Relationship between Ponderal Index, Mid-Arm Circumference/ Head Circumference Ratio and Clinical Assessment of Nutritional Status Score (CANSCORE) in the Determination of Nutritional Status of Newborn at Birth in Nigeria

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Abstract: *Background*: Early and accurate assessment of the nutritional status of newborns is important to many clinicians because of the potential immediate and late sequelae of malnutrition.

Objective: To assess the relationship between different methods of assessing the nutritional status of neonates.

Methods: Subjects were consecutive, live, singleton, full term neonates delivered in the hospital. The birth weights, Ponderal index, Mid arm circumference/head circumference ratio, birth weight for gestational age using intrauterine growth charts and Clinical Assessment of Fetal Nutritional Status Score (CANSCORE) were used to determine the nutritional status in the first 24 hours of life.

Results: Of 386 subjects, 172 (44.6%) were males and 214 (55.4%) females. Nutritional status assessment using various indices showed the following prevalence of malnutrition: using birth weights, 54 (14.0%) were LBW; MAC/HC ratio showed 56 (14.5%), with PI, 64(16.6%), weight for gestational age,112(29.0%) were SGA and CANSCORE showed 90(23.3%) as malnourished among the babies.MAC/HC showed a better specificity and had a more positive correlation than PI when compared to CANSCORE whilst PI showed a better sensitivity than MAC/HC when evaluated against CANSCORE.

Conclusions: Prevalence of FM is high in this study. Intrauterine growth charts and CANSCORE appeared to identify more babies with FM than other methods. CANSCORE in this study has revealed the rising trend in the prevalence of FM when compared with other studies with similar methodology. Early routine assessment of the nutritional status of newborns should be carried out so as to reduce the risk of increased morbidity and mortality associated with fetal malnutrition.

Keywords: Ponderal index, Mid-arm circumference/head circumference ratio, CANSCORE, Nigeria.

INTRODUCTION

Various methods have been used in attempts to determine the nutritional status of the newborn and thus identify malnourished newborns early [1]. An early and accurate assessment of the nutritional status of the newborn is important to many clinicians because of the potential immediate transition challenges and serious late effects of malnutrition on multiple organ systems. It is only by actively undertaking regular nutritional assessment that features of malnutrition can be identified, appropriately diagnosed and addressed in every baby at risk [2]. This anticipatory management of such infants at birth may decrease morbidity and improve the survival of such infants. Perinatal problems and/or long term central nervous system sequelae are known to occur primarily in babies with fetal malnutrition (FM) whether appropriate for gestational age (AGA) or small for gestational age (SGA) but less so among those who are SGA but without fetal malnutrition [3, 4]. There is thus a need for prompt identification of babies with features of malnutrition.

Various methods have been used to identify malnourished fetuses as early as possible. There is no consensus among experts with regard to the best method to be adopted based on the reliability, reproducibility, sensitivity, specificity and the ease of performing assessment of the nutritional status of the babies at birth [3]. Methods of assessing the nutritional status at birth include: birth weight, weight for gestational age assessment (using standard intrauterine growth charts) to classify newborn into: small for gestational (SGA), when the birth weight falls below the 10th percentile of the weight for the gestational age for that population), appropriate for gestational age (AGA), when the birth weight falls between 10th and 90th percentile of the weight for the gestational age for that population), and large for gestational age (LGA) when the birth weight falls above

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the 90th percentile of the weight for the gestational age for that population [5]. Others are mid-arm circumference to head circumference ratio (MAC/HC), the Rohrer's ponderal index (PI) [6], and may be recently the clinical assessment of nutritional status (CANS) and the score (CANSCORE) [1, 3]. CANSCORE is occurring more frequently in literatures and reviews of recent studies as relatively more acceptable method of determining fetal wasting because it is a purely clinical assessment like Ballard or Dubowitz assessment of gestational age scores [1, 3, 4]. It identifies babies with wasting whether small, appropriate or large for gestational age (SGA, AGA or LGA). The ratio of the MAC to HC had been shown to be a reliable index of intrauterine growth in Nigerian newborns [7] and by inference could be used to diagnose wasting at birth. Some authors [1, 8] have suggested that there is no single parameter to accurately differentiate between normal and malnourished newborns. For example with growth charts, many babies with fetal malnutrition may be missed using this method alone since the growth charts are pre- determined and accounts only for those babies whose weights fall below the tenth percentile [9]. Some have suggested that a combination of BMI and PI may be a good screening tool for detecting fetal malnutrition and that a normal BMI and/or normal PI is a good indicator of normal fetal nutrition in newborns instead of assessing nutritional status by CAN score which is time consuming [8]. The controversies rage on and on.

The main objective of the study was to identify malnutrition using various methods and determine the relationship between different methods of assessing the nutritional status of neonates.

MATERIALS AND METHODS

The subjects were consecutive, singleton, live-birth, term neonates delivered at the maternity unit of the Federal Teaching Hospital, Ido-Ekiti, Nigeria from August 2013 to January 2014. Babies with obvious congenital malformations, obvious features or stigmata of chromosomal anomalies and preterms were excluded from the study.

The gestational age (GA) of each baby in weeks was determined using mother's LMP or the earliest obstetrical ultrasound and the Dubowitz gestational age assessment chart which has been found to be reliable in Nigerian neonates [10]. When there was a discrepancy of more than two weeks between the Dubowitz score and the LMP, the Dubowitz score was used. Anthropometric measurements as well as the CANSCORE of the babies were also done within the first 24 hours of life. The CANSCORE was taken as the gold standard of nutritional assessment for this study.

Details of the methodology for each of the assessment methods are as below:

Birth Weight

Neonates were weighed nude at birth in kilograms to the nearest 10g using an electronic weighing scale. The accuracy of the scale was periodically checked and maintained using a set of standard weights as reference. Birth weight of less than 2500g was classified as Low birth weight, greater than or equal to 2500g but less than 4000g as normal birth weight and greater than or equal to 4000g as high birth weight (macrosomia). The birth weights were also plotted on a standard intrauterine growth chart [5] to obtain the percentile values and thus babies with values less than the 10th percentile were categorized as SGA, between 10th and 90th percentile as AGA and greater than 90th percentile as LGA [5].

Length

This was measured in centimeters to the nearest 0.1cm using the infantometer.

Head Circumference (HC)

This was measured in cm to the nearest 0.1cm using a standard non-stretchable cloth tape placed on the lower forehead just above the supraorbital ridges, passing round the head at the same level on each side and over the occiput posteriorly. The tape was then adjusted up and down to find the maximum reading after having been pulled very firmly to compress the hair.

Mid-Arm Circumference (MAC)

This was measured with a cloth tape at the midpoint between the acromium and olecranon of the left arm. The MAC was then measured while ensuring that the tape neither pinched the arm nor left loose [11]. The measurement was recorded in cm to the nearest 0.1cm.

Ponderal Index (PI)

This was calculated using the weight in grams x 100/[length (cm)^3]. A PI below 2.2g/cm^3 was taken to indicate malnutrition [12].

MAC/HC

This was computed from the measurements of the MAC and HC, and MAC/HC ratio below 0.27 was taken to indicate malnutrition [13].

Assessment of Nutritional Status Using CANSCORE

The nutritional status of each baby was also assessed within 24 hours of life by one of us (BOB) using the Clinical assessment of nutritional status (CANS) and the score (CANSCORE) adapted by Metcoff [3]. The CANSCORE consists of nine “superficial” readily detectable signs of fetal malnutrition. This was based on inspection and hands-on estimates of loss of subcutaneous tissue and muscles. The Hair, Cheeks, Neck and Chin, Arms, Back, Buttock, Legs, Chest and Abdomen were examined and then scored as described by Metcoff [3]. The range of score for each parameter varied between 1 and 4 with maximum score of 4 awarded to each parameter with no evidence of malnutrition and lowest score of 1 awarded to the parameter with the worst evidence of malnutrition. The total rating of the nine CANS signs is the CANSCORE for the subject. The CANSCORE ranges between 9 (lowest) and 36 (highest). Babies with CANSCORE of 25 and above were regarded as normal or having no FM [4]. Babies with CANSCORE below 25 were diagnosed as having FM. The score of 25 was used as the cut-off point based on earlier works done by Metcoff. Data entry and analysis were carried out with a personal computer using the software Statistical Package for Social Sciences (SPSS) for Windows version 17.0. The results from various methods of nutritional assessment were compared. Data were presented using pie chart, tables and scatter plots. Continuous variables were expressed as means and standard deviation (SD), median and mode. Categorical variables were expressed as proportions, ratios and percentages.

RESULTS

Babies, Gestational Ages and Birth Weights

A total of 386 babies delivered in the hospital during the study period who met the inclusion criteria formed the subjects of the present study. They consisted of 172 (44.6%) males and 214 (55.4%) females. The gestational age (GA) at delivery for the 386 babies ranged between 37 and 42 weeks with the mean (SD) of GA at delivery being 38.9 (1.4) weeks.

The birth weight for the 386 babies ranged between 1.50 and 4.90 kg and the mean (SD) birth weight was 3.01 (0.59) kg. The overall mean (SD) weight for the males was 3.14 (0.53) kg while the overall mean (SD) weight for the females was 2.90 (0.61) kg. The difference was statistically significant (p = 0.000). Fifty-four (14.0%) of the babies were of LBW (weight below 2.5kg); 321 (83.2%) were of normal weight and 11 (2.8%) babies had weights above 4kg.

Assessment of Nutritional Status Using Ponderal Index (PI)

Table **1** shows the comparison of the mean Ponderal index (PI) between males and females in relation to GA. The overall mean (SD) value was 2.72 (0.52) g/cm^3 which was within normal (2.20-2.85g/cm^3)across all the gestational ages in both sexes. The mean PI of females was higher than that of the males but not at a statistical significant level (p = 0.695). Using a cut-off PI value of 2.20g/cm^3 for malnutrition, 64 (16.6%) of the 386 babies fulfilled the criteria for the diagnosis of malnutrition. Thirty-two were

Table 1: Comparison of Mean PI between the Two Sexes in Relation to Gestational Age

Males			Females	
Gestational Age (weeks)	N	Mean (SD) PI (g/cm^3)	N	Mean PI (SD) (g/cm^3)
37	23	2.66 (0.44)	52	2.72 (0.45)
38	42	2.75 (0.42)	61	2.72 (0.45)
39	35	2.70 (0.43)	35	2.77 (0.69)
40	42	2.60 (0.44)	33	2.72 (0.78)
41	25	2.81 (0.37)	27	2.90 (0.43)
42	5	2.88 (0.22)	6	2.77 (0.04)
Total	172	2.71 (0.42)	214	2.73 (0.58)

t = 0.39, p = 0.695.

Table 2: Comparison of Mean MAC/HC Ratios between the Two Sexes in Relation to GA

	Males		Females	
Gestational Age (Weeks)	N	MAC/HC (SD)	N	MAC/HC (SD)
37	23	0.31 (0.03)	52	0.29 (0.03)
38	42	0.32 (0.03)	61	0.30 (0.03)
39	35	0.31 (0.03)	35	0.30 (0.03)
40	42	0.31 (0.02)	33	0.30 (0.03)
41	25	0.30 (0.27)	27	0.31 (0.02)
42	5	0.32 (0.01)	6	0.32 (0.02)
Total	172	0.31 (0.03)	214	0.30 (0.03)

$t = 3.26$, $p = 0.001$.

(18.6%) males and 32 (14.6%) females giving a male to female ratio of 1: 1 though there was a higher prevalence of malnutrition in males than in females. This difference was however not statistically significant (p = 0. 338).

Assessment of Nutritional Status Using MAC/HC Ratio

Table **2** shows the distribution of the mean MAC/HC value in males and females in relation to GA. The MAC/HC ratios ranged between 0.21 and 0.37. The overall mean (SD) of the MAC/HC ratio was 0.31 (0.03). The mean MAC/HC ratio were within the normal range (0.27 - 0.33) across all the gestational ages for both sexes. The mean MAC/HC ratio was however significantly higher in males than females ($t = 3.26$, $p = 0.001$).

Using a cut-off value of 0.27 for malnutrition, 56 (14.5%) of the 386 babies studied met the criteria for malnutrition. Twenty (35.7%) of the 56 babies were males while 36 (64.3%) were females giving a male to female ratio of 1:1.8. Twenty (11.6%) of the 172 males and 36 (16.8%) of the 214 females had malnutrition. Thus, a higher proportion of the females than males had malnutrition using the MAC/HC ratio but the difference was not statistically significant ($\chi^2 = 2.07$, df = 1, $p = 0.150$).

Assessment of Babies Nutritional Status in Relation to Weight for Gestational Age

Table **3** shows the distribution of babies in relation to weight for gestation using Lubchenco's standards of intrauterine growth.[9] One hundred and twelve babies were SGA giving an overall prevalence of SGA as 29.0%, 263 (68.1%) babies were AGA and 11 (2.9%) babies were LGA. There was no statistically significant difference on the prevalence of SGA at different gestational ages.

Assessment of Nutritional Status Using Clinical Assessment of Nutritional Status and the Score (CANSCORE)

The CANSCORE of the babies ranged between 15 and 35. Ninety (23.3%) of the 386 babies had

Table 3: Distribution of the 386 Babies into SGA, AGA, and LGA in Relation to GA

Gestational Age (Weeks)	*SGA N (%) #	*AGA N (%)#	*LGA N (%)#	Total N (%)+
37	25 (33.3)	47 (62.7)	3 (4.0)	75 (19.4)
38	31 (30.1)	69 (67.0)	3 (2.9)	103 (26.7)
39	19 (27.1)	46 (65.7)	5 (7.1)	70 (18.2)
40	22 (29.3)	53 (70.7)	0 (0.0)	75 (19.4)
41	15 (28.8)	37 (71.2)	0 (0.0)	52 (13.5)
42	0 (0.0)	11 (100.0)	0 (0.0)	11 (2.8)
Total	112 (29.0)	263 (68.1)	11 (2.9)	386 (100.0)

$\chi^2 = 14.8$, df = 10, $p = 0.1$.
#Figures in parenthesis are percentages of total in each row.
+Figures in parenthesis are percentages of total in each column.

Table 4: Prevalence of FM Using CANSCORE in Relation to GA in the Two Sexes

	Males (n = 172)		Females (n = 214)	
Gestational Age (Weeks)	Total	Babies with FM n (%)*	Total	Babies with FM n (%)*
37	23	6 (26.1)	52	14 (25.9)
38	42	5 (11.9)	61	16 (26.2)
39	35	5 (14.3)	35	10 (28.6)
40	42	8 (19.0)	33	9 (27.3)
41	25	12 (48.0)	27	5 (18.5)
42	5	0 (0.00)	6	0 (0.00)
Total	172	36 (20.9)	214	54 (25.2)

*Figures in the parenthesis are percentages of babies with malnutrition in each group.

CANSCORE less than 25 and were diagnosed as having FM. The 90 babies consisted of 36 (40.0%) males and 54 (60.0%) females giving a male: female ratio of 1:1.5; thus, 36 (20.9%) of the 172 males and 54 (25.2%) of the 214 females had FM. Although a higher proportion of females compared to males had FM, the difference was not statistically significant (χ^2 = 0.99, df = 1, p = 0. 320). Table **4** shows the distribution of FM in relation to gestational age and gender. There was an overall statistically significant difference in the distribution of the prevalence of FM at different gestational ages (χ^2 = 10.39, df = 4, p = 0.034).

Comparison between Fetal Malnutrition Detected by CANSCORE and PI

Figure **1** shows the scatter plots of PI against CANSCORE with the line of best fit shown. There was a positive correlation coefficient (r) between CANSCORE and PI of 0.198 (p = 0.000). Newborns identified as malnourished by PI were also evaluated

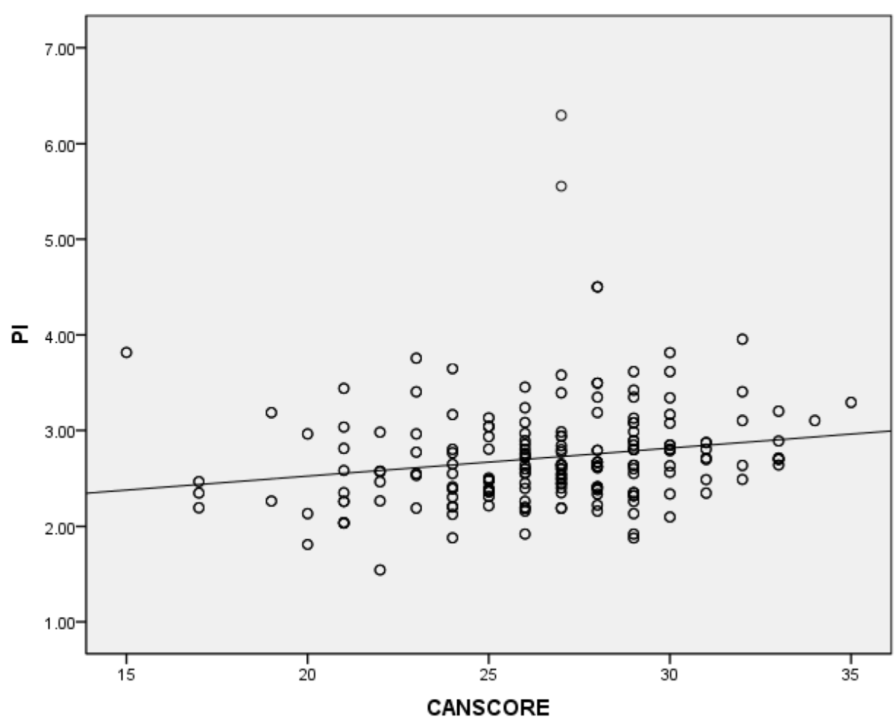

Figure 1: The scatter plots of PI against CANSCORE with line of best fit.

(r = 0.198, p = 0.000).

KEYS:

CANSCORE: Clinical assessment of nutritional status score.

PI: Ponderal index.

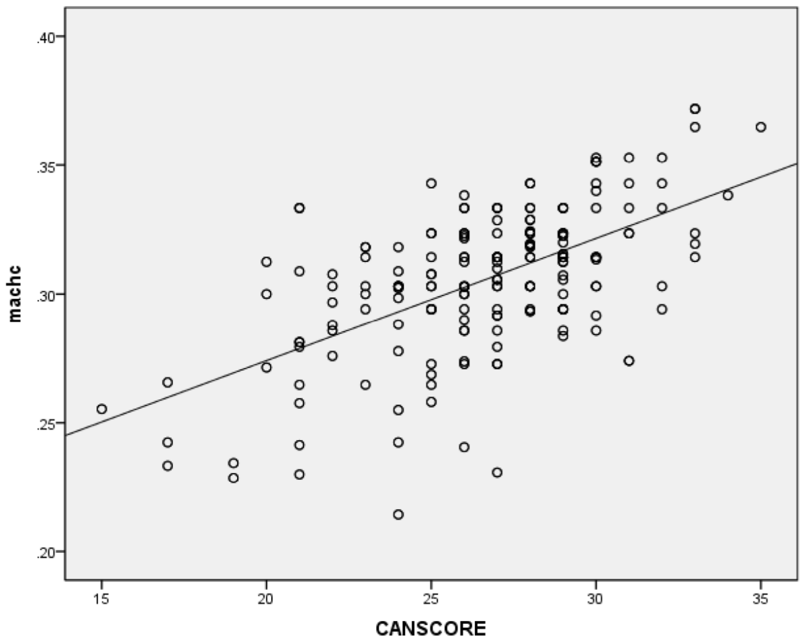

Figure 2: Scatter plot of MAC/HC against CANSCORE with line of best fit.
(r = 0.598, p = 0.000).

against CANSCORE. Sixteen (25.0%) of the 64 babies identified to be malnourished by PI were found to be well nourished by CANSCORE. Similarly, 42 (13.0%) of the 322 recognized as normal by PI were malnourished by CANSCORE. There was a statistically significant association between the number of babies identified as normal or malnourished by CANSCORE and PI (p = 0.000). Ponderal index showed a sensitivity and specificity of 53% and 95% respectively when evaluated against CANSCORE.

Comparison between Fetal Malnutrition Detected by CANSCORE and MAC/HC

Figure **2** shows the scatter plot of MAC/HC ratio against CANSCORE. Compared to PI, there was a more positive correlation coefficient of 0.589.

Newborns identified as malnourished by MAC/HC index were also evaluated against CANSCORE and 13 (23.2%) were found to be well nourished. Similarly, out of those recognized as normal by MAC/HC, 47 (12.1%) were malnourished by CANSCORE. There was a significant correlation (p = 0.000) between the number of babies identified to be malnourished or normal by CANSCORE and MAC/HC ratio. MAC/HC ratio showed a sensitivity and specificity of 48% and 96% respectively when evaluated against CANSCORE.

Comparison between Fetal Malnutrition Detected by CANSCORE and Weight for Gestational Age Chart (Standard Growth Chart)

Table **5** shows the distribution of babies with FM in relation to weight for gestational age. Sixty-two (68.9%)

Table 5: Distribution of FM in Relation to Weight for Gestational Age

Class of babies*	Babies with FM N (%)#	Babies without FM N (%)#	Total N (%)#
SGA	62 (68.9)	50 (16.9)	112 (29.0)
AGA	28 (31.1)	235 (79.4)	263 (68.1)
LGA	0 (0.0)	11 (3.7)	11 (2.9)
Total	90 (23.3)	296 (76.7)	386 (100.0)

χ^2 = 91.3, df = 2, p = 0.0001.
Keys:
*Using standard of intrauterine growth [14].
#Figures in parenthesis are percentages of total in each column.
SGA: Small for gestational age.
AGA: Appropriate for gestational age.
LGA: Large for gestational age.
FM: Fetal malnutrition.

of the 90 babies with FM were SGA while 28 (31.1%) were AGA. None of the babies who were LGA had FM. On the other hand, only 50 (16.9%) of the 296 babies without FM were SGA while 50 (44.6%) of the 112 babies who were SGA did not have FM based on CANSCORE. A statistically significant higher proportion of babies that were SGA than AGA had FM ($\chi^2 = 91.3$, df = 2, p = 0.000). Twenty-eight (31.1%) of the babies with FM would have been missed if the diagnosis of malnutrition was based on the intrauterine growth chart alone.

DISCUSSION

In developing countries, LBW is a common clinical problem with long term implications o n the growth, morbidity and mortality of the infant [14]. The present study aimed to identify the nutritional status of 386 babies that formed the subjects using the birth weights, ponderal index (PI), the mid arm circumference to head circumference (MAC/HC), weight for gestational age (using Lubchenco intrauterine growth chart) and CANSCORE. This has shown that the prevalence of malnutrition is quite high regardless of the method of assessment, for example, using birth weights, 14% were LBW at term, while with MAC/HC ratio prevalence of malnutrition was 14%, prevalence of 16.6% with PI; weight for gestational age (29% of the babies were SGA) and a prevalence of 23.3% on CANSCORE.

Compared to PI, CANSCORE therefore, identified more babies with malnutrition. Ponderal index finds its use in sub-classifying SGA babies according to the proportionality of growth restriction viz: symmetric and asymmetric SGA and this is of prognostic value [14]. But because PI relies on the principle that length is spared at the expense of weight during periods of acute malnutrition, its demerit lies in the fact that length may be sufficiently impaired making neonates with chronic insult in utero to be wrongly classified as normal by PI. Also, any potential errors of measurement of length are also invariably cubed in the application of the formula [20]. Hence, such newborns that are malnourished may be misdiagnosed as having normal nutrition. This could account for the apparently low prevalence of malnutrition using PI despite the fact that the present study included mothers with chronic medical illnesses which could pose chronic insults to the growing fetus. The mean PI of 2.72 g/cm^3 recorded in the current study is however similar to values reported in studies from Lagos [14] and Ilesa [15]. Similar prevalence of malnutrition using the PI have also been documented in these areas possibly reflecting similarities in socioeconomic conditions in these southwestern communities though, the specific influence of socioeconomic factors on the prevalence of malnutrition was not evaluated in this study.

Also, as regards MAC/HC ratio, using a cut-off value of 0.27 for malnutrition, 56 (14.5%) of the babies met the criteria for malnutrition. This prevalence is lower than 23.3% identified by CANSCORE. The MAC/HC ratio is a ratio of two anthropometric measurements which also may not identify necessarily all babies with wasting. The MAC/HC ratio however is independent of birth weight which may not be known in some cases thus making it a useful means of assessing the nutritional status of the baby when the birth weight is not known. Also, the denominator – the head circumference, is spared during periods of acute malnutrition meaning that the MAC/HC ratio can readily identify the late gestation growth retarded baby, making it a reliable index of FM even when the baby's weight is above the 10th percentile [16, 17].

The prevalence of 23.3% for FM obtained by CANSCORE in this study was much higher than the prevalence of 10.9% observed by Metcoff[3]in 1994 among the American newborns but similar to 28% reported by Sankhyan *et al*. [17] in 2009 and 24% reported by Soundarya *et al*. [8] in 2012 among Indian babies. These three figures of 23.3%, 24.0%, and 28.0% are from developing countries where intrauterine growth restriction may contribute to the high burden of LBW in these countries. Like the present study, all these previous studies [4, 17, 18] used the CANSCORE method to assess the nutritional status of neonates delivered at term. In 1999, Jayant and Rajkumar [3] reported a prevalence of 19.6% in India but a decade later a prevalence of 28.0% was reported in the same country [17]. Similarly, in 2004, Adebami *et al.* [15] reported a prevalence of 18.8%, but the present study which was conducted in the same geographical zone almost a decade later found a higher prevalence of FM of 23.3%. The higher prevalence of FM in the present study may be a reflection of increasing fetal stress in pregnancy and worsening FM which had also been observed by other researchers in similar developing countries [8, 17]. The observed increase in the prevalence of FM may be a pointer to worsening of the adverse factors that have been found to exert a significant influence in the incidence of FM such as pregnancy induced hypertension, maternal infections and under nutrition, maternal socioeconomic factors or it may be due to yet unidentified associated factors like micronutrient deficiencies. These findings may have serious implications in terms of immediate and long term outcome for such babies.

In the present study, more females than males had FM. This is similar to the finding of Adebami *et al*. [1] in 2004and Soundarya *et al.* [8] in 2012 who also found a higher prevalence of wasting among female neonates. Though the difference in the prevalence of wasting between male and female neonates was not statistically significant, it may be of clinical or epidemiological importance. It would suggest that females have a predilection to FM.

The finding that a significant association exists between the number of babies identified as normal or malnourished by CANSCORE after evaluation by PI is similar to the finding of Soundarya *et al*. [8]. In our study, PI exhibited a better specificity but poor sensitivity in identifying malnutrition. This is in concordance with other studies done by Eregie [8] and Adebami [9] but not with the study done by Georgieff [13] who found MAC/HC a more reliable index.

Looking at the relationship between MAC/HC and CANSCORE, a poor sensitivity was found with MAC/HC and this observation is similar to that made by Soundarya [8]. There was a better correlation of MAC/HC with CANSCORE than with PI.

It is also noteworthy that more than two-thirds of the babies with FM were SGA. This could be of value in peripheral centers where there may not be availability of intrauterine growth charts or the presence of skilled personnel to interprete the chart because the CANSCORE being a simple clinical index for identifying babies with FM can be easily be carried out by the bedside and would help at the same time to identify a large number of SGA babies. It is however subjective, more time consuming than calculating indices such as PI and MAC/HC. It also requires expertise and some researchers have suggested that the score of the hair is the least correlated with nutritional status of all the parameters scored [28]. Nonetheless it is agreed that the CANSCORE is a simple and quantifiable method for the assessment of FM at birth [9, 18].

CONCLUSION

A high prevalence of fetal malnutrition has been shown by the present study. Unlike industrialized nations where one-half of all LBW babies are born preterm, most LBW infants in developing countries are born at term and are affected by fetal growth restriction [19]. Anthropometric methods alone may be insufficient to identify all babies with FM and FM may be present despite normal anthropometric parameters. Whilst CANSCORE accurately diagnoses FM, a combination of different methods of assessing the nutritional status of newborns may maximally differentiate normal and abnormal nutrition. The worsening prevalence of FM in most developing countries should be of great concern to stakeholders and concerted efforts must be made to control this trend.

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CONFLICT OF INTEREST

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