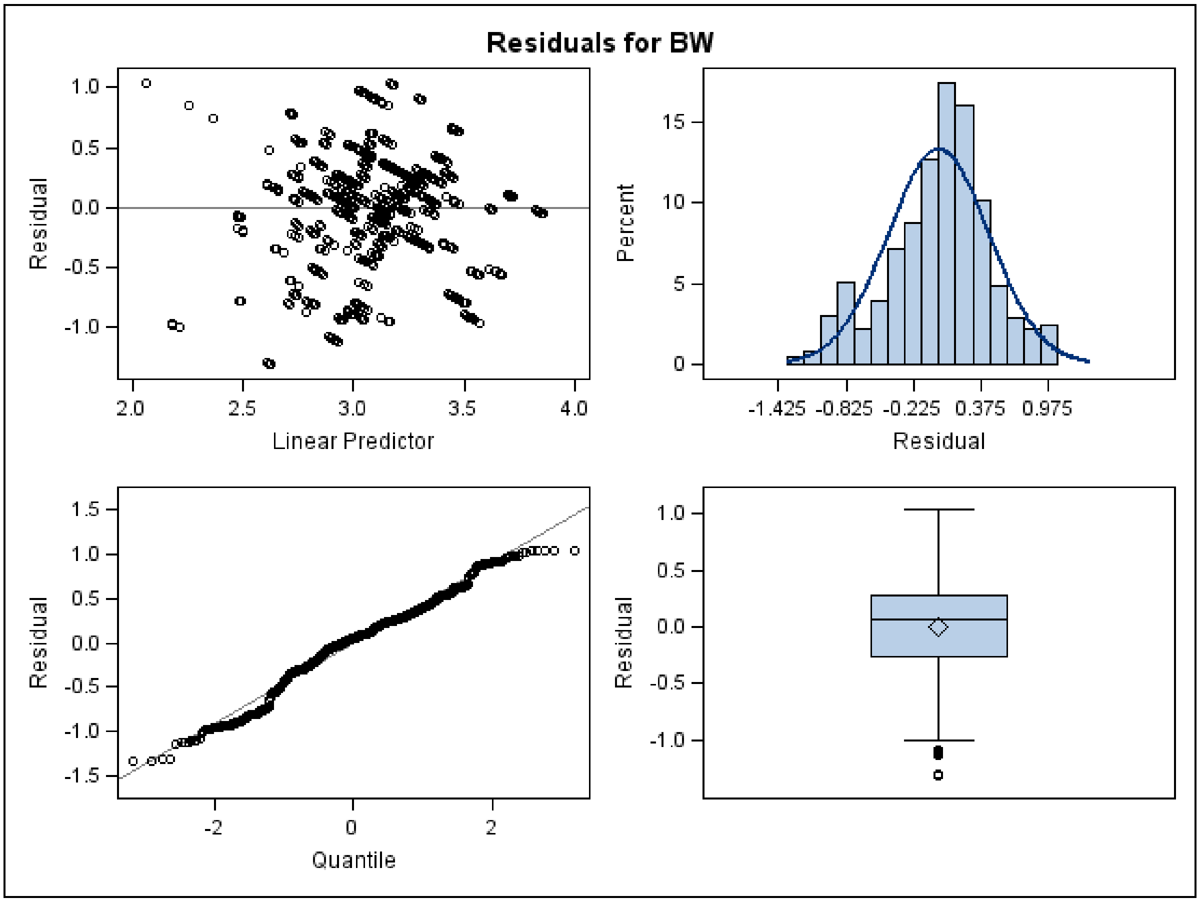

Figure 4.14 Residual plots of birth weights

- **Example of the predictive use of the models**

Trend model

$$MW = 64.512 - 0.586t_i + 0.149t_i^2$$

$MW = 64.512 - 0.586t_i + 0.149t_i^2$

For i= 0,1,2,3,…,10

MW_0 =64.512kg

MW_{10} = 64.512 – 0.586(10) + 0.149(100)

= 73.552kg

The mean maternal weight gain during pregnancy = 73.552- 64.512 = 9.04kg

Change in MW = -0.586 + 0.298t_i

For I = 1,2,3,…,9,10

Change in MW= -0.586 + 0.298(9)

= 2.096kg

- **Regression model of the maternal weight**

Consider a woman with GA=37.50, FH=38.25.50, BMI=26.54, NAV=6.31, parity=2, and assume the woman is not employed and from 1. Rural area and 2. Urban area.

Solution

$$MW = 1.5192X1 - 0.5848X3 + 1.0353X4 + 1.3750X5 + 1.1362X6 + 30.2000X12 + 29.7456X13 + 25.3674X14 + 34.3487X15 - 4.4493X20. --(4.4)$$

.

=1.5192time$_i$ – 0.5848(37.5) + 1.0353(38.25) + 1.3750(6.31) + 1.1362(2) + 0.2000(1) + 0 + 0 – 4.4493(1)

MW = 1.5192time$_i$ + 54.3693 for rural pregnant women.

For i=9

This imply 1.5192(9) + 54.3693 = 68.0421 for rural

and

MW= 1.5192time$_i$ +58.8186 for urban pregnant women

for i=9

ŷ = 1.5192 (9) + 58.8186 = 72.492kg for urban

- **Regression model for predicting birth weight**

Consider a woman with GA=37.50, FH=38.25.50, BMI=26.54, NAV=6.31, parity=2, and assume the husband is not employed.

solution

$$BW = -1.9029+0.0847X_2+0.0390X_3+0.0371X_4+0.0394X_5+0.0095X_6-(0.2932X_{14}+0.1487X_{15}+0.1298X_{16}). - - - - - - - - - - - - - - (4.6)$$

= -1.9029 + 0.0847(37.5) + 0.0390(38.25) + 0.0371(6.31) + 0.0394(2) + 0.0095(26.54) – (0.2932(1) + 0.1487(0) + 0.1298(0))

= 2.8993kg for unemployed husband

= 3.0438kg for unskilled husband

= 3.0627kg for skilled husband

= 3.1925kg for salary earner husband

Hence, the expected birth weight of a baby whose father is not employed and had the above parameters is 2.8993kg and a mother whose husband is a salary earner and had the above parameters will have a baby birth weight to be 3.20kg.

4.4 Discussions

There were 247 participants who delivered babies in the Tamale Teaching hospital during the period of our visit. Eighty seven of these participants were dropped as a result of giving birth to twins, and those women who did not attend antenatal for at least three times (3 months). Only one hundred and sixty participants were used for the analysis. Out of these 160 participants, we had 904 observations. From the total number of 160 participants, only 14.73% were from rural area and 85.27% came from the urban area. The higher number of urban women may be as a result that, most of the rural women were dropped due to limited number of antenatal visits(less than three times) and lack of education. The rural area had the least birth weight of 1.7kg as compared to the least urban birth weight of 1.2kg but both location had the same maximum birth weight of 4.2kg. The mean birth weight in the rural area was 3.0kg and that of the urban area had a mean birth weight of 3.1kg. The study estimated the overall mean birth weight to be 3.1kg which is in agreement with the study by (Edward *et al*., 2012). The study found mean birth weight in Ghana to be 3.2kg while the mean birth weights for the normal and LBW infants were 3.4kg and 2.1kg respectively.

The patterns of change in maternal weight by groups were determined, and we observed that, all the groups showed significant effects with the exception of the maternal education which was not significant. The test of parallelism was performed and was observed to be significant and we concluded that the patterns were not coincidence and equal. The percentages of the birth weights were determined as well as the cumulative percentages. The prevalence analysis showed that, 10.60% of the babies had birth weight less than 2.5kg. This shows that, the low birth weight prevalence rate in the region was 10.60%. The most recent evidence on Ghana shows that approximately 10% of all births are LBW (GSS, 2009). Edward *et al.* (2012) study estimated LBW prevalence in Northern Region to be 5.26% which is lower than our estimate (10.6%) for the Region.

The study observed that, majority of the babies had a normal birth weight (2.5kg to 4.5kg). The normal birth weight (NBW) prevalence was observed to be 89.4%. We also observed that, there was no incidence of high birth weight (>4.5kg) in the region.

A trend model was fitted to determine the maternal weight at time t_i. Quadratic model was observed to have the best fit for the prediction. The model is given by $MW = 64.512 - 0.586t + 0.149t^2$.The present study findings demonstrated that mean maternal weight gain was 9.04kg of a full term pregnancy, lower than the weight gain recommended by the Institute of Medicine (IOM, 2009) for women with pre-gestational BMI within the normal range (18.5kg/m^2 – 24.9kg/m^2) but within the range of overweight (BMI of 25kg /$m^2$to 29.9kg/m^2).The mean weight gain during pregnancy obtained in this study was also comparable to other studies carried out by some other researchers in the world. However, the studies conducted by Barbara et al.(2000), Ekblad et al.,(1992) and Phaneendra et al.(2001), found mean weight gains during pregnancy of 15.4 kg (SD=5.2 kg), 13.0 kg (SD=3.0 kg) and 8.0 kg (SD = 2.6 kg)respectively which were higher than the findings of the present study with the exception of Phaneendra et al.(2010), which is lower than the present study.

Also, various covariance structures were fitted to determine the covariance structure that best fit the change in maternal weight during pregnancy. Akaike's information criterion and the Bayesian information criterion methods were used to select the best covariance structure. Among the covariance structures, first-order

Autoregressive moving average (ARMA(1, 1)) had the least AIC and BIC values, hence the best fit.

Stepwise selection method with the BIC was used to select a predictive model for maternal weight during pregnancy and the parameter estimates were obtained to fit the mixed effects model for predicting maternal weight. The study selected time to treatment, gestation age, fundal height, number of antenatal visit, parity, maternal occupation and location to be the best model for predicting maternal weight during pregnancy. Edward et al. (2012), study suggested gestation age, maternal age, marital status and parity were the best predictors of maternal weight. We also used generalized linear model to obtain the parameter estimates to fit a regression model for the birth weight. We observed that, maternal age, gestation age, fundal height, number of antenatal visits, parity, BMI and education are the significant determinants of birth weight. The non significant factors were location, sex of baby, marital status and maternal occupation. Husband occupation showed differentials in the significant levels. Stepwise selection method with BIC was used to select a predictive model.

The significant variables for prediction of birth weight were gestation age, fundal height, number of antenatal visits, parity, BMI and husband occupation. The non significant variables were dropped and the parameter estimates were obtained.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.0 Introduction

The chapter concludes the study and makes some recommendations based on the findings.

5.1 Conclusion

Generally all the women who were considered in the study experienced some weight increased of varied levels from the start of weighing to labour. The minimum mean, the maximum mean and the overall mean weights were 63.7kg, 71.3kg and 67.4kg respectively. The youngest and the oldest mother were 18 years and 41 years respectively.

The profiles of maternal weight among all the factor levels were neither parallel nor equal but all did show increased weight over time. The trend of change in maternal weight was quadratic distributed. The mean maternal weight gain was estimated as 9.04kg which is within the recommendation of IOM for overweight pre-pregnancy BMI ($25kg/m^2$ – $29.9kg/m^2$) .

Factors such as time to treatment, gestation age, fundal height, number of antenatal visits, parity, maternal occupation and location were selected to fit the best linear mixed effects model using stepwise selection method with BIC.

The study also observed that the minimum birth weight, the maximum birth weight and the overall birth weight to be 1.2kg, 4.2kg and 3.1kg respectively.

Factors such us age of mother, gestation age, fundal height, body mass index (BMI), parity and number of antenatal visits significantly determines the birth weight of a baby. The best predictors of birth weight were found to be gestation age, fundal height, BMI, parity, number of antenatal visit and the husband occupational status.

The study also estimated low birth weight (LBW) prevalence in the Region to be 10.60% and normal birth weight (NBW) prevalence to be 89.4%. There was no evidence of high birth weight (HBW) in the region.

5.2 Recommendations

The following are recommendations based on the findings of this work:

i. Stakeholders should put measures to educate women on the needs to attend antenatal during Pregnancy since number of antenatal visit is a significant determinant of birth weight.

ii. Clinicians and health workers should have a way of linking the IDs of women from antenatal to postnatal so that further research can compare maternal weight gain during pregnancy to that of the baby weight gain during postnatal.

iii. It is also recommended that, stakeholders should put much effort to educate girl child in the Northern Region, since women with higher education had babies with higher birth weight than those women who had no education or little education.

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& Public Health ,Vol. 2 No. 10

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