Chapter 1

Introduction

Pregnancy is one of the most critical and unique period in a women’s life cycle. Due to higher nutritional requirement this group is considered too vulnerable and critical in life span (Mamta Singh et al 2009).

Although fetal growth and development are driven by the programme encoded in its genome, the genetic regulation of fetal growth is influenced by the intra-uterine environment in which the fetus grows. One factor that is critical for fetal survival and health is the supply of nutrients and oxygen from the mother. The ability of a mother to provide nutrients to her baby depends on her nutritional status, body size, body composition and metabolism, all of which are being established throughout the mother’s own fetal life, childhood and adolescence. Assuming that adequate nutrition is available, the fetus can reach its growth potential, resulting in the birth of a healthy newborn of appropriate size (M.S. Martin-Gronert 2006).

1.1 Changes in maternal body composition and weight gain

Based on data from two studies of more than 3800 British women in the 1950s (Hytten and Leitch 1971) established 12.5 kg as the physiological norm for average weight gain for a full-term pregnancy of 40 weeks. On an average, this level of weight gain was shown to be associated with optimal reproductive outcome and was used as the basis for estimating components of weight changes in healthy pregnant women.
Table 1 show that the fetus accounts for approximately 27% of the total weight gain, the amniotic fluid for 6% and the placenta for 5%. The remainder is due to increases in maternal tissues, including the uterus and mammary glands, adipose tissue (fat), maternal blood volume and extra cellular fluid, but not maternal lean tissues. Approximately 5% of the total weight gain occurs in the first 10–13 weeks of pregnancy. The remainder is gained relatively evenly throughout the rest of pregnancy, at an average rate of approximately 0.45 kg per week.

(Hytten and Leitch 1971) estimated that for an average weight gain of 12.5 kg, approximately 3.35 kg of fat would be stored by the mother (Table 1.1).

The WHO review showed that a birth weight of 3.1–3.6 kg (mean 3.3 kg) was associated with optimal fetal and maternal outcomes. The range of maternal Weight gains associated with this optimal birth weight was 10–14 kg; with an average weight gain of 12 kg (WHO 1995).

The amount of weight gain required during pregnancy to achieve a favorable outcome is also influenced by pre-pregnancy bodyweight. In 1990, the Institute of Medicine (IOM) in the USA published a report which re-evaluated the evidence regarding optimal weight gain during pregnancy. The report concluded that pre-pregnancy bodyweight should be taken into account when advising on optimal weight gain. The recommendations for total weight gain according to pre-pregnancy body mass index (BMI) are shown in Table 1.2. For women with a normal pre-pregnancy BMI, a weight gain of around 0.4 kg per week during the second and third trimesters is recommended. For underweight women, a weight gain of 0.5 kg per week is the target, whereas for overweight women, 0.3 kg per week is recommended (IOM 1990).
Excessive weight gain during pregnancy is associated with a number of complications which are similar to those associated with overweight and obesity (e.g. elevated blood pressure). Moreover, extreme weight gain during pregnancy is more likely to lead to overweight and obesity in the mother post-partum. Conversely, low gestational weight gain in women who are underweight or of normal weight prior to pregnancy is associated with the risk of having a low birth weight (LBW) baby (Gold Goldberg 2002). LBW is related to an increased risk of a number of adult diseases (C.S. Williamson 2006).

Table 1.1 Components of weight Gain during Pregnancy

<table>
<thead>
<tr>
<th>Body component</th>
<th>increase in weight (kg) at 40 weeks</th>
<th>percentage(%) of total weight gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product of conception</td>
<td></td>
<td></td>
</tr>
<tr>
<td>fetus</td>
<td>3.40</td>
<td>27.2</td>
</tr>
<tr>
<td>placenta</td>
<td>0.65</td>
<td>5.2</td>
</tr>
<tr>
<td>amniotic fluid</td>
<td>0.80</td>
<td>6.4</td>
</tr>
<tr>
<td>Maternal tissues</td>
<td></td>
<td></td>
</tr>
<tr>
<td>uterus</td>
<td>0.97</td>
<td>7.8</td>
</tr>
<tr>
<td>Mammary gland</td>
<td>0.41</td>
<td>3.3</td>
</tr>
<tr>
<td>Blood</td>
<td>1.25</td>
<td>10.0</td>
</tr>
<tr>
<td>Extracellular, Extravascular fluid</td>
<td>1.68</td>
<td>13.4</td>
</tr>
<tr>
<td><strong>Total weight gain</strong></td>
<td><strong>12.50</strong></td>
<td><strong>100.0</strong></td>
</tr>
<tr>
<td>Assumed fat deposition</td>
<td>3.35</td>
<td>26.8</td>
</tr>
</tbody>
</table>

adapted from Hytten and Leitch(1971)
Table 1.2 The institute of Medicine (IOM) recommended ranges for total weight gain for pregnant women. (IOM 1990).

<table>
<thead>
<tr>
<th>Pre-pregnancy BMI (kg/m²)</th>
<th>Recommended Weight gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 19.8</td>
<td>12.5 - 18 kg</td>
</tr>
<tr>
<td>19.8 - 26</td>
<td>11.5 - 16 kg</td>
</tr>
<tr>
<td>&gt; 26 - 29</td>
<td>7 - 11.5 kg</td>
</tr>
<tr>
<td>&gt; 29</td>
<td>≥ 6 kg</td>
</tr>
</tbody>
</table>

BMI, Body mass index

1.2 Nutritional Requirements during Pregnancy:

1.2.1 Energy

The maternal diet during pregnancy must provide sufficient energy to ensure the delivery of a full-term, healthy infant of adequate size and appropriate body composition. The total energy cost of pregnancy has now been estimated at around 321 MJ (77 000 kcal). This is based on data from longitudinal studies and factorial calculations of the extra energy required during this period (FAO/WHO/UNU 2004).

1.2.2 Protein

The total protein requirement during pregnancy has been estimated to be approximately 925 g for a woman gaining 12.5 kg and delivering an infant of 3.3 kg (Hytten 1980). Protein is not gained at a constant rate, the rate at which protein is deposited increases as pregnancy progresses. Estimates for the first, second, third and fourth quarters are 0.64, 1.84, 4.76 and 6.10 g of protein per day, respectively (FAO/WHO/UNU 1985).
However, more recent estimates from longitudinal studies of women in developed countries (e.g. UK, USA) suggest protein gains in pregnancy may be lower, in the range of 497 to 696 g for an average weight gain of 12 kg (FAO/WHO/UNU 2004).

### 1.2.3 Lipids

No dietary reference intakes (DRIs) for total lipids during pregnancy have been established. The amount of fat in the diet should depend on energy requirements for proper weight gain (IOM 2002).

However, pregnant women and those planning a pregnancy need an adequate dietary intake of essential fatty acids and their longer-chain derivatives, DHA and AA, which are necessary for the development of the brain and nervous system of the fetus, particularly in late pregnancy (BNF 1999). The best dietary source of long chain \( n-3 \) fatty acids (EPA and DHA) is oil-rich fish (C.S. Williamson 2006).

The Institute of medicine has established DRIs for carbohydrate intake during pregnancy. The estimated average requirement (EAR) is 135g / day, and the adequate intake (AI) is 175 g / day (IOM, 2002). The recommended amount of 135 to 175 g/d is the quantity needed to provide enough calories in the diet, to prevent ketosis, and maintain appropriate blood glucose levels during pregnancy (L. Kathleen Mahan 2004).

### 1.3 Fetal Nutrition and Growth

Fetal nutrition is the main regulator of fetal growth in late gestation. However the influence of maternal nutrition on fetal growth is also dependent on the relative efficiency of the fetal supply line, the timing and balance of changes in maternal nutrition, and the indirect effects of altered maternal nutrition on fetal endocrine status and substrate balance (Jane E. Harding 2001).
Cross breeding and embryo transplant experiments in a variety of animal species have clearly demonstrated that size at birth is largely determined by the maternal uterine environment, with the parental genotype having a relatively small influence (Snow MHL 1989).

Fetal growth in late gestation is normally limited by maternal size and her capacity to supply nutrients to her fetus; a phenomenon known as maternal constraint. Thus fetal growth in late gestation is normally regulated by fetal nutrient supply (Gluckman P 1992). This principle of the nutritional regulation of fetal growth is relatively easily demonstrated in animal species. In pregnant sheep, maternal under-nutrition in late gestation results in prompt slowing of fetal growth, and fetal growth resumes with maternal re-feeding [a) Harding JE 1997, b) Harding JE 1997]. However such a relationship is more difficult to demonstrate in human pregnancy. There are case reports of women with severe under-nutrition for medical reasons resulting in impaired fetal growth which is at least partially reversed by improving maternal nutrition status (Rivera-Alsina ME 1984), (Adami GF 1992). Nevertheless, in general the relationship between maternal nutrition and fetal growth is difficult to demonstrate in human pregnancy. This difficulty in demonstrating a direct relationship between maternal nutrition and fetal growth relates largely to the very indirect relationship between maternal nutrition and fetal nutrition. The mammalian fetus grows at the end of a long and sometimes precarious “supply line”, linking maternal diet at one end with fetal tissue nutrient uptake at the other (Bloomfield FH 1998). The supply line includes maternal diet, maternal metabolism and endocrine status, uterine and umbilical blood flows and placental transfer capacity and metabolism. Relatively large changes in maternal nutrition may have little impact on fetal nutrition if the capacity of the fetal
supply line allows a large margin of safety for fetal growth. Conversely, common clinical causes of impaired fetal growth in well nourished populations such as maternal hypertension associated with reduced uterine blood flow, or placental infarcts resulting in reduced placental transfer capacity, may severely limit fetal nutrient supply without a corresponding change in maternal nutrition.

The indirect relationship between maternal nutrition and fetal growth is further confused by the influence of the timing and balance of maternal nutrient intake on fetal growth. Much of the work on nutrient balance has come from human studies. Although randomized controlled trials of maternal dietary supplements have shown relatively little effect on birth weight, supplements with a relatively high proportion of calories provided as protein actually result in reduced mean birth weight (Kramer M.S 1999). Similarly, in a relatively well nourished population, the combination of high carbohydrate intake in early pregnancy and low protein intake in late pregnancy was shown to be associated with reduced birth-weight, low ponderal index and reduced placental weight (Godfrey K 1996), (Godfrey KM 1997). The proportions of protein and carbohydrate in a woman’s diet in pregnancy have also been shown to influence both the placental size and the blood pressure of the adult offspring (Campbell DM 1996).

There is also increasing evidence that maternal nutrition around the time of conception is particularly critical in the regulation of fetal growth.

Maternal weight before pregnancy is an important influence on birth size in women, but it is not yet clear to what extent improved maternal nutrition in early pregnancy may influence birth size independent of nutritional status at pregnancy onset.

Although it is clear from experimental data that nutrition influences fetal growth in late gestation, the mechanisms by which this occurs are far from clear. It appears
superficially logical to assume that nutrient limitation to the fetus at a given stage of
development is likely to inhibit growth of organs that are growing rapidly at that time.
However, simple limitation of substrates to growing organs leading to reduction in size
of those organs is an inadequate explanation. For example, maternal protein restriction
in pigs results in reduced fetal weight and length at mid-gestation at a time when the
fetus is extremely small and fetal protein requirements for growth are unlikely to have
been limiting (Pond WG 1991). Similarly, maternal under-nutrition in either early or
late gestation in sheep, leading to fetal under nutrition and limited nutrient supply to
growing organs (Oliver MH 2000), (Harding JE 2001).

1.3.1 Variation in Fetal Growth:

1.3.1.1 Fetal Body Composition

The fetus undergoes marked changes in body composition during pregnancy. The
general trend is towards progressive increase in fat, protein, and mineral content. Some
of the most drastic changes take place in the last five weeks of pregnancy when fat and
mineral content increases substantially.

Given a healthy mother and fetal access to needed amount of energy, nutrients and
oxygen and freedom from toxins, fetal genetic growth potential is achieved (Rosso P,
Winick M 1974).

However, as evidenced by the relatively high rate of low birth weight in the United
States, optimal conditions required for achievement of genetic growth potential often do
not exist during pregnancy. Variations in fetal growth and development are not
generally due to genetics causes but are rather due to environmental factors such as
energy, nutrient, and oxygen availability, and to conditions that interfere with genetically programmed growth and development (Gluekman PD 2003).

Insulin like growth factor-1 (IGF-1) is the primary growth stimulator of the fetus. It promotes uptake of nutrients by the fetus and inhibits fetal tissue breakdown. Levels of IGF-1 are sensitive to maternal nutrition; it is decreased by under nutrition. Low levels of IGF-1 decrease muscle and skeletal mass and produce asymmetrical growth factors such as pre-pregnancy underweight and shortness, low weight gain during pregnancy, poor dietary intakes, smoking, drug abuse and certain clinical complications of pregnancy are associated with reduced fetal growth (National Academy of Sciences 2005).

1.4 Assessment of Growth and Centile Charts

Optimal growth depends on genetic constitution, normal endocrine function, adequate nutrition, absence of chronic disease, and a nurturing environment. Fetal, infant, environmental, and maternal factors can interact to impair intrauterine and postnatal growth (Pinyerd BJ 1992). Observed genetic differences in birth weight among various populations are small and although there are some racial/ethnic differences in growth, these differences are relatively minor compared to worldwide variations in growth due to health and environmental influences (i.e., poor nutrition, infectious disease, socio-economic status) (Habicht JP 1974- Martorell R 1989). Few ethnic differences in weight and growth of infants and children would remain if they all lived in a similar environment and received the same optimal nutrition and care (Habicht JP 1974, Beaton G 1990- de Onis M 1996).

Growth assessment is the single most useful tool for defining health and nutritional status in children at both the individual and population levels. This is because
disturbances in health and nutrition, regardless of their etiology, almost always affect
growth (de Onis M 1996). Proper growth monitoring consists of serial assessments of
both weight and height measurements over time so that growth velocity can be assessed.
In some situations, a single set of measurement may be used for screening populations
or individuals to identify the abnormal nutritional status and priority for treatment.
Growth monitoring strives to improve nutrition, to reduce the risk of inadequate
nutrition, to educate caregivers, and to produces early detection and referral for
conditions manifested by growth disorders (Garner P 2000).

Although growth monitoring is an important standard component of pediatric services
throughout the world, little research has been performed to evaluate its potential
found only two well-designed studies that evaluated benefits and possible harms of
routine growth monitoring on the child and mother (Garner P 2000, Hall D 2000).
Evaluation of these two programs in developing countries demonstrated no real health
benefits or harms.

1.4.1 Creating Centile charts

A centile chart is a size for age chart that is used to decide whether the size of a child
falls within the normal (average) range or whether the child is larger or smaller than
normal. The size of a healthy child will increase normally with age. Without knowing a
child’s age, one cannot decide whether the size is normal or not. Therefore, accurate
ages are needed while using a centile chart.

A centile chart is based on the size measurements of thousands of healthy children
recorded at different ages. A centile chart is made up of lines called centiles. Most
centile charts have 7 centile lines on them, i.e. the 3rd, 10th, 25th, 50th, 75th, 90th and
97th centiles. Ninety seven percent of healthy children will fall below the 97th centile. Similarly 50% of healthy children will fall below the 50th centile and 3% below the 3rd centile. Therefore, each centile indicates what percentage of healthy children should have a size that falls below that line. This method enables one to compare the size of any child with the expected size of children of the same age.

A growth curve shows not only whether the child’s size is normal or not, but also whether the child is growing normally, faster or slower than expected. Therefore, a growth curve is a far better method of assessing growth than using size measurements taken on one occasion only, as it reflects the child’s growth rate. If the child’s growth rate is normal, the growth curve will closely follow along (be parallel to) the centile lines and not cross more than one centile. (Online 1)

Centile charts are supposed to demonstrate the statistical scatter of the normal population. Therefore, a great many individuals must have the relevant parameter measured so that the sample size is large enough to be statistically rigorous. (Online 2)

1.5 Objective of present study and chapter wise:

The present study makes an attempt to collect evidence of foetal growth through maternal sonography report which includes the most important foetal growth parameters since second trimester to the end of pregnancy. In depth studies were undertaken by different researchers focusing on effect of maternal dietary intakes, habits and weight gain on pregnancy outcomes (Carol Philipps 1977, Gogoi Gourangie 2007, Zahra Panahandeh 2009). It is, however worthwhile to note that there is large evidence regarding role of micro and macronutrients on pregnancy outcomes (Rao TVRK 2004,
JF Ludvigsson 2004, Sjurdur F Oslen 2007, Ahmed A 2007) but rarely plotting of foetal growth measurements have been observed.

Accordingly, this study was carried out to observe the impact of maternal nutrition on growth of foetus with an anthropological perspective. The aim of the study was, to study the effects of maternal dairy intake on foetal growth measurements and also plotting of the different percentiles for male and female foetus.

Specific objectives were formulated as follow:

- To study the relationship between education, socio-economic status of the respondents with the maternal nutrition and foetus growth.
- To study the habitual dietary intake by both 24-h diet recall and food frequency questionnaire.
- To find out the relation between maternal nutrition and growth parameter of foetus and also the pregnancy outcome.
- To construct the growth charts of foetus growth through sonography for; Head circumference, Abdomen circumference, Femur length and Bi-parietal diameter.

The research work is presented in different chapters are:

**Chapter 1 Introduction**

It gives a brief introduction to pregnancy, and more about foetus nutrition and growth, placental transfer of nutrient to the foetus and assessment of growth and centiles chart.

**Chapter 2 Literature Review**

In the present chapter knowledge regarding maternal nutrition and pregnancy outcome are dealt. In addition, a numerous number of review in effect of maternal milk consumption and calcium supplementation during pregnancy on growth of foetus. An introduction to the earlier investigation on the effect of maternal confounder on the
growth of foetus and pregnancy outcomes including; maternal weight gain, maternal pre-pregnancy BMI and maternal work status.

**Chapter 3 Methodology**

The entire methodological details are described in this chapter including; Sample Design, Sampling unit, Source list, Size of sample, Parameters of interest, Sampling procedure, Interview Method, Assessment of dietary adequacy, description of Fetal biometric parameters, Morphometry, describing Statistical Analysis, Growth chart Monitoring, Data processing for qualitative and quantitative variables and calculation of Z-score (standard score) for dietary data.

**Chapter 4 Analysis of maternal Dietary Intake and Pregnancy Outcome**

In this chapter the descriptive and inferential statistics were applied on dietary variables, demographic variables, newborn growth measurements and also maternal anthropometrics measurements. In addition, the finding is presented along with discussion.

**Chapter 5 Analysis of maternal Dietary Intake and Foetus growth Pattern**

In this chapter the inferential statistics was carried out between dietary data and foetal growth measurements and also plotting of the foetal growth chart and foetal growth percentiles are observed.

**Summary** In this part, summary of major finding is presented along with significance, strength and limitation of the study and also conclusion.