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Associations Between Maternal Nutritional Characteristics and the Anthropometric Indices of Their Full-term and Pre-term Newborns

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Abstract: A retrospective descriptive study was designed to compare maternal nutritional characteristics with the anthropometric data of their full-term and pre-term newborns. 100 post-partum women and their newborns were selected from Government Hospital, Mumbai. The case records and hospital records were examined to gather information about the last known pre-pregnancy weight, gestational weight gain, placental weight, gestational age of mothers. Prenatal data with regard to maternal height, third trimester weight and hemoglobin concentration were recorded by the hospital. Postnatal data with regard to maternal mid upper arm circumference and neonatal birth weight, length, mid upper arm circumference, head circumference, chest circumference was recorded using standardized technique. The technique of three days diet recall was used to obtain the maternal third trimester dietary intake. Maternal third trimester daily nutrient intake among terms deliveries was significantly higher [with regard to energy (2254 kcal), protein (69.7 g), carbohydrate (320.3 g)] as compared to those with pre-term deliveries [energy (2048 kcal), protein (59.7 g), carbohydrate (285.4 g)] ($p<0.05$). Though not statistically significant, the average birth weight of term newborns (2849 g) was higher than pre-term newborns (2772 g) ($p=0.444$). Positive correlations were noted with maternal third trimester hemoglobin concentration and birth weight ($r=0.587$, $p=0.001$), length ($r=0.347$, $p=0.044$), mid upper arm circumference ($r=0.387$, $p=0.028$) and chest circumference ($r=0.496$, $p=0.006$) of pre-term newborns, after adjustments for pre-pregnancy weight, gestational age (weeks), parity. There was a significant correlation between maternal third trimester energy and carbohydrate intake with birth weight, length, head circumference, chest circumference of term babies. Maternal energy intake did not influence head circumference of pre-term. Protein intake was associated with birth weight of all deliveries. Regression analysis showed positive association between head circumference and fat intake among term delivery ($r=0.357$, $p=0.002$). In conclusion, this study showed that maternal third trimester hemoglobin concentration correlated with birth weight, length, mid upper arm circumference and chest circumference of pre-term newborns. This study highlights significant dietary influences on anthropometric indices among newborns. Hence nutritional status and hemoglobin concentration of the mothers was found to contribute significantly to the newborns size at birth.

Key words: Anthropometry, maternal, neonatal, nutrient intake, term delivery, pre-term delivery

INTRODUCTION

Pregnancy is one of the most critical and unique period of woman's life cycle. It is a condition of great stress as many anabolic activities take place and fetal growth is accomplished by extensive changes in maternal body composition and metabolism (Sachdeva *et al.*, 2009).

Maternal nutrition before and during pregnancy has the most important determinant influence during the development of the fetus. The crucial dietary recommendation during pregnancy is to consume a balanced diet as described by the Indian Council of Medical Research (ICMR) which includes extra nutrients for pregnancy and lactation (Khoushab and Saraswathi, 2010). The stark reality however is that the incidence of Low Birth Weight (LBW) babies continues to be high in India at about 30% in contrast to 5-7% in developed countries (Kashyap and Dwivedi, 2006).

Studies have shown effect of maternal dietary intake during pregnancy on fetal outcome (Khoushab and Saraswathi, 2010; Jackson and Robinson, 2001). Sufficient research evidence points out to the fact that poor nutritional status pre-pregnancy and during pregnancy is associated with inadequate weight gain, anemia, retarded fetal growth, low birth weight, still births, preterm delivery, Intrauterine Growth Retardation (IUGR), increased morbidity and mortality rates which may threaten the health and life of the mother and the newborn (Sachdeva *et al.*, 2009). According to Barkers hypothesis IUGR babies are at risk of obesity, hypertension, insulin resistance and coronary heart disease in later life (Akram and Arif, 2005). It is important to assess neonatal nutritional status at birth. There are various methods to identify nutritional status of neonates at birth like weight for gestational age, birth

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weight, birth length, Head Circumference (HC), Chest Circumference (CC), ponderal index and Mid Upper Arm Circumference (MUAC) (Mohan *et al.*, 1990).

It is well known and documented that, maternal nutritional status viz maternal pre-pregnancy weight, pre-pregnancy body mass index, total weight gain during pregnancy, third trimester weight and MUAC are associated with neonatal anthropometric measurements at birth (Walker *et al.*, 2003; Yekta *et al.*, 2006; Mohsen and Wafay, 2007). Unfortunately most of this data is western or from countries like Pakistan, etc and very limited Indian research data is available related to comparison of maternal nutrition characteristics and neonatal anthropometry (Khoushab and Saraswathi, 2010; Hadipour *et al.*, 2010; Yucel and Cynar, 2009). Hence an attempt was made to study dietary macronutrient intakes and its influence on term and pre-term newborn anthropometric indices as it influences future life quality and health of the newborns.

MATERIALS AND METHODS

Participants: Post-partum women and newborns (n=100) were selected from a Government Hospital at Parel, Mumbai from May to December 2009 using random convenience sampling research design. The subjects consisted of 72 full term newborns and 28 preterm newborns.

Before the commencement of the study a clearance was obtained from the hospital's ethical committee. After delivery, women were taken to the ward and an informed consent was obtained and those willing were enrolled for this study. Inclusion criteria were: preterm and term, live birth neonate, those newborns and mothers whose hospital stays exceeded 24 hrs, newborns born by vaginal delivery and cesarean delivery. Mothers with diabetes mellitus and cardio vascular disease, twin newborns and newborns having major congenital malformation were excluded from the study.

Measurements

Mothers: Maternal background information, height, last known pre-pregnancy weight, gestational weight gain during pregnancy, third trimester weight, third trimester hemoglobin concentration, placental weight, gestational age and number of children were obtained from hospital records. Height was measured using a stadiometer (Seca, China). Third trimester weight was measured using electronic weighing scale (Atlas, India). During antenatal checkup, just before delivery third trimester weight and hemoglobin concentrations were recorded by the hospital. MUAC was measured using non stretchable measuring tape after delivery (Jelliffe, 1966). Pre-pregnancy Body Mass Index (BMI) was calculated {BMI=Weight (kg)/Height (m^2)}. Women were classified according to Asian BMI classification. Based on gestational age, mothers were categorized as term delivery (37-42 weeks) and pre-term delivery (<37 weeks).

Newborns: Newborn weights were measured using electronic weighing scale (Everday, India). Length, HC, CC and MUAC were measured within 48 hrs after birth using non-stretchable measuring tape (12). Genders of babies born were obtained from hospital records. Ponderal Index for newborns were calculated as [weight (gm)/length ($cm)^3$]x 100 (Miller and Hassanein, 1971).

Dietary assessment: After delivery, maternal third trimester dietary recall was carried out. Retrospective three day dietary recall was obtained to study the dietary pattern and nutrient intake of the women. Household measurements like standardized measuring cups, spoons and food models-cardboard cutouts to indicate size and thickness of phulkas, chapattis and bhakris were used to get accurate information about the quantity of food consumed by the mothers. Macronutrient consumptions were calculated by using Nutritive Value of Indian Foods (Gopalan *et al.*, 1989).

Statistical analysis: The statistical analysis of data was done using SPSS version 17. Data were divided into two groups according to term (37-42 weeks) and pre-term (<37 weeks) deliveries. T-test was used to determine the significant difference between two groups. Pearson correlation and regression analysis (ANOVA) was used to determine effect of maternal nutrient intake, anthropometric measurements and hemoglobin concentrations on newborns anthropometric measurements. P value of <0.05 was considered to be significant.

RESULTS

In this retrospective descriptive study, 100 post-partum women of the Government Hospital's maternity ward were included based on study selection criteria. Mean age of the women was 27.45±3.89 years and they were housewives. When classified according to gestational period, there were 72 women with term delivery (37-42 weeks) while 28 were pre-term deliveries (<37 weeks). There were 72 full term newborns (35 male newborns and 37 female newborns) and 28 preterm newborns (15 male newborns and 13 female newborns). Among the full-term babies, 46 were first, 24 were second and 2 were third in their ordinal positions, whereas among the preterm babies, 15 were first and 13 were second.

Comparison of mean age, anthropometric profile, hemoglobin and placental weight between mothers of term and pre-term deliveries are presented in Table 1. Mothers who delivered term newborns (37-42 weeks) showed significantly higher hemoglobin concentration and placental weight as compared to pre-term deliveries.

Table 1: Comparison of mean age, anthropometric profile, hemoglobin and placental weight between mothers of term and pre-term deliveries

	Term (37-42 weeks) (n=72) (Mean±SD)	Pre-term (<37 weeks) (n=28) (Mean±SD)	Significant (2 tailed)
Age (yrs.)	27.88±03.92	26.36±03.65	p = 0.080
Height (cm)	154.67±07.53	155.77±06.91	p = 0.504
Pre-pregnancy weight (kg)	51.46±09.51	50.64±12.26	p = 0.724
Pre-pregnancy BMI (kg/m^2)	21.51±03.64	20.96±05.38	p = 0.620
Third trimester weight (kg)	63.91±10.16	61.44±13.59	p = 0.325
Gestational weight gain (kg)	12.45±03.97	11.37±02.94	p = 0.140
Third trimester weight gain (kg)	1.83±01.43	1.84±01.28	p = 0.984
Mid upper arm circumference (cm)	26.47±02.65	25.56±03.31	p = 0.155
Hemoglobin (gm/dL)	11.15±01.02	10.72±01.19	p = 0.076
Placental weight (gm)	480±35.89 (n=35)	450±44.72 (n=6)	p = 0.075

Table 2: Mean anthropometric measurements of newborns at birth

	Normal range	Term (37-42 weeks) (n=72) (Mean±SD)	Pre-term (<37 weeks) (n=28) (Mean±SD)
Weight (gm)	2500-4000	2849.71±462.28	2772.14±426.72
Length (cm)	46-56	48.72±2.48	48.32±2.55
Ponderal index (gm/cm^3)	Pre-term-2-3.5 Full-term- 2.25-3.5	2.45±0.35	2.46±0.36
Mid upper arm circumference (cm)	>9	9.67±1.14	9.63±0.73
Head circumference (cm)	33-37	33.81±1.47	33.48±1.27
Chest circumference (cm)	30.5-35	31.70±1.69	31.38±1.44

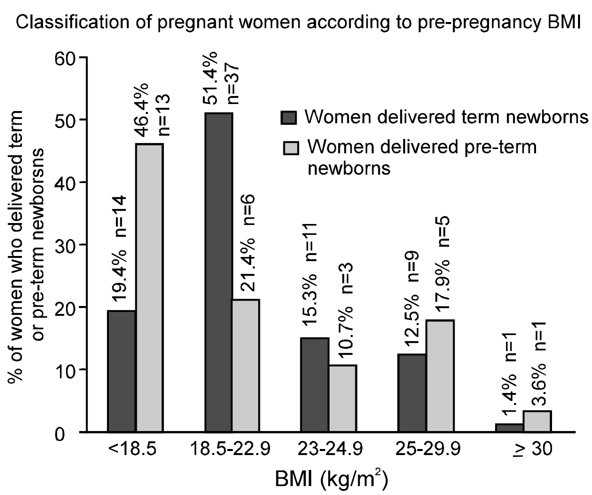

Fig. 1: Classification of pregnant women according to pre-pregnancy Body Mass Index (BMI) (Misra *et al*., 2009)

It was observed that 51.4% women (n=37) with term deliveries and 21.4 women (n=6) with pre-term deliveries belonged to the BMI category 18.5-22.9 kg/m^2 whereas 19.4% women (n=14) with term deliveries and 46.4% women (n=13) with pre-term deliveries belonged to the BMI category<18.5 kg/m^2 (Misra *et al*., 2009) (Fig. 1).

Mean anthropometric profiles of newborns at birth and normal accepted cut-offs range (Akram and Arif, 2005; Ahmed *et al*., 2000; Madara *et al*., 2007) are shown in Table 2. No significant difference was found between term and pre-term group. All measurements were within normal range. Though not statistically significant, the average weight at birth was higher in the newborns who were born term (2849.71±462.28 g) than pre-term (2772.14±426.72 g) (p=0.444).

Correlation between newborns anthropometric measurements and maternal mean age, anthropometric profile and hemoglobin concentration of mothers who delivered term or pre-term newborns was studied. Among term newborns a significant association was found between maternal age and newborn length (r=0.311, p=0.005), ponderal index (r=0.205, p=0.046) after adjusting for pre-pregnancy weight, gestational age (weeks) and parity. Pre-pregnancy weight was significantly associated with newborns weight at birth (r=0.209, p=0.039). In term and pre-term newborns pre-pregnancy BMI of mothers was not found to be associated with any anthropometric measurements of newborns at birth.

A significant association was found between maternal anthropometric measurements like pre-pregnancy weight (r=0.423, p=0.012), third trimester weight (r=0.501, p=0.003), third trimester weight gain (r=0.438, p=0.010), gestational weight gain (r=0.395, p=0.019), MUAC (r=0.437, p=0.010) and HC of pre-term newborns. A significant association was observed between maternal third trimester weight gain and CC of newborns who were born pre-term (r=0.430, p=0.011). Regression analysis revealed that maternal hemoglobin concentration was significantly associated with MUAC (r=0.883, p=0.020) of newborns. However, when adjustments were made for pre-pregnancy weight, gestational age (weeks) and parity; maternal age (r=0.384, p=0.029) and MUAC (r=0.368, p=0.035) was correlated to birth length. Third trimester weight (r=0.340, p=0.048) and gestational weight gain (r=0.472, p=0.009) was correlated with newborns HC. Maternal third

Table 3: Comparison of mean third trimester energy and nutrient intake between mothers of term and pre-term deliveries

	Recommended Dietary Intake (RDI)*	Term (37-42 weeks) (n = 72) (Mean±SD)	Pre-term (<37 weeks) (n = 28) (Mean±SD)	Significant (2 tailed)
Energy (kcal)	2249.0	2254.50±511.44	2048.75±382.43	p = 0.057
Protein (gm)	82.2	69.70±016.76	59.70±013.65	p = 0.013
Carbohydrate (gm)	343.0	320.34±080.72	285.44±060.63	p = 0.041
Fat (gm)	60.0	66.81±018.59	62.73±013.59	p = 0.231

*Indian Council of Medical Research (ICMR), 2009

trimester hemoglobin concentration was correlated with birth weight (r=0.587, p=0.001), length (r=0.347, p=0.044), MUAC (r=0.387, p=0.028) and CC (r=0.496, p=0.006) of pre-term newborns and not with term newborns.

Majority of the women were non-vegetarian. A significant difference was observed in caloric (p=0.057), protein (p=0.013) and carbohydrate (p=0.041) intakes between mothers delivering term and pre-term newborns. Mothers who delivered term newborns consumed 100% of the recommended energy intake as compared to pre-term maternal energy intake of 91.1% (ICMR, 2009) (Table 3).

Correlation between newborns anthropometric measurements and mean third trimester energy and nutrient intake of mothers who delivered term or pre-term newborns was studied. Regression analysis (95% CI) revealed that maternal third trimester daily energy intake was significantly associated with birth weight (r=0.363, p=0.002), length (r=0.474, p=0.000) and CC (r=0.369, p=0.001) of term newborns, though HC (r=0.332, p=0.003) was also associated with maternal third trimester energy intake after adjusting for variables.

Maternal daily energy intake was strongly associated with birth length (r=0.374, p=0.050) and CC (r=0.430, p=0.022) of pre-term newborns and when after adjustments for pre-pregnancy weight, gestational age (weeks) and parity, birth weight also associated with maternal energy intake (r=0.347, p=0.045).

With reference to daily protein intake during third trimester, it was observed that birth weight (r=0.245, p=0.021), length (r=0.310, p=0.005) and CC (r=0.222, p=0.033) of newborns who were born term was strongly correlated with protein intake whereas in pre-term newborns maternal daily protein intake was significantly correlated with birth weight of newborns (r=0.406, p=0.022) after making adjustments for variables.

Maternal third trimester carbohydrate intake was significantly associated with birth weight (r=282, p=0.009), length (r=0.341, p=0.002), HC (r=0.280, p=0.010) and CC (r=0.332, p=0.003) of term newborns after adjustments for pre-pregnancy weight, gestational age (weeks) and parity. There was no association found between maternal carbohydrate intake and pre-term newborns anthropometric measurements.

There was a significant correlation observed between daily fat intake during third trimester and birth weight (r=0.252, p=0.033), length (r=0.295, p=0.012), HC (r=0.357, p=0.002) and CC (r=0.352, p=0.002) of newborns who were born term. However when variables were controlled only birth weight (r=0.222, p=0.033) and length (r=0.282, p=0.009) of newborns correlated with maternal fat intake. Regression analysis showed the significant association with term newborns HC and maternal fat intake (r=0.357, p=0.002). There was no correlation observed between daily fat intake during third trimester and pre-term newborns anthropometric measurements.

DISCUSSION

This study attempts to compare maternal characteristics with anthropometric data of newborns when classified as term and pre-term group. Only maternal age, hemoglobin and placental weight were significantly different between term and pre-term deliveries. By WHO criteria mothers with pre-term deliveries were anemic (WHO, 1992). A premature infant will have a lower birth weight than a term infant (Mahan and Stump, 2008). Similar result was observed in the present study. However adjustment for sex, birth order, gestational age (weeks) was not possible due to small sample size.

Studies have reported frequent pre-term deliveries among lean (<18.5 kg/m^2), overweight (25-29.9 kg/m^2) and obese ($\geq$30 kg/m^2) women (Mokuolu *et al.*, 2002; Chereshneva *et al.*, 2008). In the present study women who delivered pre-term newborns had a mean BMI of 20.96±5.38 kg/m^2. Fetal under-nutrition may be due to low pre-gestational maternal weight. Evidence indicates that women with low pre-pregnancy BMI are morelikely to have smaller infants than heavier women, even whentheir gestational weight gain is the same (Yucel and Cynar, 2009). No significant association was observed among newborn anthropometry (term and pre-term) with pre-pregnancy BMI.

The present study found an association between maternal age and newborn ponderal index which is an indicator of wasting. Yucel and Cynar (2009) reported that maternal pre-gestational weight was an important factor influencing newborn's birth weight and ponderal index. Similar correlations were observed in the present study among term deliveries with respect to birth weight. HC is a good indicator of intrauterine and childhood malnutrition. Small or large HC at birth leads to neurological abnormalities (Johnston and Turner, 2011; Schor and O'Reilly, 2011). The strong association observed among pre-term newborn HC and pre-

pregnancy weight, third trimester weight, third trimester weight gain, gestational weight gain, MUAC indicates that maternal nutritional status before and during pregnancy has an effect on fetal intra uterine growth. Brown *et al*. (2002) observed that third-trimester maternal weight gain did not predict weight, length or HC of the newborn but it did predict newborn's ponderal index. Another study reported that weight of mother in late pregnancy was associated with the neonatal ponderal index, HC and CC and the rate of weight gain in second half of pregnancy was associated with birth weight, ponderal index and HC to length ratio (Walker *et al*., 2003).

CC measuring <30.5 cm at birth indicates LBW (Dhar *et al*., 2002). Studies did not report an association between newborn CC and maternal third trimester weight gain and hemoglobin concentration. A study has shown that first trimester hemoglobin concentrations were positively associated whereas second and third trimester hemoglobin concentrations were negatively associated with birth weight, crown heel length, HC, placenta weight and ponderal index (Thame *et al*., 1997). One more study found that the maternal hemoglobin level was positively correlated with neonatal birth weight, length and HC (Hadipour *et al*., 2010). Maternal hemoglobin concentration has a strong influence on neonatal parameters. In the present study maternal hemoglobin concentration was correlated to birth weight, length, MUAC and CC of pre-term newborns. This was not observed among term newborns which indicate that maternal anemia is attributed to chronic deprivation of oxygen to developing fetus (Pollack and Divon, 1992).

Studies among rural intakes have reported diets deficient in energy however these being urban families the study observed that recommended caloric intake was being met by the diet. One review article reported that no significant effects of energy and protein intake during pregnancy were detected on pre-term birth, but significantly reduced risks were observed for stillbirth and neonatal death (Kramer and Kakuma, 2010).

A study reported that mean weight, length and HC of newborn infants were significantly higher in mothers receiving more than 2000 kcal and 75 gm protein which was observed in the present study as compared to pregnant women whose dietary caloric and protein intake were less than 1500 kcal and 45 gm protein in third trimester (Bhatia *et al*., 1983).

A study reported that a very high protein intake (143 gm/d) was associated with low birth weight (Jackson and Robinson, 2001). The study also reported that high protein intake caused reduced ponderal index among large birth weight infants but not among low birth weight infants. The reason why high maternal protein intake in human should negatively influence fetal size is unclear. In contrast to this findings a recent study has reported that higher daily energy intake (>2500 kcal) and protein (>60 gm) intake of women during third trimester gave birth to neonates with normal birth weight, whereas low energy intake (<1500 kcal), protein (<49.9 gm) and calcium intake of women gave birth to LBW neonates (Khoushab and Saraswathi, 2010). Similar findings have been reported in present study.

Thinness at birth was associated with low contribution of carbohydrate to dietary energy intake (Langley-Evans and Langley-Evans, 2003). Amount of carbohydrate intake was found to influence birth weight, length, HC and CC of term newborns in the study which means that maternal under-nutrition is attributed to infant proportion at birth.

Hence, it can be seen that mothers who delivered term newborns had higher hemoglobin concentration, placental weight and pre-pregnancy weight and these newborns were born with higher weight and ponderal index at birth, whereas mothers who delivered pre-term newborns had less pre-pregnancy weight, gestational weight gain and hemoglobin concentration and these newborns were born with lower weight, HC and CC at birth.

Similarly higher maternal caloric, protein, carbohydrate and fat intake during third trimester lead to higher birth weight, length, HC and CC of newborns who were born term whereas low third trimester hemoglobin level and less newborns weight at birth was observed in pre-term deliveries as compared to term deliveries who consumed less protein during third trimester.

This study has revealed strong association between maternal dietary energy, protein, carbohydrate and fat intake and various newborns anthropometric variables. Recent epidemiological evidence of an association between poor fetal growth and adult disease highlights the need to reconsider the influences which act on the fetus and the role maternal nutrition may play (Jackson and Robinson, 2001). More research needs to be undertaken in this area to examine these complex relationships among dietary macronutrient intakes and neonatal anthropometric indices, though the present study is just an observational data presented.

Conclusion: To summarize, this retrospective descriptive study of pre-term and term deliveries found strong association among hemoglobin concentration with birth weight, length, mid upper arm circumference and chest circumference of pre-term newborns. There was a significant co-relation between maternal third trimester energy and carbohydrate intake with birth weight, length, head circumference, chest circumference of term babies. Maternal energy intake did not influence head circumference of pre-term but was correlated with birth weight, length, chest circumference of term newborns. Protein intake was associated with birth weight of all deliveries. Dietary fat intake influences birth weight, length of term deliveries. On a short-term basis, interventions should improve maternal hemoglobin concentration and macronutrient intake in pregnancy, which in turn affect maternal weight gain and the anthropometric indices of the newborns.

Limitation:

- Pre-pregnancy weight and third trimester three day dietary recall was retrieved from memory by the women studied.
- Sample size studied was small and detailed neonatal anthropometry was not done.

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Key messages:

- Relationship between maternal anthropometry with anthropometric measurements of newborn at birth.
- Associations between third trimester maternal nutrient intakes in terms of energy, carbohydrate, protein, fat, as obtained retrospectively, on neonatal anthropometric indices.

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