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Arm area measurements as indices of nutritional reserves and body water in African newborns

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Summary
Although application of non-invasive techniques for early evaluation of body water, calorie and protein reserves has been available for more than two decades, there is a dearth of information on the evaluation of extracellular water, protein and calorie reserves in the African newborn. A cross-sectional study of arm area measurements was undertaken in 510 term new-born infants consisting of 318 infants who were normal weight term infants (NWTI) with a mean birth weight of 2898.5 ± 287.7 g and 192 low birth weight term infants (LBWTI) with a mean birth weight of 2176.5 ± 194.7 g. The triceps skin fold thickness (TSF), the arm fat area (AFA), percentage of arm area (AFA%) and arm water area (AWA) were significantly greater in females than males weighing >2500 g at birth *($P < 0.05$)*, though the mean birth weight and mid-upper arm circumference (MUAC) were similar *($P > 0.05$)*. With the exception of AFA%, all measured and calculated indices were significantly lower in LBWTI than in the NWTI irrespective of sex *($P < 0.05$)*. The measurements may aid detection of newborns at risk of developing malnutrition in an area of the world where childhood undernutrition is common.

Keywords: *Arm-area, Measurements, Nutritional Reserves, African, Newborns*

Résumé
Quoique l'application des techiniques non-invasive pour l'evaluation precauce de leau, caloires, des reserves en proteines du corps, a été disponible il ya de cela plus de 20 ans, il n'ya pas assez d'information sur l'evaluation de l'eau extracellulaire, des proteins et des reserves on calories chez les nouveaux nés Africains. Une etude periodique des measures de la region de la main avait ete entreprise chez 510 nouveaux-nes faits de 318 enfants qui ont en un poids normal a la noissance (NWTI) avec un poids moyen a la noissance de 2898.5 ± 287.7 g et 192 enfants a faible poids a la naissance (LBWTI) avec un poids moyen a la naissance de 2176.5 ± 194.7 g. L'epaisseur de la peau du tricepse (TSF), la graisse de la region de la main (AFA), le pourcentage de la graisse de la region de la main (AFA %) et d'eau de la region de la main (AWA) ont ete significativement plus gramh chez filles par rapport aux garcons ayant un poids 2500 g à la naissance (*P* 0.05), quoque le poids moyen a la naissance et la circomference de moitie superieure de la main (MUAC) etaient similaires (*P* 0.05). A l'exception de de l'AFA %, tous les indices mesures et calcules avaitent ete significativement faible chez les enfants a faible proids a la naissance. Compare a ceux a poids normal a la naissance irrespectif de leux sexe (P 0.05). Ces mesures pourraient aide dans la detection precauce des nouveaux nes a risque de developer la malnutrition dans les regions du mondes ou la malnutrition des nouveaux nees est commune.

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Introduction

The assessment of nutritional status by application of non-invasive techniques to the upper arm has made early identification of malnutrition and evaluation of body water, calorie and protein reserves relatively easy [1-3]. In early childhood, subcutaneous fat and muscle mass are important indicators of calorie and protein reserves, respectively [1,4] and these in the newborn signify the state of foetal nutrition [2]. In the tropics, where maternal and early childhood malnutrition is common, it is important to define the adequacy of nutritional reserves in the new-born and also evaluate the extracellular water content. These measurements may aid early detection of newborns at risk of developing malnutrition in early childhood and therefore promote appropriate intervention. These reserves can be evaluated by densitometric potassium-40 [5] and ^{15}N creatine [6] which are impracticable for routine use, and by the relatively simple dynamic change in tricipital skin fold measurements [3,4]. There is dearth of information on the extracellular water, protein and calories reserves in African newborn infants. Therefore, the aim of this study was to define baseline indices of protein and calorie reserves based on tricipital skin fold measurement.

Subjects and measurements

All term newborn infants delivered at the State Hospital, Adeoyo, Ibadan Nigeria, over a six-month period were recruited into the study. The gestational age was confirmed by ultrasound imaging during early second trimester (16 weeks). The following measurements in the newborn infants were taken within 24 hours of delivery: weight, length, occipito-frontal circumference (OFC), mid-upper arm circumference (MUAC) and tricipital skinfold thickness (TSF). The social classes of the mothers of these newborn infants were determined using the method of Famuyiwa *et al* [7]. The nude weight was measured by a Waymaster scale (Model 1615K, *Reading, United Kingdom*) to the nearest 50 g. The OFC and MUAC were measured to the nearest millimetre using a non-stretchable tape.

The TSF was measured over the posterior surface of the left triceps muscle, halfway between the olecranon and acromion with the arm extended by the side of the body. The TSF measurements were taken with the baby in the mother's arm, clutched lightly to the mother's shoulder. The caliper readings were taken at 15 and 60 seconds and repeat measurements at 15 and 60 seconds were taken one hour after the first readings in each child using the Holtain calipers (*Holtain Limited, Crosswell, Crymmych, Wales, United Kingdom)* by one of us (AKS). These measurements were taken with the calipers exerting a uniform pressure of 10 g/mm^2 and the values were measured to the nearest 0.1 mm. The average coefficient of variation between the measurements was 6.8%.

The following indices expressed in mm^2 were calculated by standard formulae [3,4,8] based on the assumption that no variation in diameter occurs throughout the humeral length [3,4,8] and skin fold compressibility is closely related to extracellular water content of the body [3,4].

$$\text{Arm Area (AA)} = \frac{MUAC^2}{4\pi}$$

Arm Muscle Area (AMA)

$$= \frac{(MUAC - \pi TSF_{15})^2}{4\pi}$$

Arm Fat Area (AFA)

$$= \frac{AA - MUAC - \pi\ TSF_{60})^2}{4\pi}$$

Arm Water Area (AWA)

$$= AA - AMA\text{-}AFA$$

Arm Fat Area% (AFA%)

$$= \frac{AFA \times 100}{AA}$$

All results were grouped and analysed based on birth weight < 2500 g or ≥ 2500 g and sex of subjects. The results were expressed as mean ± 1 standard deviation (SD).

The data were analysed using the SPSS (Version 6.1) software. Inter–and intragroup comparison were made using Mann-Whitney-U and Kolmmogorov-Smirnove Z-tests for 2 independent samples. The level of statistical significance was determined by student 't' test with a critical value of 1.96 at 0.05 level of significance.

Results

There were 510 term new-born infants and their mothers belonged to social classes 4 and 5. There were 318 subjects with birth weight ≥ 2500 g (Normal Weight Term Infants, NWTI), with a mean birth weight of 2898.5 ± 28.7 g and 192 term subjects weighing < 2500 g (Low Birth Weight Term Infants – LBWTI) with a mean birth weight of 2176.5 ± 194.7 g. Table 1 shows that all the calculated and measured anthropometric data with the exception of AFA% were significantly greater in the NWTI than in the LBW TI.

Table 1: Anthropometric and arm area measurements (mean ± SD)

Parameters	Birthweight < 2500 g n = 192	Birthweight ≥ 2500 g n = 318	P value
Birthweight (kg)	2176.5 ± 194.7	2898.6 ± 287.7	<0.005
Length (mm)	464.9 ± 17.8	497.3 ± 15.0	<0.005
MUAC (cm)	9.41 ± 0.86	10.64 ± 0.90	<0.005
TSF15 (mm)	3.60 ± 0.93	4.04 ± 0.94	<0.05
TSF60 (mm)	3.21 ± 0.87	3.62 ± 0.85	<0.05
AFA%	20.32 ± 4.74	20.44 ± 4.03	>0.05
AWA	0.16 ± 0.05	0.19 ± 0.10	<0.01
AFA	1.43 ± 0.43	1.82 ± 0.48	<0.0005
AMA	5.41 ± 0.93	6.82 ± 1.13	<0.0005

In the NWTI group, females demonstrated significantly greater AFA, AFA% and AWA than the male-born infants *(P<0.05)*, though the weight, length and MUAC, AA and AMA were similar in both sexes *(P > 0.05)*. The mean TSF thickness at 15 and 60 seconds were lower in males than females *(P<0.01)*. The mean OFC was larger in term normal weight male infants than females *(P<0.05)*.

Table 2 shows the measured anthropometric data in the NWTI. There were no statistically significant differences in the weights, length, MUAC, AA and AMA of the male and female newborn infants. Whereas the TSF_{15} and TSF_{60} were higher in the girls *(P<0.01)*; OFC was greater in the boys *(P<0.01)*, and each of AWA, AFA and %AFA was greater in the girls than the boys *(P<0.05)*.

Table 2: Anthropometric data (mean ± SD) in the normal weight term infants

Sex	Weight (g)	Length (mm)	MUAC (cm)	TSF15 (mm)	TSF60 (mm)	OFC (cm)	AA (mm^2)	AMA (mm^2)	AWA (mm^2)	AFA (mm^2)	AFA %
Boys	2865.69	498.41	10.58	3.84	3.46	34.94	878	687	017	173	19.68
n = 152	(239.06)	(12.33)	(0.78)	(0.75)	(0.68)	(0.90)	(132)	(106)	(010)	(040)	(3.19)
Girls	2905.88	495.53	10.73	4.27	3.81	34.47	900	683	022	191	21.25
n = 166	(303.75)	(18.39)	(1.00)	(1.05)	(0.96)	(1.23)	(149)	(121)	(010)	(054)	(4.63)
P value	>0.05	>0.05	0.05	<0.01	<0.01	<0.01	>0.05	>0.05	>0.05	>0.05	>0.05

In the LBWTI, the anthropometric values and calculated areas were similar in both males and females (Table 3).

Tables 4 and 5 show the percentile distribution of each measured and calculated parameters in NWTI

Table 3: Anthropometric data (mean ± SD) in term low birth weight infants

Sex	Weight (g)	Length (mm)	MUAC (cm)	TSF_{15} (mm)	TSF_{60} (mm)	OFC (cm)	AA (mm^2)	AMA (mm^2)	AWA (mm^2)	AFA (mm^2)	AFA (%)
Boys	2173.53	465.24	9.24	3.45	3.07	33.0	6.69	5.20	0.15	1.33	19.99
n = 101	(224.39)	(16.45)	(0.75)	(0.61)	(0.62)	(1.41)	(1.09)	(0.94')	(0.04)	(0.31)	(3.84)
Girls	2194.44	464.94	9.61	3.71	3.31	32.83	7.22	5.67	0.17	1.51	20.37
n = 191	(173.96)	(18.99)	(1.14)	(1.14)	(1.05)	(1.04)	(1.17)	(0.91)	(0.06)	(0.50)	(5.54)
P value	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05S

Table 4: Percentile distribution of parameters in male new borns ≥ 2500 g (n = 152)

	Percentile				
Parameters	5	25	50	75	95
Weight (g)	2500	2700.00	2850.00	3075.00	3530.00
Length (mm)	477.7	488.00	501.00	508.00	520.00
MUAC (cm)	9.00	10.00	10.50	11.00	12.07
TSF 15 (mm)	2.8	3.4	3.8	4.3	5.3
AA (mm^2)	6.45	7.96	8.77	9.63	11.59
AFA (mm^2)	5.34	6.08	6.71	7.43	9.10
AFA%	14.34	17.50	19.17	21.70	25.49
AWA (mm^2)	0.09	0.14	0.18	0.20	0.36

Table 5: Percentile distribution of parameters in female newborns

	Percentile				
Parameters	5	25	50	75	95
Weight (g)	2532.50	2662.50	2850.00	3050.00	3450.00
Length (mm)	468.00	482.25	494.00	503.75	532.85
MUAC (cm)	9.02	10.00	10.50	11.43	12.00
TSF 15 (mm)	2.73	3.30	4.20	4.80	6.35
AA (mm^2)	6.49	7.96	8.77	10.39	1.46
AMA (mm^2)	4.91	5.89	6.93	7.70	8.69
AFA (mm^2)	1.12	1.46	1.82	2.22	2.93
AFA%	14.09	17.45	21.16	24.38	30.26
AWA (mm^2)	0.09	0.16	0.19	0.26	0.35

Discussion

The declining economic fortunes of sub-Saharan Africa make undernutrition and its consequences inevitable in many mothers and probably in many of their offsprings. Therefore the early detection of the newborn at risk of developing malnutrition with prompt institution of appropriate measures is an important step in the prevention of this problem later in the childhood. Anthropometric evaluation of the upper limb has become a useful indicator of nutritional status of children and it is assumed that skin fold thickness indicates calorie reserves and arm size reflects protein reserves [1]. Thus, arm area measurements are better indicators of fat and protein reserves than TSF and MUAC [4]. The present study evaluated the protein and caloric reserves of the newborn infants as a reflection of the nutritional status of the foetus [2]. The findings in this study as in Caucasian studies [2,3,9,10] demonstrated that females have greater TSF thickness than male newborns irrespective of the birthweights though on a less remarkable scale in the LBWTI.

Skin fold thicknesses are of clinical significance in neonatology as they shed light on foetal nutrition [2] as body weights indicate the total amount of body fat, muscle bulk, size of head and water. Despite the poor economic background of the mothers of these neonates, the AMA and AWA of the NWTI are comparable with or greater than those reported in Caucasian newborn infants [3,4,11,12], suggesting that the Nigerian newborn infants start life with a good protein reserves. The differences between protein and calorie reserves between NWTI and LBWTI may imply that there is retardation of growth in the term low birth weight newborns before birth or there was chronic inadequate nutritional intake during gestation. The clinical implications of the lower calorie reserve in LBWTI may explain the positive relationship between hypoglycaemia at 4 hours and skinfold thickness [14].

The lower calorie reserve as measured by TSF, AFA and AFA is lower in the NWTI studies when compared with that of Caucasian newborn infants, suggesting that stresses such as malaria, measles, diarrhoeal illness and recurring acute respiratory infections or inadequate nutritional intake may easily precipitate severe malnutrition [4]. The AWA in this study represented only 2% of the total arm area which is similar to the 1% reported by Sann *et al.* [4]. At birth and subsequently, the AWA represented only a minor part of total arm area, since it was only 2% of the arm area. Therefore AWA could be excluded from the calculations of both AFA and AMA [4].

Some authors [4,13,15] have stressed the importance of arm area measurements in the assessment of nutritional status as they represent better estimates of the relative contributions of fat and muscle to the total arm area than MUAC and TSF. The arm area measurements may serve as a reflection of the relative contribution of fat and/or protein reserves in the determination of poor growth in an infant. Serial arm area measurements will therefore be a useful tool in determining the source of poor growth in a community. The arm area measurement in the new born is a good indicator of the state of foetal nutrition and may indicate poor nutritional status in the prenatal and/or intrauterine periods. In our area of the world, where for many reasons, nutrition is often suboptimal during infancy, the present study provides a baseline data of protein and calorie reserves by simple arm area measurements. These data generated may be used to identify at risk neonates in the neonatal period and appropriate intervention programmes instituted.

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