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Study of Fetal Malnutrition: Its Etiology, Early Assessment in Developing Country

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ABSTRACT

Fetal malnutrition (FM) is a clinical state, characterized by intrauterine loss of or failure, to acquire normal amount of fat and muscle mass. Various terminologies used for describing intra uterine malnutrition includes small for gestational age (SGA), intra uterine growth restriction (IUGR) and placental insufficiency. It is important to recognize FM in newborn babies because of the high incidence of neonatal morbidity and long-term sequelae. Present study was a cross sectional, observational and analytical study, conducted in post-natal ward and NICU of department of Pediatrics of Peoples College of Medical Sciences and Research Centre, Bhopal during one and half year (1st December, 2018 to 31st may, 2020) of study period. Aim of study ''Study of fetal malnutrition- its etiology, early assessment in developing country''. Mean value of all anthropometric parameters i.e. birth weight, length, head circumference, chest circumference and mid arm circumference was significantly lower in those with FM as compared to those without FM ($p<0.001$). All full term (37- 42 weeks of gestational age) newborns delivered at People's Hospital, Bhopal during the study period were included in the study. All babies were examined thoroughly as per pre-defined proforma (Annexure-II). GESTATIONAL AGE (GA) was assessed by using Modified Ballard scoring system within first 24-48 hours of life; babies who were found to be full term i.e., 37-42 weeks by Ballard scoring system were enrolled in the study. Written consent (Annexure-III) was taken from parents before enrolling the babies in the study. The mean value of weight, length, head circumference, chest circumference, MAC, MAC/HC, PI, BMI and CAN Score in subjects included in present study was 2774.25 g, 47.54 cm, 33.25 cm, 30.95 cm, 9.51 cm, 0.28, 2.56 $g\ cm^{-3}$, 12.20 $kg\ m^{-2}$ and 26.94, respectively. Male to female ratio was 1.12: 1. Fetal malnutrition was found in 18.5% babies as assessed by the CAN score of <25. Weight for GA ($p<0.001$), MAC/HC ($p<0.001$), PI ($p<0.001$), BMI ($p<0.001$) and length for GA ($p<0.001$) all were found to have significant association in predicting the fetal malnutrition when CAN score of <25 was taken as the cut off value. Mean value of all anthropometric parameters i.e. birth weight, length, head circumference, chest circumference and mid arm circumference was significantly lower in those with FM as compared to those without FM ($p<0.001$). Maternal risk factors such as PIH, aneamia, maternal infection and poor socioeconomic status have significant association with FM, whereas birth spacing (year), BMI of mother and hypothyroidism were not significantly associated with the presence of FM. The area under the curve (AUC) for the birth weight (0.891), MAC (0.855), BMI (0.837), PI (0.761), length (0.749) and MUAC/HC (0.714) with p-value of <0.001 was observed. AUC was highest for birth weight followed by MAC and BMI. This highlight that all these three parameters have good sensitivity and specificity for identifying FM ($p<0.001$).

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Key Words
Fetal malnutrition, head circumference, clinical assessment of nutrition

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INTRODUCTION

Fetal malnutrition (FM) is a clinical state, characterized by intrauterine loss of or failure to acquire normal amount of fat and muscle mass. This term was coined by Scott and Usher in 1963[1].

Assessment of fetal malnutrition should be included in the evaluation of all newborns regardless of the classification of their weight for gestational age (GA), as birth weight alone is a poor indicator of nutritional status at birth[2,3].

Various terminologies used for describing intra uterine malnutrition includes small for gestational age (SGA), intra uterine growth restriction (IUGR) and placental insufficiency. Although these terms are used synonymously with FM but both are quite different as they do not assess the accumulation of subcutaneous fat and muscle mass in the fetal body[2]. Also, they do not take account of genetic and ethnic variations amongst different populations[4].

It is important to recognize FM early in neonates as there is a high incidence of neonatal morbidity and mortality as well as long term neurological sequelae associated with it. Studies have shown that children with FM are more likely to have lower IQ scores, require higher need of special education, have neurologic disabilities, intellectual disabilities, learning disorders or seizures in late childhood as compared to children without FM[5,6]. Neurologic alterations may be aggravated by events like hypoglycemia or feeding difficulties happening during the neonatal period that are more common in FM babies. Furthermore, FM is associated more frequently with cardiovascular, endocrine and metabolic disorders during late child hood and adolescent age group[6,7].

The incidence of low birth weight (LBW) babies (<2500 g) continues to be high in India at about 18% in contrast to 5-7% in developed countries[8,9]. High incidence of LBW babies in India is due to the neglected health and education of females, teenage marriages and pregnancies, frequent pregnancies, maternal malnutrition, bad obstetric history, pregnancy induce hypertension (PIH), anemia and infections[10].

Nutritional status at birth can be assessed by using various anthropometric parameters [weight, length, head circumference (HC), chest circumference (CC), midarm circumference (MAC), proportionality indices [Body mass index (BMI), Ponderal index (PI), Kanawati Index (MAC/HC)] and Clinical Assessment of Nutritional status score (CAN score)[3,11,12].

Weight for gestational age is most commonly used anthropometric index to identify newborn's nutritional status. It classifies new born into Appropriate for gestational age (AGA), Small for gestational age (SGA) and Large for gestational age (LGA). FM is a clinical state which may be present at almost any birth weight and gestational age.

In FM subcutaneous tissues and underlying muscles mass are diminished and the skin of arms, legs, elbows, knees and interscapular region is very loose. In severe FM, neonate may look "emaciated" or "marasmic" as the skin appears too large for the baby[13].

Assessment in perinatology (Maternal-Fetal medicine) uses anthropometry as an essential tool to monitor growth and evaluate the nutritional and functional (circulatory and respiratory) status of newborns (NB). It is an economical, non-invasive and easy-to-execute tool that can improve understanding of growth patterns and their variations[14].

Maternal Urinary tract infection and genital tract infection during pregnancy were associated with LBW baby or preterm delivery, urinary tract infection also associated with pregnancy induce hypertension (PIH), anemia and amnionitis which also leads to LBW or preterm LBW newborn[15].

It is important to recognize FM in newborn babies because of the high incidence of neonatal morbidity and long-term sequelae. Reference criteria used for defining FM has been very variable. Weight at birth has been the most common criteria adopted by investigators and LBW is defined as birth weight less than 2500 gms but this method does not identify FM which indicates a clinical state that may be present at almost any birth weight[2].

Various instruments have been used to identify children with malnutrition. In older children and adults, Body mass index (BMI) is used as the gold standard in determining body proportions and adiposity for the screening of malnutrition. In neonates also as in older children's various criteria have been used to identify and classify FM. The most common criterion used is birth weight. Researchers have argued that birth weight alone may not reflect the true state of nutrition in utero[11,16,17].

Recording of birth weight in villages has continued to be major problem in our country, therefore search was continued for an alternative measurement which could replace birth weight recording to screen for high-risk infants. Mid arm circumference (MAC) recorded at birth was related to birth weight and outcome.

Since neonatal morbidity and mortality is more closely related to nutritional status of newborn at birth than to the birth weight for gestational age alone. A simple, practical, clinically applicable scoring system Clinical Assessment of Nutritional Status Score (CAN score) was developed by Metcoff to differentiate malnutrition from appropriately nourished babies, irrespective of birth weight for any gestational age[2].

Aims and objectives: Present study was a cross sectional, observational and analytical study, conducted in post-natal ward and NICU of department of Pediatrics of Peoples College of Medical Sciences and Research Centre, Bhopal during one and half year (1st December, 2018 to 31st May, 2020) of study period.

Aim of study: Study of fetal malnutrition: Its etiology, early assessment in developing country.

- To assess fetal nutritional status by assessing newborn using CAN score
- To assess fetal nutritional status by assessing new born using selected anthropometric indices
- To compare the assessment of fetal nutritional status using CAN score with selected anthropometric indices

Source of data: New born babies were recruited from People's Hospital, which is a allied hospital of Peoples College of Medical Sciences and Research Centre Bhopal, a tertiary referral Centre, getting patients from all socio-economic groups. A total of four hundred eleven new born babies were included in this study.

Inclusion criteria: All full-term (37 completed weeks of gestation) newborns as assessed by Modified Ballard score system.

Exclusion criteria:

- New-borns <37 completed weeks of gestation
- New-borns with congenital anomalies
- Babies born to mothers with Gestational Diabetes Mellitus

Sample size: All full term (37-42 weeks of gestational age) newborns delivered at People's Hospital, Bhopal during the study period were included in the study.

MATERIALS AND METHODS

Written consent (Annexure-III) was taken from parents before enrolling the babies in the study. Babies who fulfilled the exclusion criteria were excluded from the study. All babies were examined thoroughly as per pre-defined proforma (Annexure-II). Gestational age (GA) was assessed by using Modified Ballard scoring system within first 24-48 hrs of life; babies who were found to be full term i.e., 37-42 weeks by Ballard scoring system were enrolled in the study.

Equipment/Instruments required:

- Electronic weighing machine
- Infantometer
- Flexible non stretchable tape (Fig. 1)

Fig. 1: Infantomter

Variables studied in the study:

- Mode of delivery
- Singleton/multiple gestation
- Gestational age as assessed by modified ballard score
- Birth weight
- Length
- Head circumference
- Chest circumference
- Mid arm circumference
- Mid arm circumference/Head circumference
- Pondrel index (PI) 11. Body mass index
- CAN score
- High risk factors in mothers

Birth weight: Nude birth weight at birth was measured to the nearest 10 g using electronic weighing scale (Fig. 2). Birth weight was plotted on Lubchenco chart for weight for gestational age and baby was classified as SGA (wt/gestational Age less than 10th percentile), AGA (between 10th to 90th percentile) and LGA (more than 90th percentile).

Measurement of weight

Length: Crown to Heel Length was measured to the nearest 0.1 cm using an infantometer and length was plotted on length for gestational age Lubchenco chart (Fig. 3 and 4).

Head circumference: Occipito-frontal circumference was taken as the largest circumference of the skull using a flexible non stretchable tape to the nearest of 0.1 cm (Fig. 5). Head circumference was also plotted on Lubchencho chart and classified as head circumference less than 10th centile and more than 10th centile.

Measurement of head circumference

Chest circumference: was taken at the level of nipple using flexible non-stretchable tape to the nearest 0.1 cm (Fig. 6).

Mid arm circumference (MAC): Measured in the left arm, at a point midway between tip of the acromion and the olecranon process using a flexible non stretchable tape to the nearest 0.1 cm. MAC less than -2SD was taken as abnormal (Table 1).

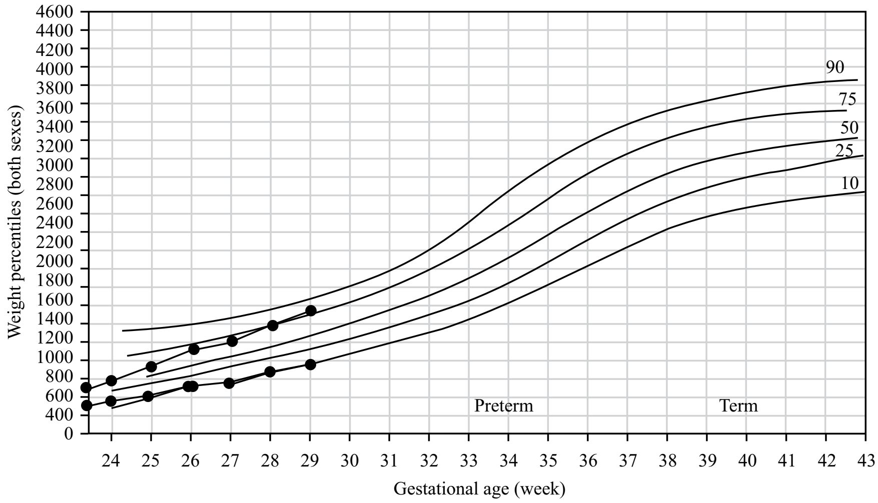


Fig. 2: lubchencho chart: weight for gestational age

Fig. 3: Measurement of length by infantometer

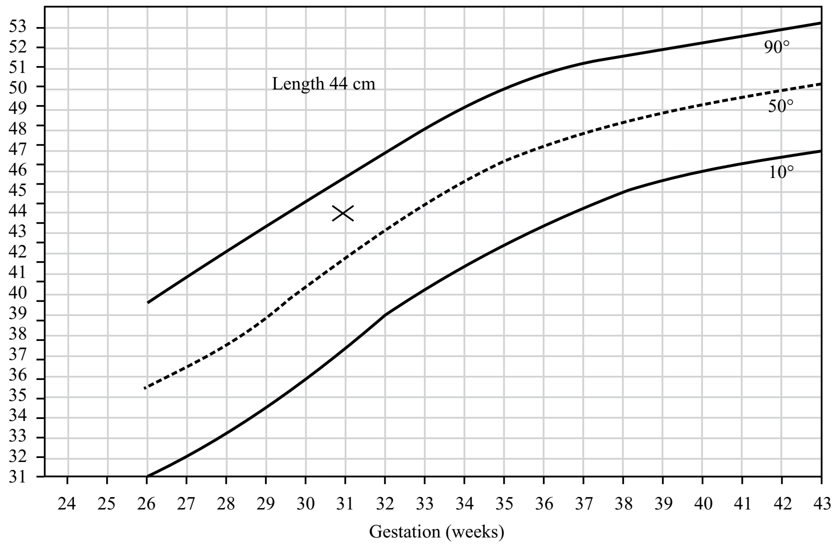


Fig. 4: Lubchencho chart: length for gestational age

- Mid arm circumference/head circumference Ratio (MAC/HC) (Kanawati Index): A cut off value of <0.25 was used in this study to define malnutrition (Fig. 7)[4]
- Ponderal index (PI):

$$PI = Weight (gms) \times 100/ Length (cms)^3$$

- Ponderal index less than 2.2 g cm^{-3} was considered as an indicator of malnutrition[18].
- Body mass index (BMI):

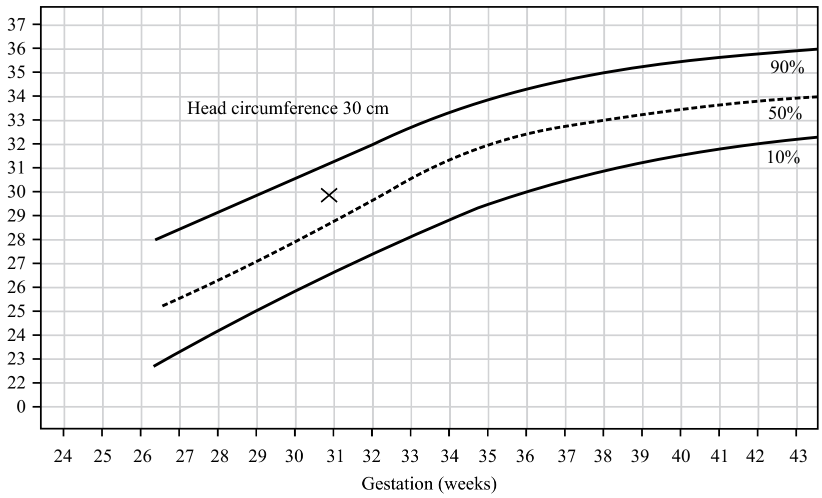


Fig. 5: Lubchencho chart: head circumference for gestational age

Fig. 6: Measurement of chest circumference

Table 1: Mid-arm Circumference measurement

Gestational age (weak)	N	MAC (cm)	MAC/HC	Birth weight (g)
25-26	5	4.90±0.7	0.22±0.02	838±249
27	7	5.25±0.3	0.22±0.01	1022±143
28	10	5.50±0.5	0.23±0.02	1064±193
29	6	5.70±0.4	0.23±0.02	1159±132
30	8	6.00±0.7	0.23±0.02	1307±159
31	6	6.40±1.0	0.23±0.03	1399±308
32	14	7.00±0.5	0.24±0.02	1658±231
33	12	7.00±0.8	0.24±0.02	1750±281
34	6	8.30±0.5	0.27±0.01	2291±348
35	12	8.10±0.6	0.26±0.01	2299±308
36	12	8.30±0.6	0.26±0.02	2364±329
37	6	9.5±0.7	0.28±0.02	2901±194
38	22	9.50±0.7	0.28±0.01	3054±348
39	22	9.70±0.9	0.28±0.02	3076±398
40	36	10.10±0.6	0.29±0.02	3261±311
41	11	10.20±0.6	0.29±0.02	3447±337
42	5	10.60±0.5	0.30±0.01	3383±186

Mid-arm Circumference measurement, MAC to HC ratio and Birth weight of infant of 25-42 weeks of gestational age expressed in Mean±- SD

$$BMI = Weight\ (kg)/Length\ (m)^2$$

- BMI was plotted on BMI charts for different gestational age available for female and male child separately. BMI less than 10th centile was considered abnormal (Fig. 8 and 9)[19]

Maternal risk factors: Mother's age, parity, birth spacing, Body Mass Index, history of pregnancy induce hypertension (PIH), thyroid disorder, anemia, socio economic status were recorded. Modified Kuppuswamy Scale was used to determine the socioeconomic class of the family, It takes into account educational status of the head of the family, occupation of the head of the family and monthly family income in rupees. Maternal infection were also recorded which include history of urinary tract infection (UTI), TORCH infection, chorioamnionitis during pregnancy, raised wbc counts (>15000) and fever during last trimester (Table 2).

Statistical analysis: All data compiled in Microsoft Excel and the data analysis was performed using softwares IBM SPSS ver. 20 and MED CALC 19.5.

Table 2: Socio economic class of family as per modified kuppuswamy scale

Score	Socioeconomic class
26-29	Upper (I)
16-25	Upper middle (II)
11-15	Lower middle (III)
5-10	Upper lower (IV)
<5	Lower (V)

Frequency distribution and cross tabulation were used to prepare the tables. Quantitative data is expressed as mean and standard deviation whereas categorical data is expressed as number and percentage. Means were compared using One Way Anova test. Percentage and numbers were compared using Chi square test and level of significance was considered at 5%.

Figure 10 shows Gestational age (GA) assessment by new Ballard scoring system.

Table 3: Distribution of babies according to gender

Gender	Frequency	Percentage
Male	217	52.80
Female	194	47.20
Grand total	411	100.00

Fig. 7: Measurement of mid arm circumference

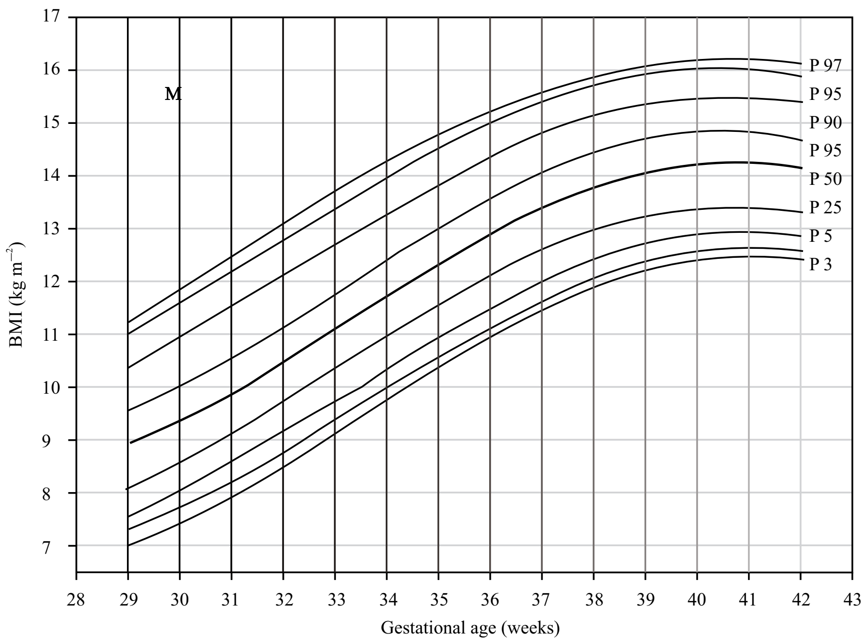


Fig. 8: BMI for gestational age male newborn

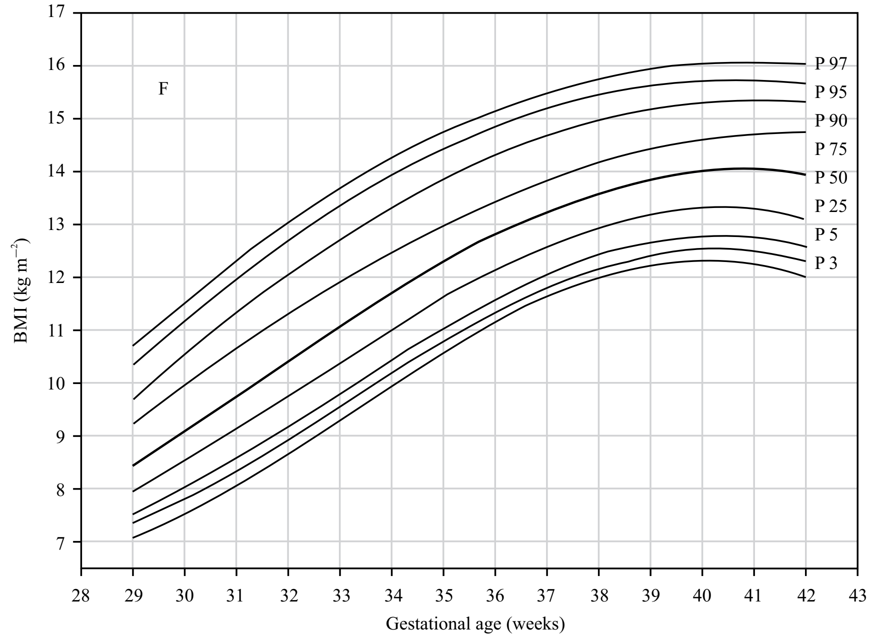
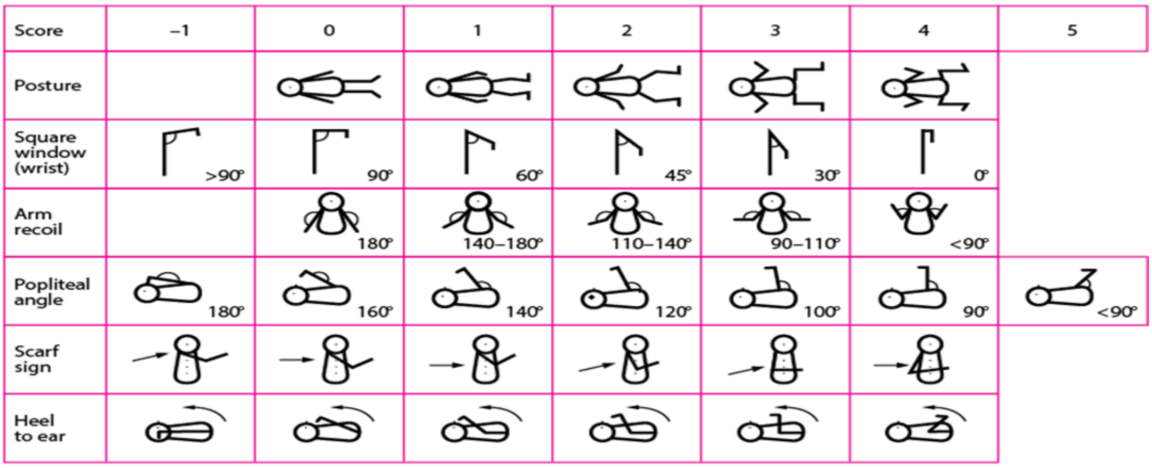


Fig. 9: BMI for gestational age in female new born

Neuromuscular Maturity



Physical Maturity

Skin	Sticky, friable, transparent	Gelatinous, red, translucent	Smooth, pink; visible veins	Superficial peeling and/or rash; few veins	Cracking, pale areas; rare veins	Parchment, deep cracking; no vessels	Leathery, cracked, wrinkled
Lanugo	None	Sparse	Abundant	Thinning	Bald areas	Mostly bald	
Plantar surface	Heel-toe 40–50 mm: –1 < 40 mm: –2	> 50 mm, no crease	Faint red marks	Anterior transverse crease only	Creases anterior 2/3	Creases over entire sole	
Breast	Imperceptible	Barely perceptible	Flat areola, no bud	Stippled areola, 1–2 mm bud	Raised areola, 3–4 mm bud	Full areola, 5–10 mm bud	
Eye/Ear	Lids fused loosely: –1 tightly: –2	Lids open; pinna flat; stays folded	Slightly curved pinna; soft; slow recoil	Well curved pinna; soft but ready recoil	Formed and firm, instant recoil	Thick cartilage, ear stiff	
Genitals (male)	Scrotum flat, smooth	Scrotum empty, faint rugae	Testes in upper canal, rare rugae	Testes descending, few rugae	Testes down, good rugae	Testes pendulous, deep rugae	
Genitals (female)	Clitoris prominent, labia flat	Clitoris prominent, small labia minora	Clitoris prominent, enlarging minora	Majora and minora equally prominent	Majora large, minora small	Majora cover clitoris and minora	

Maturity Rating

Score	Weeks
–10	20
–5	22
0	24
5	26
10	28
15	30
20	32
25	34
30	36
35	38
40	40
45	42
50	44

Fig. 10: new ballard score for gestational age assessment

Table 4: Anthropometric indicators of growth in study cohort (n = 411)

Variable	Mean	SD
Weight (g)	2774.25	405.78
Length (cm)	47.54	1.64
Head circumference (cm)	33.25	1.12
Chest Circumference (cm)	30.95	1.36
MAC (cm)	9.51	0.70
Kanawati Index (MAC/HC)	0.28	0.016
PI (g cm^{-3})	2.56	0.29
BMI (kg m^{-2})	12.20	1.40
CAN score	26.94	2.31

Table 5: Distribution of babies into well-nourished and malnourished groups based on different parameters

Parameters	No of patients	Percentage
CAN score		
<25	76	18.5
≥25	335	81.5
Total	411	100
MAC/HC		
<0.25	23	5.6
≥ 0.25	388	94.4
Total	411	100
Ponderal index		
<2.2	56	13.6
≥2.2	355	86.4
Total	411	100
Weight for GA		
<10th centile	36	8.8
≥ 10th centile	375	91.2
Total	411	100
BMI		
< 10th centile	210	51.09
≥10th centile	201	48.91
Length for GA		
<10th centile	16	3.90
≥10th centile	395	96.1
Total	411	100

Table 6: Comparison of Mean±SD of anthropometric data of babies with and without FM

	CAN score		
Parameters	With FM (<25)	Without FM (≥25)	p-value
Birth Weight (gm.)	2325.53±274.40	2870.90±358.46	<0.001
Length (cm)	46.29±1.85	47.85±1.46	<0.001
Head Circumference (cm)	32.04±1.04	33.50±0.98	<0.001
Chest Circumference (cm)	29.76±1.47	31.24±1.18	<0.001
MAC (cm)	8.89±0.56	9.67±0.57	<0.001

Fetal malnutrition (FM) is a clinical state defined by intra uterine loss or failure to acquire normal amount of subcutaneous fat and muscle mass and is independent of birth weight and gestational age. During the study period of one and half year from 1st December 2018 to 31st may 2020 we have enrolled 411 full term new born babies and nutrition status of each new born is assessed at 24-48 hrs of life by using CAN Score and other anthropometric parameters. Table 3 shows distribution according to gender. Mean (SD) of weight, length, head circumference, chest circumference and mid arm circumference (MAC) and proportionality indices like BMI (weight in kg/ length in m^2, PI (weight in grams/ length in cm^3×100) and Kanawati Index (MAC/HC) are calculated (Table 3).

Table 4 shows the distribution according to gender. Male to female child ratio was 1.12: 1 in present study.

Table 12: Comparing maternal risk factors in babies with and without FM

Maternal risk factors	With FM (CAN score <25)	Without FM (CAN score ≥25)	p-value
Birth spacing (years)			
< 3	27	108	0.090
≥3	14	103	
Primi	35	124	
BMI of mother			
< 18.5	0 2	0.164	
18.5-25	40	131	
25-30	28	163	
>30	8 39		
PIH			
Absent	41	299	<0.001
Present	35	36	
Hypothyroid			
Absent	60	264	0.978
Present	16	71	
Socio-economic status			
Upper	0 10	0.003	
Upper middle	9 95		
Lower middle	50	193	
Upper lower	16	36	
Lower	1 1		
Anemia			
Absent	57	305	0.001
Mild	10	15	
Moderate	8 14		
Severe	1 1		
Maternal infection			
Absent	26	259	<0.001
Present	50	76	

Table 5 shows the characteristic of study cohort. Mean weight, length, head circumference, chest circumference, MAC, MAC/HC, PI, BMI and CAN Score is 2774.25 g, 47.54 cm, 33.25 cm, 30.95 cm, 9.51 cm, 0.28, 2.56 g cm^{-3}, 12.20 kg m^{-2} and 26.94, respectively.

The distribution of babies into well-nourished and malnourished groups using cut-offs of various parameters (Fig. 11). It shows that most commonly used anthropometric parameter, weight for gestational age identified 36 (8.8%) babies as malnourished, while BMI cutoff (<10th centile) could identify 210 (51.09%) babies as malnourished. CAN score (<25) used as gold standard in present study could identify 76 (18.5%) babies as malnourished (Table 6).

In present study nutritional status of new born is assessed by CAN score and compared with selected anthropometric parameters. Comparison of Mean±SD of anthropometric data of babies done with and without FM (as by CAN score cutoff of <25 as gold standard). It was found that birth weight, length, HC, CC and MAC all were significantly lower in those with FM as compared to those without FM Table 7 (p<0.001).

In present study maternal risk factors were identified in each new born baby and compared in babies with and without FM. We found significant association between presence of PIH, anemia, infection and poor socioeconomic status of mother with FM. Whereas risk factors such as birth spacing (year), BMI of mother and hypothyroidism has got no association with FM (Table 8, Fig. 13-17).

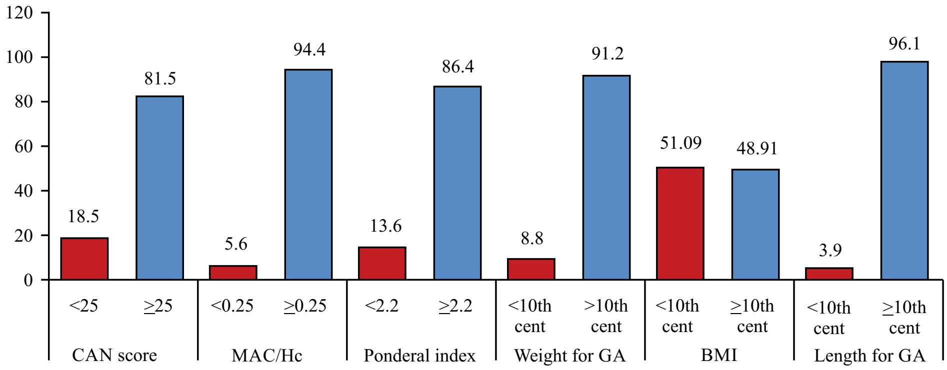


Fig. 11: Distribution of babies into well-nourished and malnourished groups using cut-offs of various parameters

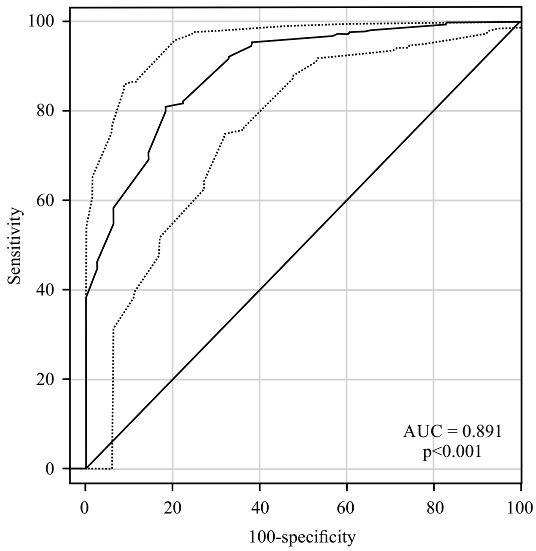


Fig. 12: AUC for the birth weight for determining FM (0.891 with p-value of <0.001)

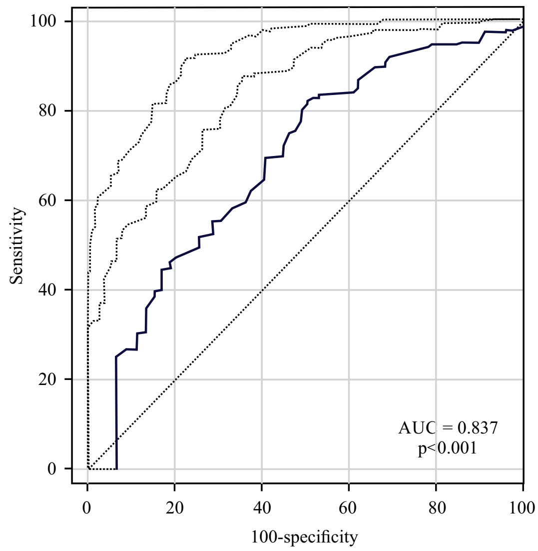


Fig. 14 AUC curve for BMI for determining FM (0.837 with p-value of <0.001)

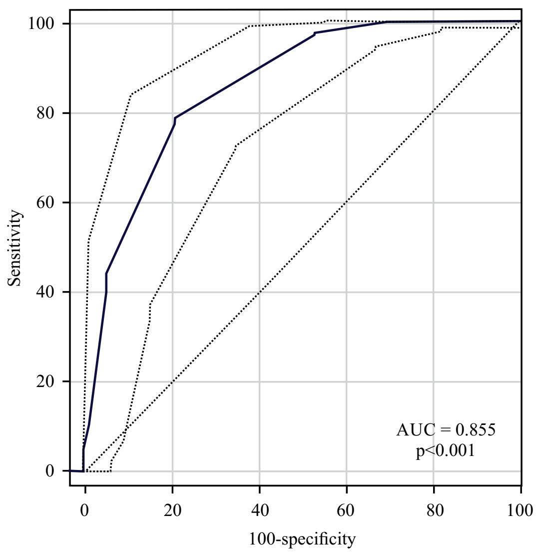


Fig. 13: AUC for MAC for determing FM (0.855 with p-value of<0.001)

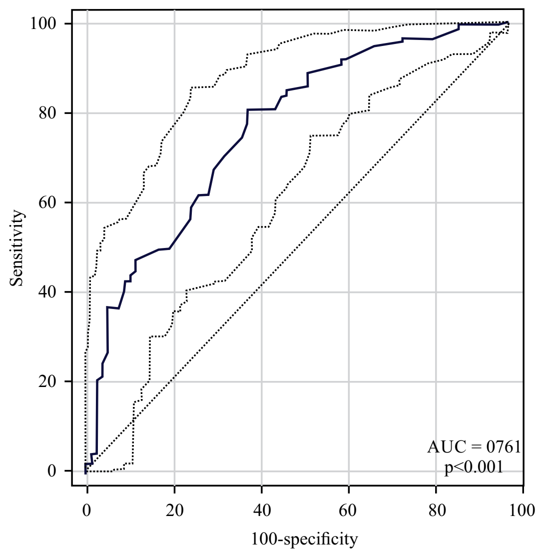


Fig. 15: AUC curve for PI in determing FM (0.761 with p-value of <0.001)

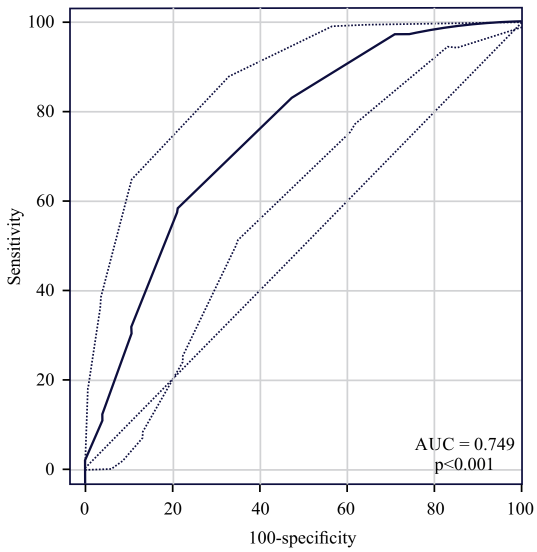


Fig. 16: AUC cure for length for GA in determining FM (0.749 with p-value of <0.001)

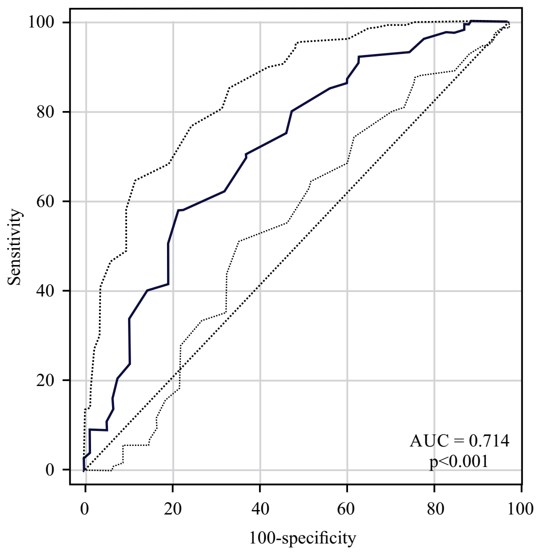


Fig. 17: AUC curve for MAC/HC for determining FM (0.714 with p-value of <0.001)

Table 13: AUC curve for various parameters with 95% confidence interval

Variable	AUC	Std. error (SE)	95% confidence
Interval (CI)			
CAN score	1.000	0.000	1.000-1.000
Birth weight	0.891	0.020	0.853-0.930
MAC	0.855	0.026	0.805-0.905
BMI	0.837	0.024	0.785-0.880
PI	0.761	0.031	0.701-0.822
Length	0.749	0.033	0.684-0.814
MAC/HC	0.714	0.033	0.702-0.831

DISCUSSION

Present study is aimed to assess the nutritional status of new born using CAN score and compare it with other selected anthropometric indices. It concludes that the CAN score can identify FM with greater efficacy and can detect FM in babies who are missed by other commonly used methods of nutritional assessment.

In a study by Deodhar et al FM was identified in 19.6% babies using CAN score cutoff of < 25; out of this, 84.2% babies were SGA and 12.9% babies were AGA as per weight for gestational age criteria[10]. Kashyap and Dwivedi[20] observed that CAN score identified FM in 27.4% babies and among these babies, 8.3% were classified as AGA by weight for gestational age criteria. Also, 11.35% babies who were classified as well nourished by PI (>2.2 g cm^{-3}) were found to be malnourished by CAN score. Similar results were obtained by many investigators[3,14,15,16]. Similarly, in present study CAN score identified FM in 18.5% babies whereas weight for GA criteria identified 8.8% babies as SGA and 91.2% as AGA; 12.3% babies who were identified as AGA, were found to be malnourished by CAN score.

The study also concluded that FM is best identified by CAN Score, BMI is best screening tool for FM and when coupled with PI will identify most normally nourished newborns[21]. Present study observed 18.5% babies to be malnourished by using CAN score and 13.6% by PI which is less than observed by Abhay (32.29 and 24.48% respectively).

To classify nutritional status of new born, PI has been used by various investigators[22]. PI relies on the principle that length is spared at the expense of weight during period of acute conditions; whereas, weight and length velocities are proportionately impaired in chronic insults. Therefore, using PI alone as a method of nutritional assessment can misclassify the babies. The other drawback of PI is that any error in calculating length is cubed in the calculation of PI[23].

Many cities now have multi-ethnic population and application of weight standard alone may be inappropriate in studying nutritional status. To overcome this problem, many investigators Meadows *et al.*[4] and Mohan *et al*.[24] studied MAC/HC ratio in identifying nutritional status and concluded that this ratio shows no intra ethnic variation and can be used as screening test for identifying babies whose growth is retarded, even when their weight does not fall below 10th centile. However, in chronic in-utero insult, head circumference is also reduced because of proportionate growth retardation; therefore such babies are missed by MAC/HC ratio. Similarly, babies with hydrocephalus may give falsely low reading even when they are normally nourished. CAN score can identify FM in these babies too who are missed by PI and MAC/HC ratio[4,24].

In a study by Ezenwa *et al*.[14] the nutritional status of full term new born baby was done using CAN score and compared it with PI, BMI and MAC/HC. FM was identified in 14.5, 10.3, 13.1 and 2.8% of babies using CAN score, PI, BMI and MAC/HC ratio respectively. Out of FM babies identified by CAN score, PI, MAC/HC and BMI identified FM in 19.5, 12.3 and 53.7% babies respectively which shows that BMI was most sensitive anthropometric index for detecting FM. In present study CAN score identified FM in 18.5% babies whereas MAC/HC, PI, weight for gestational age, BMI and length for gestational age identified FM in 5.6, 13.6, 8.8, 51.09 and 4.4% newborn babies respectively. Out of FM identified by CAN score, MAC/HC, PI, weight for gestational age, length for gestational age and BMI identified FM in 16.2, 38.2, 39.2, 15.8 and 89.5% new born babies respectively . Thus, present study also shows that BMI has maximum sensitivity in identifying FM.

In present study we assessed the FM by preparing Receiver Operating Characteristic curve (ROC curve) and Area Under Curve (AUC). The ROC-AUC analysis showed that AUC for birth weight, MAC, BMI, PI, length and MAC/HC for determining FM was 0.891, 0.855, 0.837, 0.761, 0.749 and 0.714, respectively with a p-value of <0.001. AUC was highest for birth weight followed by MAC and BMI. This highlight that all these three parameters have higher sensitivity in determining FM (p-value <0.001). similarly a study done by Sen observed that AUC for birth weight (0.796, 95% CI 0.741-0.850) followed by MAC (AUC 0.776, 95% CI 0.721-0.831) can be considered to be the best surrogate anthropometric measures of low birth weight. However, they have not used the CAN score as a measure of FM in their study. This highlights that birth weight and BMI are strongly associated with FM, however if coupled with CAN score can provide better assessment for FM.

In a study done by Ajay, assessment of nutritional status of new born was done using CAN score cutoff of <25 as well as <21along with other anthropometric parameters. In this study more number of babies were clustered between 21 and 24, so they have taken modified CAN score cutoff as < 21[25]. On the contrary, in present study.

large number of babies were clustered between 27 to 29 CAN score, so we selected <27 as modified cutoff score. The explanation behind considering this modified cutoff is that in a community large proportion of babies cannot be called as abnormal. In present study, on using modified CAN score cutoff <27, the percentage of FM went up from 18.5-32.11%. This signifies that when we are using modified CAN score cutoff of <27, we are able to detect more malnourished newborn than using cutoff of <25.

In present study, maternal infections were found to have significant association with FM. Similar association was also seen in studies done by other investigators. Sasanow *et al*.[26] They observed that HIV, malaria, periapical infection, urinary tract infection, vaginal trichomoniasis, placental malaria and severe chorio-amnionitis all can affect the fetal growth.

Maternal infection leads to loss of appetite, nausea and vomiting which further decrease mother's dietary intake. Maternal infections can also elicit a systemic inflammation that can restrict foetal growth through reduction in placental vascularization and diminished nutrient or oxygen transfer to fetus.

In addition, systemic inflammation has shown to alter a hormonal pathway that drives the elongation of long bones in human fetus and children. In normal pregnancy, fetal growth is largely driven by peptide harmones called insulin like growth factors (IGFs) that are secreted by maternal tissues, placenta and fetus[27]. Both maternal infection and placental infection can be associated with down regulation of IGF expression in the placenta, low IGF concentrations in maternal, amniotic cord and newborn plasma and higher concentrations of specific binding proteins that inactivate IGFs in fetal circulation[28-30].

Present study found PIH to be significantly associated with FM. Patho physiologic mechanism of vasospasm and decreased intravascular volume may play an important role in fetal growth and explain increased incidence of intra uterine growth restriction. However, all prior studies on PIH and its impact on fetal growth have failed to control for confounding factors like parity, smoking and multiple gestation associated with PIH and therefore the direct impact of PIH as an independent variable on fetal growth has been difficult to determine.

Present study observed that anemia in mother has significant association with FM, which has been observed by other researchers also. Anemia in pregnancy has a recognizable association with fetal outcome. Increased incidence of low birth weight babies is seen if the mother is anemic in her third trimester only. Increased incidence of preterm deliveries is seen if the mother is anemic in her second and third trimesters. Supplementing iron earlier and maintaining optimal Hb (10-12 g dL^{-1}) throughout gestation has better overall outcome regarding premature deliveries and low birth weight babies.

Socio-economic status affects maternal as well as fetal nutrition. Poor socio- economic status is associated with poor nutritional status of mother, pregnancy at younger age and short inter pregnancy interval which leads to FM. Present study also observed the same outcome and maximum number of FM cases were from lower middle and upper lower class. Similar association was seen in previous studies also.

Limitations of the study: Being a hospital based and single centered study, it is difficult to extrapolate the results found in large community. In present study, observations were done by single observer only. Therefore, inter-observer variations could not be calculated.

Strength of the study: 1) Sufficiently large sample size that includes neonates belonging to all socio- economic strata was the main strength of this study.

Implication of study: Malnourished neonates missed by most commonly used parameter i.e. Weight for GA (>10th centile) can be detected by CAN score as malnourished. Proper nutritional counselling of mother and long term follow up of these babies can prevent neuro- developmental adverse outcomes of these babies.

Fetal malnutrition (FM) is a clinical state characterized by intrauterine loss of or failure to acquire normal amount of fat and muscle mass. The term was coined by Scott and Usher in 1963.

It is important to recognize FM in babies because of high incidence of neonatal morbidity and mortality and long term neurological sequelae associated with it. Existing terminologies for describing intra uterine malnutrition includes, small for gestational age (SGA), intra uterine growth restriction (IUGR) and placental insufficiency. None of these terminologies are synonymous with FM as they do not assess the accumulated subcutaneous fat and muscle mass in the fetal body. Also, they do not take account of genetic and ethnic variations amongst different populations.

Present study is designed to identify the nutritional status by clinical assessment of newborn using CAN score and compare it with selected other anthropometric indices. It was a cross sectional, observational and analytical study and included all full term new born babies (gestational age assessed by Modified Ballard score system) delivered at People's Hospital from 1st December 2018 to 31st may,2020, which is a allied hospital of Peoples College of Medical Sciences and Research Centre Bhopal, a tertiary referral centre getting patients from all socio-economic groups. New born less than 37 completed weeks gestation, congenital anamolies and babies born to mother with gestational Diabetes mellitus (Infant of diabetic mother) were excluded from study. The study was done in the department of Pediatrics of People's College of Medical Sciences and Research centre, Bhopal after obtaining clearance from was Research Advisory Committee and Institutional ethical committee. Exhaustive literature review was conducted to get important and relevant informations concerning fetal malnutrition and its clinical assessment using CAN score and other anthropometric methods for appropriate study design development and implementation.

Data was collected within 24-48 hrs of life of newborn (n = 411) after obtaining written consent from parents. Birth weight was recorded using digital electronic weighing machine, length was measured using infantometer, Head circumference, chest circumference and mid arm circumference was measured using non stretchable measuring tape. Proportionality indices like Kanawati Index (MAC/HC), PI and BMI was calculated for each new born baby and clinical assessment of new born using CAN score (based on superficial physical findings) was done for each newborn. Data was compiled using Microsoft Excel and analyzed using softwares SPSS® Version 20 and MED CALC 19.5.

The results can be summarized under following points:

- The mean value of weight, length, head circumference, chest circumference, MAC, MAC/HC, PI, BMI and CAN Score in subjects included in present study was 2774.25 g, 47.54 cm, 33.25 cm, 30.95 cm, 9.51 cm, 0.28, 2.56 g cm^{-3}, 12.20 kg m^{-2} and 26.94, respectively
- Male to female ratio was 1.12: 1
- Fetal malnutrition (FM) was found in 18.5% babies as assessed by the CAN score of <25
- Out of 411 babies, 76 (18.5%) were with FM (CAN score <25), 23 (5.6%) had MAC/HC ratio <0.25, 56 (13.6%) had Ponderal Index of <2.2, weight for GA was <10th centile in 36 (8.8%) and BMI was <10th centile in 51.09% babies
- Weight for GA (p<0.001), MAC/HC (p<0.001), PI (p<0.001), BMI (p<0.001) and length for GA (p<0.001) all were found to have significant association in predicting the fetal malnutrition when CAN score of <25 was taken as the cut off value
- Mean value of all anthropometric parameters i.e. birth weight, length, head circumference, chest circumference and mid arm circumference was significantly lower in those with FM as compared to those without FM (p<0.001)
- Maternal risk factors such as PIH, aneamia, maternal infection and poor socioeconomic status have significant association with FM, whereas birth spacing (year), BMI of mother and hypothyroidism were not significantly associated with the presence of FM
- In present study, more babies are clustered between CAN score of 27 to 29. Therefore we took modified CAN score cutoff of <27 and calculated its association with other anthropometric parameters
- When modified CAN score cutoff of <27 was considered, 132 (32.1%) babies were found to be malnourished as compared to 76 (18.5%) babies

with CAN score cutoff of < 25. Also there is strong strength of association (p-value < 0.001) between modified CAN score cutoff of <27 and variables like weight for GA, PI, BMI and MAC/HC

- With modified CAN score cutoff of <27, percentage of FM among AGA babies goes up from 12.26% to 26.66%
- The area under the curve (AUC) for the birth weight (0.891), MAC (0.855), BMI (0.837), PI (0.761), length (0.749) and MUAC/HC (0.714) with p-value of <0.001 was observed. AUC was highest for birth weight followed by MAC and BMI. This highlight that all these three parameters have good sensitivity and specificity for identifying FM (p<0.001)

CONCLUSIONS

Fetal malnutrition (FM) is a major problem in developing countries like India as compared to developed countries. FM is a clinical state defined by intrauterine loss or failure to acquire normal amount of subcutaneous fat and muscle mass and is independent of birth weight and gestational age. Previous studies have shown that commonly used method of classifying babies on basis of weight for GA as SGA, AGA and LGA may miss to diagnose FM in some of the cases who are affected late in third trimester. Various methods are used for assessment of nutritional status of new born but each method has its own limitations.

Based on the findings of present study it was found that CAN Score is a simple and systematic method to identify FM over and above those babies identified by commonly used anthropometric parameters like weight for GA, length for GA, MAC/HC, BMI and PI.

CAN score is a simple method which does not require any sophisticated equipment or time-consuming calculations. Hence, CAN score can be used as an ideal method for screening malnourished babies in our community.

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