Annals of Human Biology, September–October 2005; 32(5): 639–649

Anthropometry of Malawian live births between 35 and 41 weeks of gestation

B. F. KALANDA[1,2], S. VAN BUUREN[3], F. H. VERHOEFF[1], & B. J. BRABIN[1,4]

[1]*Child and Reproductive Health Group, Liverpool School of Tropical Medicine, Liverpool, UK,* [2]*College of Medicine, University of Malawi, Blantyre, Malawi,* [3]*Department of Statistics, TNO Prevention and Health, Leiden, The Netherlands, and* [4]*Emma Kinderziekenhuis, Academic Medical Centre, University of Amsterdam, The Netherlands*

(Received 5 January 2005; revised 21 March 2005; accepted 13 June 2005)

Abstract
The aim of this analysis was to construct cross-sectional gestational age specific percentile curves for birthweight, length, head and mid-arm circumference for Malawian babies, and to compare these percentiles with reference values for babies born to women with normal pregnancies, from a developed country. A cross-sectional study which enrolled pregnant women attending two study hospitals between March 1993 and July 1994 was undertaken. Data on maternal socio-economic status, newborn anthropometry, previous obstetric history and current pregnancy were collected. Smoothed percentile values were derived using the LMS method. Malawian reference percentiles were constructed for fetal growth from 35 weeks' gestation for singleton births. Mean birthweight, length and head circumference were lower at all gestational ages for Malawian compared with Swedish newborns. Fetal growth per completed gestational week was higher by 60 g in weight, 0.5 cm in length and 0.2 cm in head circumference in Swedish compared with Malawian babies. Growth restriction was present from 35 to 41 weeks' gestation. The pattern for the 10th percentile suggested that this was occurring from well before 35 weeks' gestation in a proportion of babies.

Keywords: *Fetal growth, percentiles, Malawi, Sweden*

Introduction

Fetal growth curves can be used for screening high-risk neonates at birth (Nishida et al. 1985, Fok et al. 1987). Cross-sectional anthropometric data plotted by gestational age at birth have been used to construct fetal growth curves (Lubchenko et al. 1963, 1966), and represent a useful construct of fetal growth. Such curves may underestimate the growth of infants who reach term and the proportion of preterm infants who are growth restricted (Hediger et al. 1985). Babies categorized as small based on these curves may also not be at increased risk of neonatal morbidity, in spite of being constitutionally small

Correspondence: Professor B. J. Brabin, Child and Reproductive Health Group, Liverpool School of Tropical Medicine, Pembroke Place, Liverpool L3 5QA, UK. E-mail: b.j.brabin@liv.ac.uk

ISSN 0301–4460 print/ISSN 1464–5033 online
DOI: 10.1080/03014460500228675

(Brenner et al. 1976, Wilcox 1981, Altman and Hytten 1989, Lawrence et al. 1989, Mongelli and Biswas 2001).

There are few examples of fetal growth curves for babies from developing countries, especially for those born in rural areas. In spite of their potential limitations, analysis of appropriate cross-sectional data from developing countries is important because of its scarcity. The objective of the present analysis was to construct fetal growth curves for Malawian neonates whose mothers were living in a poor rural area with a high prevalence of malaria during pregnancy. The Malawian data were compared with reference values from a developed country.

Methods

Study area

This study was undertaken between March 1993 and July 1994 in Chikwawa District, in the lower Shire Valley, southern Malawi. This is a rural area where malaria transmission is holoendemic. HIV prevalence at this time was 25.6% in the adult pregnant population (Verhoeff et al. 1999a). Chikwawa District is about 4800 km^2 and 10–300 m above sea level. The average rainfall in the study period was 520 mm $year^{-1}$, of which 88% fell in the months of November–March (SUCOMA 1995). Small-scale agriculture of maize, sorghum, cotton and sugar cane were the primary source of food and income. The estimated population size was 3 566 832 of which 77 701 were women of child-bearing age (National Statistical Office 1998). The study was located in the two hospitals in the District, Chikwawa District Hospital, a government hospital with free services and Montfort Hospital, 30 km away, which is a fee-paying mission hospital.

Enrolment

All women attending antenatal clinics were enrolled in the study after obtaining informed consent. Information on delivery was collected only from women who also attended the hospital facilities of Chikwawa District Hospital or Montfort Hospital for delivery. For logistic reasons, it was not possible to obtain this information from home or health centre deliveries. Birthweight was measured immediately after birth on a Salter scale to the nearest 10 g, and the baby was examined for gestational age between 6 and 24 h infant age using a modified Ballard method (Verhoeff et al. 1997). Gestational age is often estimated from the last menstrual period (LMP) but this may be inaccurate due to errors in dates from menstrual cycle variation. Where no reliable LMP is available, postnatal examination of the newborn with clinical scoring for external and/or neurological characteristics can be used. The modified Ballard method used in this study scores for external criteria only and this technique compares favourably with other gestational age assessments based on newborn examinations (Verhoeff et al. 1997). Birth length was measured in centimetres to the nearest 0.1 cm, with the baby laid supine on a locally made standardized measuring board. Head circumference (occipito-frontal) was measured in centimetres (to the nearest millimetre) using a tape measure (TALC, Guildford, UK). Measurements were taken midway between the eyebrows and the hairline at the front of the head and around the occipital prominence. Mid-upper arm circumference was measured using a standard tape measure (TALC, Guilford) at the mid-point of the left upper arm (to the nearest millimetre).

Definitions

Underweight (low weight for age (*W/A*)), thinness (low weight for length (*W/L*)) and stunting (low length for age (*L/A*)) were defined as a standard deviation score of greater than or equal to -2.0. Rohrer's index was computed as birthweight (g)/birth length^3 (cm) (World Health Organization 1995). Prematurity was defined as birth earlier than 37 weeks of gestation, and low birthweight as less than 2500 g.

Sample size

A sample of 100 observations for each gestational week has been recommended as optimal for estimation of growth curves although smaller samples can be adequate to draw percentile curves (Cole 1990). Of the 4104 pregnant women recruited at the antenatal clinics, 1571 (38%) also delivered in the study hospitals. There were 86 twins, 55 stillbirths, and four twins who were stillborn. For three babies information was missing. These births were excluded providing 1423 singleton infants for the analysis. Of these, 49.9% were male, 17.3% preterm and 14.9% low birthweight. Primigravidae comprised 24.3%, and 22.4% were adolescent (< 20 years). Due to small sub-group sample sizes the births below 35 weeks ($n < 10$), only data for infants born at or later than 35 weeks' gestation is presented, providing a minimum sample size of 32 for each gestational interval, and greater than 100 for five of the seven gestational intervals analysed. A total of 1334 infants were included in the analysis.

Analysis

Data were analysed using SPSS for windows, version 11.0 (2001). Growth curves were drawn using smoothed percentile standards derived by the LMS program (Cole 1988, 1989) version 1.16 (2000). The LMS method assumes that the data can be normalized by using a power transformation which stretches one tail of the distribution and shrinks the other to remove the skewness. The optimal power to obtain normality is calculated for each of a series of age groups and the trend summarized by a smooth (L) curve. Trends in the mean (M) and coefficient of variation (S) are similarly smoothed. The optimal L, M and S curves were selected by comparing them with the deviance of alternative models. The resulting L, M and S curves contain the information to draw any centile curve. Standard deviation scores were calculated using the EPI Info 2002, Nutrition Programme, and the CD 2000 Reference standard. Twins and stillbirths were excluded from the analysis. Comparison was made with a Swedish reference data set for birth registrations from 1977 to 1978 (Karlberg et al. 1985). The Swedish data set was used as this is the only current data set which provides reference values for all three anthropometric measurements (weight, length and head circumference). In addition, the Swedish sample excluded babies with stillbirth or serious neonatal disorders, or whose mothers had pregnancy-related disorders such as haemorrhage, cervical insufficiency, urinary infection, eclampsia or pre-eclampsia. Babies whose mothers had syphilis, diabetes, hypertension, heart and kidney disease were also excluded (Karlberg et al. 1985).

Ethical approval

The study received ethical approval from the Malawi College of Medicine Health Sciences Research Committee.

Table I. Anthropometric data by gestational age and sex.

Gestation (weeks)	Sample size		Birthweight (g)		Rohrer's index ($1000\,g\,cm^{-3}$)		Birth length (cm)		Head circumference (cm)		MUAC(cm)	
	M	F	M	F	M	F	M	F	M	F	M	F
35	16	16	2308	2575	24.7	34.5	45.2	44.6	32.3	32.1	9.1	10.0
			(547)	(373)	(3.6)	(30.9)	(2.8)	(5.7)	(1.6)	(1.1)	(1.2)	(1.0)
36	80	78	2719	2750	26.7	27.2	46.7	46.5	33.1	32.7	10.0	10.1
			(459)	(475)	(3.8)	(3.4)	(1.8)	(2.2)	(1.4)	(1.4)	(1.0)	(0.9)
37	115	70	2867	2848	27.7	27.4	47.3	47.0	33.7	33.5	10.3	10.2
			(412)	(383)	(10.9)	(3.3)	(2.4)	(1.8)	(1.4)	(1.3)	(0.7)	(0.9)
38	124	144	3062	2927	27.6	27.0	48.1	47.7	34.1	33.7	10.5	10.4
			(373)	(339)	(3.1)	(2.7)	(1.6)	(1.6)	(1.2)	(1.3)	(0.8)	(0.7)
39	167	143	3110	2962	27.4	27.1	48.4	47.8	34.3	33.8	10.5	10.4
			(333)	(368)	(2.5)	(3.0)	(1.6)	(1.8)	(1.1)	(1.3)	(0.7)	(0.8)
40	147	202	3200	3033	27.7	28.3	48.7	47.7	34.5	33.8	10.7	10.6
			(402)	(389)	(2.7)	(9.1)	(1.6)	(2.3)	(1.2)	(1.2)	(0.8)	(0.8)
41	12	20	3117	3154	27.5	27.5	48.4	48.6	34.1	33.9	10.6	10.7
			(385)	(320)	(2.0)	(2.8)	(1.9)	(1.6)	(1.4)	(1.1)	(0.7)	(0.7)

M, male; F, female. Values in parentheses are standard deviations.

Results

Anthropometric measurements by gestational age and sex

Anthropometric measurements for the different gestational age groups are summarized in Table I. Mean gestational age for males was 38.1 (SD = 1.9) and for females 38.3 (SD = 1.8) weeks ($p = 0.004$). The mean values (standard deviation) for birthweight, birth length, head circumference and mid-upper arm circumference (MUAC) for males were 2977 g (477), 47.8 cm (2.3), 33.9 cm (1.6) and 10.4 cm (0.9), respectively (Table I). The corresponding values for females were 2900 g (438.8), 47.3 cm (2.4), 33.5 cm (1.56) and 10.3 cm (0.9). The difference for birthweight ($p = 0.003$), length ($p < 0.001$) and head circumference ($p = 0.001$) were statistically significant.

The birthweight and length-for-gestational-age centile curves for females (P_{10}, P_{50}, P_{90}) were lower than those of males (Figures 1 and 2). Head-circumference-for-gestational-age centiles for females were also below those for males across all centile lines (Figure 3). There were small differences for the MUAC percentile values between male and females (Figure 4). Prior to 37 weeks of gestation, ponderal indices for females were higher than for males but subsequently values converged (Figure 5).

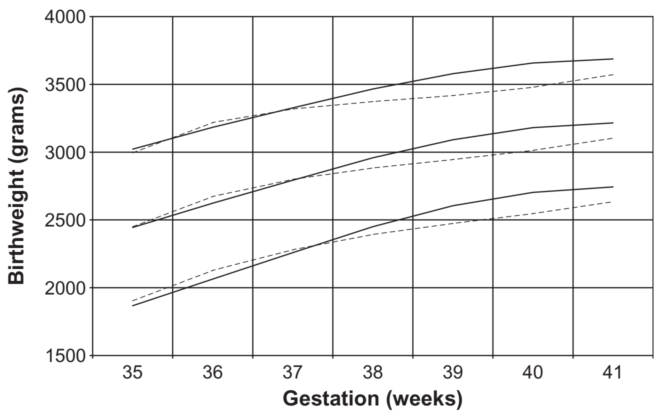

Figure 1. Birth-weight-for-gestational-age centiles (10th, 50th, 90th) for males (——) and females (-------).

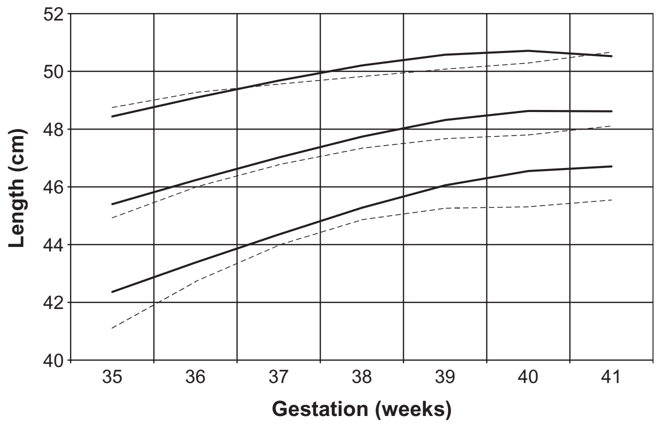

Figure 2. Length-for-gestational-age centiles (10th, 50th, 90th) for males (——) and females (-------).

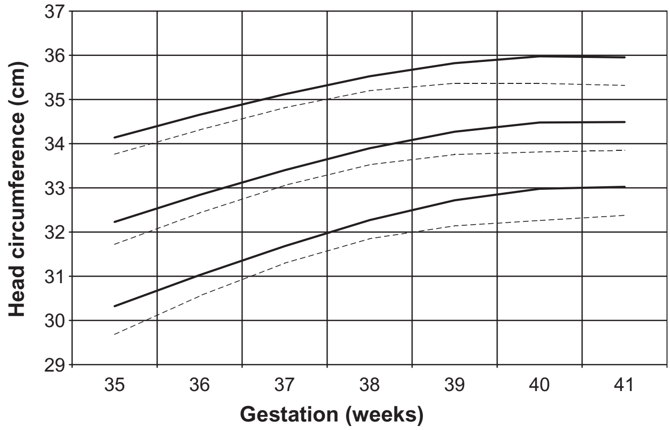

Figure 3. Head-circumference-for-gestational-age centiles (10th, 50th, 90th) for males (——) and females (-------).

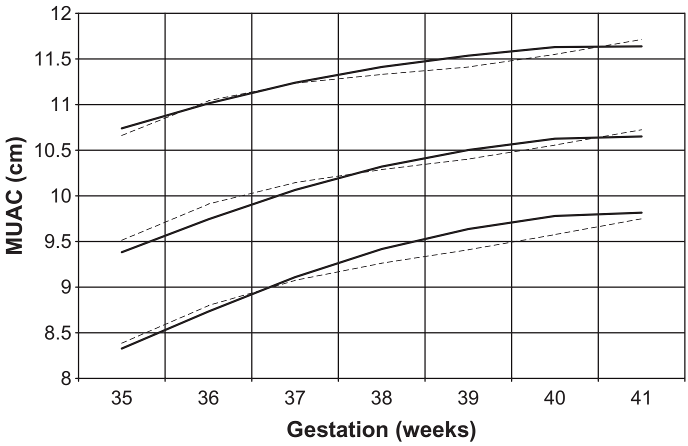

Figure 4. MUAC-for-gestational-age centiles (10th, 50th, 90th) for males (——) and females (-------).

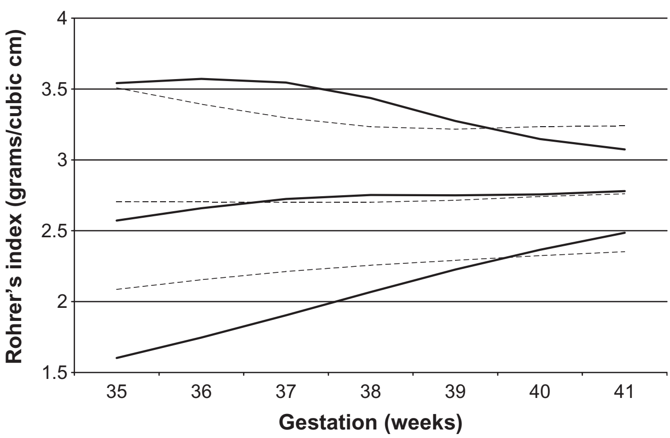

Figure 5. Rohrer's index-for-gestational-age centiles (10th, 50th, 90th) for males (——) and females (-------).

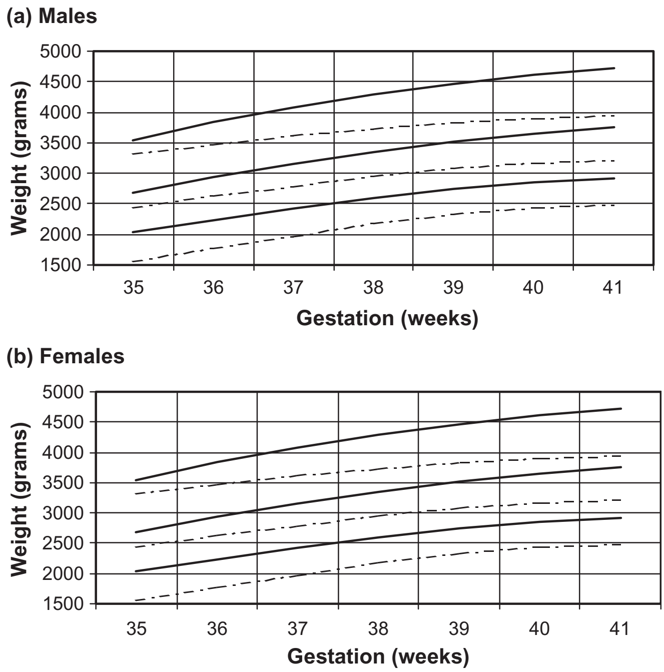

Figure 6. Birth-weight-for-gestational-age (mean $\pm$ 2 standard deviations) for Swedish (——) and Malawian (- — - —) babies.

Comparison with Swedish reference values

Between 35 and 41 weeks' gestation mean values for anthropometric parameters for Malawian babies were below Swedish reference values (Figures 6–8). Mean birthweight per gestational week was higher by 60 g, birth length by 0.5 cm and head circumference by 0.2 cm in Swedish compared with Malawian babies.

Discussion

Reference data for comparison of birth size was obtained from Swedish birth registrations. The World Health Organization (WHO) has recommended using the Williams Reference (Williams et al. 1982, World Health Organization 1995) and previously, Verhoeff et al. have used this for analysis of Malawian weight percentiles (Verhoeff et al. 1999b). There are currently no recommended international reference values for birth length or head circumference. International comparative data may be available from 2005 following completion of WHO Multicentre Growth Reference Study (M. de Onis, WHO, personal communication). Previously WHO has proposed use of Swedish (Wilcox 1981, Karlberg et al. 1985) or Canadian reference data (Arbuckle et al. 1993). In the present analysis, the Swedish reference was used as length and head circumference measurements are available, which are not provided by other data sets.

There was a fall-off in birthweight from 35 weeks' gestation in Malawian babies compared to reference values. This was apparent for the Malawian 50th and 90th percentiles, but not the 10th percentile, which remained well below but parallel to the reference 10th percentile. This pattern suggests that fetal growth restriction was occurring in these Malawian babies before 35 weeks' gestation in comparison to reference values. A similar pattern occurred

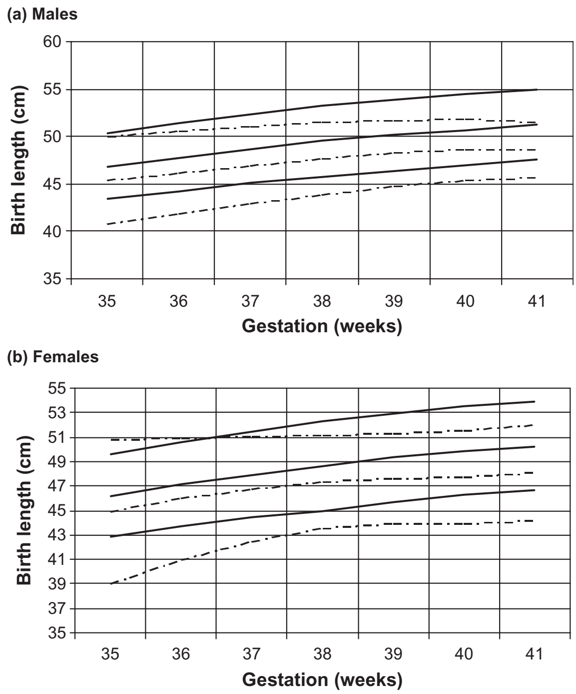

Figure 7. Birth-length-for-gestational-age (mean $\pm$ 2 standard deviations) for Swedish (——) and Malawian (- — - —) babies.

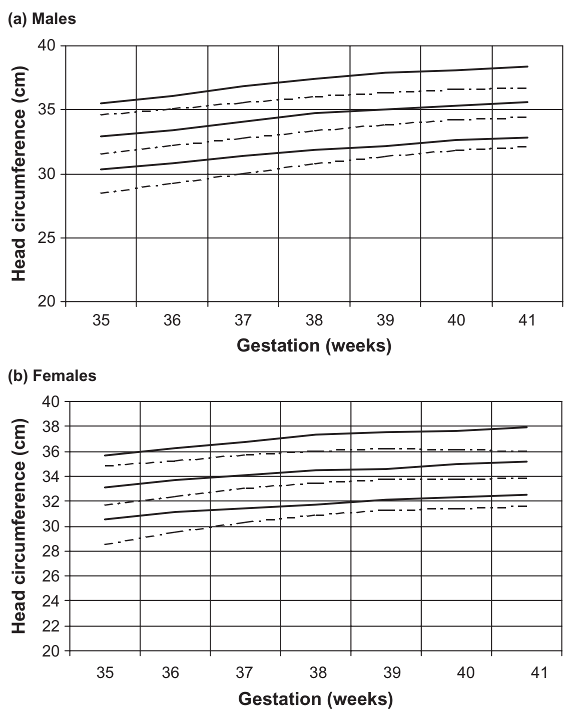

Figure 8. Head circumference-for-gestational-age (mean $\pm$ 2 standard deviations) for Swedish (——) and Malawian (- — - —) babies.

for birth length. Head circumference percentile values (10th, 50th, 90th) were parallel to but below reference values, also indicating restriction in head growth earlier in gestation than 35 weeks.

Malaria commonly occurs in mothers in this area of Malawi and is likely to have restricted placental function (Brabin et al. 2004). The combined effect of maternal malaria and HIV infection would act synergistically to influence fetal growth especially late in gestation (Kalanda et al. 2005). Although the high prevalence of malaria in these mothers limits application of these percentile curves as normative reference data for non-malarious areas of Africa, they nevertheless are a useful baseline data set for assessing changing patterns of fetal growth which should result from improved malaria and HIV control in pregnancy. The comparison with the external reference for a non-malarious group allows a proportional estimate of the overall extent of fetal growth restriction that is occurring in these babies.

Acknowledgements

We are grateful for support received from staff at Chikwawa and Montfort Hospitals and to B. Makwiza, S. Mlanga, V. Nakoma, M. Gwaza and H. Banda and to laboratory technicians for technical support. Financial support was provided by the Gates Malaria Partnership (GMP) and the European Commission Programme for Life Sciences and Technologies for Developing Countries (Contract TS3* CT 920083).

References

Altman DG, Hytten FE. 1989. Intrauterine growth retardation: Let's be clear about it. Br J Obstet Gynaecol 96:1127–1128.

Arbuckle TE, Wilkins R, Sherman GJ. 1993. Birthweight percentiles by gestational age in Canada. Obstet Gynecol 81:39–48.

Brabin BJ, Romagosa C, Abdelgalil S, Menéndez C, Verhoeff FH, McGready R, Fletcher KA, Owens S, d'Alessandro U, Nosten F, et al. 2004. The sick placenta—the role of malaria. Placenta 25:359–378.

Brenner WE, Edelman DA, Hendricks CH. 1976. A standard of fetal growth for the United States of America. Am J Obstet Gynecol 126:555–556.

Cole TJ. 1988. Fitting smoothed centile curves to reference data. J R Stat Soc A 151:385–418.

Cole TJ. 1989. Using the LMS method to measure skewness in the NCHS and Dutch national height standards. Ann Hum Biol 16:407–419.

Cole TJ. 1990. The LMS method for constructing normalised growth standards. Eur J Clin Nutr 44:45–60.

Fok TF, Lam TK, Lee N, Chow CB, Au Yeung HCL, Leung NK, Davies DP. 1987. A prospective study on the intrauterine growth of Hong Kong Chinese Babies. Biol Neonate 51:312–323.

Hediger ML, Scholl TO, Schall JI, Miller LW, Fischer RL. 1985. Fetal growth and the etiology of preterm delivery. Obstet Gynecol 85:175–182.

Kalanda BF, Van Burren S, Verhoeff FH, Brabin BJ. 2005. Anthropometry of fetal growth in rural Malawi in relation to maternal malaria and HIV status. Arch Dis Child (Fetal and Neonatal issue) 90:F161–F165.

Karlberg P, Niklasson A, Ericson A, Fryer JG, Hunt RG, Lawrence CJ, Munford AG. 1985. A methodology for evaluating size at birth. Acta Paediatr Scand 319(suppl.):26–37.

Lawrence CJ, Fryer JG, Karlberg P, Niklasson A, Ericson A. 1989. Modelling of reference values for size at birth. Act Paediatr Suppl 350:55–69.

Lubchenco LO, Hansman C, Boyd E. 1963. Intrauterine growth in length and head circumference as estimated from live births at gestational ages from 26 to 42 weeks of gestation. Pediatrics 37:403–408.

Lubchenco LO, Hansman C, Dressler M, Boyd E. 1966. Intrauterine growth as estimated from liveborn birthweight data at 24 to 42 weeks of gestation. J Pediatr 45:793–800.

Mongelli M, Biswas A. 2001. A fetal growth standard derived from multiple modalities. Early Hum Dev 60:171–177.

National Statistical Office (NSO). 1998. Malawi population, housing census. Summary of Final Results, Vol. 1, Zomba, Malawi.
Nishida H, Sakamoto S, Sakanoue M. 1985. New fetal growth curves for Japanese. Act Paediatr 319(suppl.):62–67.
SUCOMA (Sugar Corporation of Malawi). 1995. Meteorological data, 1993–1994, Nchalo, Malawi.
Verhoeff FH, Milligan P, Brabin BJ, Mlanga S, Nakoma V. 1997. Gestational age assessment by nurses in a developing country using the Ballard method, external criteria only. Ann Trop Paediatr 17:333–342.
Verhoeff FH, Brabin BJ, Hart CA, Chimsuku L, Kazembe P, Broadhead R. 1999a. Increased prevalence of malaria in HIV infected pregnant women and its implications for malaria control. Trop Med Int Health 4:5–12.
Verhoeff FH, Brabin BJ, Van Buuren S, Chimsuku L, Kazembe P, Wit JM, Broadhead RL. 1999b. An analysis of intra-uterine growth retardation in rural Malawi. Eur J Clin Nutr 55:682–689.
Wilcox AJ. 1981. Birthweight, gestation and the fetal growth curve. Am J Obstet Gynecol 139:863–867.
Williams RL, Creasy RK, Cunningham GC, Hawes WE, Norris FD, Tashiro M. 1982. Fetal growth and perinatal viability in California. Obstet Gynecol 59:624–632.
World Health Organization. 1995. Physical status: The use and interpretation of anthropometry. Geneva: WHO.

Résumé. Le but de cette analyse est de construire des courbes transversales de percentiles spécifiques de l'âge gestatif pour le poids à la naissance, la longueur du corps, la circonférence de la tête et du bras chez des nourrissons du Malawi et de comparer ces percentiles avec ceux de bébés nés de femmes ayant eu une grossesse normale dans un pays développé. Un étude transversale a incorporé des femmes enceintes qui fréquentaient deux centres hospitalo-universitaires entre mars 1993 et juillet 1994. Des valeurs lissées de percentiles ont été établies par la méthode des plus petits carrés moyens. Les percentiles de référence du Malawi ont été construits pour des croissances fœtales de 35 semaines d'enfants non gémellaires. Le poids de naissance moyen les circonférences de la tête et du bras sont plus bas à tous les âges gestatifs chez les les nouveaux-nés Malawiens que chez leurs pairs suédois. La croissance fœtale par semaine de gestation achevée est plus élevée chez les suédois de 60 g en poids, 0,5 cm en longueur et 0,2 cm en circonférence de la tête que chez les malawiens. Des restrictions à la croissance ont été présentes entre la 35$^{\text{ème}}$ et la 41$^{\text{ème}}$ semaine de gestation. L'allure du 10$^{\text{ème}}$ percentile suggère que ceci se produit longtemps avant la 35$^{\text{ème}}$ semaine de gestation pour une partie des bébés.

Zusammenfassung. Das Ziel dieser Analyse war, Schwangerschaftsdauer-spezifische Querschnittsperzentilkurven für Geburtsgewicht, Länge, Kopfumfang und Umfang des mittleren Armes für Säuglinge aus Malawi zu konstruieren, und diese Perzentilen mit Referenzwerten für Säuglinge aus normalen Schwangerschaften aus einem entwickelten Land zu vergleichen. Mit schwangeren Frauen, die sich zwischen März 1993 und Juli 1994 in zwei Studienkrankenhäusern vorgestellt hatten, wurde eine Querschnittstudie gemacht. Daten betreffend den mütterlichen sozio-ökonomischen Status, Neugeborenenmaße, frühere geburtshilfliche Anamnese und die jetzige Schwangerschaft wurden gesammelt. Mit LMS-Methode wurden geglättete Perzentilwerte gerechnet. Referenzperzentilen wurden für fetales Wachstum von Einlingen aus Malawi ab der 35. Gestationswoche konstruiert. In allen Altersgruppen waren das mittlere Geburtsgewicht, die Länge und der Kopfumfang von Neugeborenen aus Malawi niedriger als von Schwedischen Neugeborene. Mit jeder vollendeten Schwangerschaftswoche waren Schwedische Neugeborene um 60 g schwerer, um 0,5 cm länger und hatten einen um 0,2 cm größeren Kopfumfang als Neugeborene aus Malawi. Gehemmtes Wachstum fand sich von der 35 bis zur 41 Schwangerschaftswoche. Der Verlauf der 10 Perzentile legte nahe, dass dies bei einem Teil der Kinder bereits deutlich vor der 35 Schwangerschaftswoche bestanden hatte.

Resumen. El objetivo de este análisis fue construir curvas percentilares transversales, específicas para la edad gestacional, para el peso al nacimiento, longitud, circunferencias de la cabeza y del brazo medio, en niños de Malawi, y comparar estos percentiles con los valores de referencia para niños nacidos de mujeres con embarazos normales de un país desarrollado. Se emprendió un estudio transversal que incluía mujeres embarazadas que acudían a dos hospitales estudiados entre Marzo de 1993 y Julio de 1994. Se recogieron datos sobre el nivel socioeconómico materno, la antropometría del recién nacido, la historia obstétrica previa y el embarazo actual. Los valores percentilares suavizados se derivaron mediante el método LMS. Los percentiles de referencia de Malawi se construyeron para el crecimiento fetal a partir de la semana 35 de gestación para los nacimientos simples. En Malawi, los valores medios del peso al nacimiento, longitud y circunferencia de la cabeza fueron menores a todas las edades gestacionales, comparados con los recién nacidos suecos. El crecimiento fetal por semana de gestación completada fue 60 g mayor para el peso, 0,5 cm para la longitud y 0,2 cm para la circunferencia de la cabeza en los niños suecos comparados con los de Malawi. La restricción del crecimiento estaba presente desde la semana 35 a la 41 de gestación. El patrón del percentil 10 sugería que esto ocurría ya antes de la semana 35 de gestación en una cierta proporción de bebés.