Maternal & Child Nutrition

DOI: 10.1111/j.1740-8709.2011.00330.x

Original Article

Is home birth a marker for severe malnutrition in early infancy in urban communities of low-income countries?

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Abstract

This matched case-control study set out to determine the association between place of delivery and severe undernutrition in early infancy in a low-income country. All infants (aged 0–3 months) with severe undernutrition attending four well-child clinics for routine immunization in inner-city Lagos, Nigeria were matched for age and sex with well-nourished peers. The main outcome measures were the adjusted-matched-odds ratios from conditional logistic regression analysis of undernutrition based on *z*-scores below –3 for weight-for-age, height/length-for-age and body-mass-index-for-age using current World Health Organization's Multicentre Growth Reference (WHO-MGR). From an eligible population of 7075 mother-infant pairs, 918 severely undernourished infants were enlisted as cases matched with 1836 controls. While there was no statistically significant difference between infants born outside hospitals as a group compared to those born in hospitals, infants delivered at residential homes compared to public hospitals had two-to-three fold odds of being severely underweight ($p = 0.002$), severely stunted ($p < 0.001$) and severely wasted ($p = 0.008$) after controlling for potential confounders. Infants delivered in private hospitals were also significantly associated with severe stunting ($p = 0.032$). This study demonstrates that delivery in homes and private hospitals are potential markers for severe undernutrition in early infancy in this urban population and merits closer attention in any early nutritional intervention in comparable settings of low-income countries.

Keywords: place of delivery, malnutrition, early detection, immunization clinics, primary care, developing country, Africa.

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Introduction

An estimated 20 million children worldwide suffer from severe wasting or severe acute malnutrition (weight-for-height *z*-scores of less than –3 and/or associated oedema) and the vast majority reside in sub-Saharan Africa and South Asia [Bhutta *et al*. 2008; World Health Organization (WHO) & United Nations Children's Fund (UNICEF) 2009]. At least 10% of children below 5 years of age living in developing countries are severely malnourished (UNICEF 2009). These children experience physiological and metabolic adaptations to conserve energy and preserve essential processes, including reductions in the functional capacity of organs and slowing of cellular activities (Karaolis *et al*. 2007). As the nutritional deficit becomes more severe, these adaptations weaken the body's immunity to infection with the risk of high-case fatality (Collins *et al*. 2006). Although the term 'malnutrition' refers to both undernourished

and overweight/obese infants, it is commonly used synonymously with undernutrition in most of the literature from the developing world [WHO 1999, 2007; WHO & UNICEF 2009].

For many years, the WHO guidelines for the management of severe malnutrition in developing countries were designed for hospital-based practice and have limited utility especially in countries where majority of births occur outside hospitals and/or with limited access to facility-based care (WHO 1999). Concerns about the capacity of hospitals including adequate skilled manpower to deliver timely and effective inpatient treatment for all cases of severe malnutrition with or without medical complications prompted the introduction of community-based guidelines by WHO, known also as the 'CTC' (community-based therapeutic care) (Collins *et al*. 2006; Collins 2007). The CTC seeks to mobilize community participation for early presentation and compliance as well as outpatient/community-based treatment of uncomplicated forms of severe acute malnutrition (Collins 2007; WHO & UNICEF 2009). However, like the erstwhile hospital-based guidelines, the CTC is aimed at severely malnourished children from the age of 6 months (WHO 2007) and do not adequately reflect emerging evidence of the timing of growth faltering in the first 3–6 months of life (Rivera & Ruel 1997; Victora *et al*. 2010) and the potential benefits of timely intervention (Skuse *et al*. 1994; Ross *et al*. 2009). Community-oriented early detection has been shown to facilitate effective management or prompt referral for inpatient care at the evolution of severe acute malnutrition and before the onset of life-threatening complications (Collins *et al*. 2006; Collins 2007; WHO 2007; Giugliani *et al*. 2010).

Studies exploring the prevalence and pattern of severe undernutrition in the first 3 months of life are rare possibly because of the challenges of case detection through anthropometric measurements (Myatt *et al*. 2006). From the limited available studies in Africa, for example, the reported prevalence of severe undernutrition may be as high as 12.5% for severe stunting (Espo *et al*. 2002; Maleta *et al*. 2003; Olusanya *et al*. 2010). While majority of births in low-income countries currently occur outside hospitals and in rural areas (UNICEF 2009), studies exploring the relationship between severe undernutrition with place of delivery in urban settings in South Asia and sub-Saharan Africa are also rare. Available studies on severe undernutrition are either drawn from a rural population (Espo *et al*. 2002; Maleta *et al*. 2003; Saha *et al*. 2009) or do not investigate the pattern in the first 3 months of life (Rahman *et al*. 2009; Vesel *et al*. 2010). Yet, at least 5 million people are estimated to migrate every month from the rural areas into the already overcrowded cities in developing countries, while the current urban population of 39% in Africa is projected to hit 50% by 2030 at an estimated annual growth rate of 4.7%, the highest worldwide (UN-Habitat 2008). A recent joint report by WHO and UN-Habitat (2010) further provides a vivid picture of the multifaceted health and environmental risks confronting urban women and their offspring in the developing world.

This community-based study, therefore, set out to determine the pattern of severe malnutrition in the first 3 months of life and its relationship with place of delivery to facilitate early case finding in urban settings of low-income countries.

Key messages

- Evidence on the pattern of severe malnutrition in early infancy and its relationship with place of delivery among the urban population is rare but required in view of the imminent urban transition in many developing countries.
- This study has shown that infants delivered at home and, to a lesser degree, those delivered in private hospitals in urban settings are at increased risks of severe malnutrition from early infancy.
- Existing well-child clinics for routine immunization may serve as platform for the timely detection of the affected infants and promotion of home-based therapeutic nutritional intervention as recommended by World Health Organization.

Methods

Study design and setting

This case–control study was conducted in an inner-city area of Lagos, Nigeria with an estimated population of about 250 000 (National Population Commission 2006). The community is served by one general hospital, one children's hospital, one specialist maternity hospital and seven primary health care centres, all of which are state owned as well as several private hospitals and traditional maternity homes. The city of Lagos itself was the capital of Nigeria until 1991 but remains the nation's commercial and financial hub (Federal Republic of Nigeria 2010). It is about 95% urbanized and is reputed to have the best and highest number of health care facilities in the country (Federal Republic of Nigeria 2010).

Study population

The participants were mother–infant pairs drawn from a previously reported study population under a pilot universal newborn infant hearing screening programme (Olusanya *et al*. 2009, 2010). In brief, all infants aged 0–3 months attending four primary health care centres that administered routine Bacille Calmette–Guérin (BCG) immunization from July 2005 to March 2008 were consecutively enlisted for the primary study. The four centres in this study accounted for over 75% of BCG vaccinations in this location. BCG and diphtheria-pertusis-tetanus vaccinations in the first 3 months of life have the highest uptake in sub-Saharan Africa usually in excess of 80% (UNICEF 2009). Cases and controls were matched by infant's age and gender at the ratio of 1:2. Although post hoc power analysis for retrospective studies is a subject of debate, an indication of whether the study sample was sufficiently powered to provide reliable estimates of statistically significant differences between cases and controls was attempted to complement the evidence from the confidence intervals (CI) of the estimates (Hoenig & Heisey 2001). Thus, assuming a 9.0% exposure risk among infants with severe undernutrition and 5.5% exposure risk among well-nourished infants with an odds ratio (OR) of 1.70, a sample size of 916 cases and 1832 controls will have 90% power to detect a 3.5% difference in exposure risk between the two groups at 95% CI. If the effect of case–control matching were considered, the required total sample size would be lower than 2748. Ethical approval was obtained from Lagos State Health Management Board, Nigeria and University College London, UK (Olusanya *et al*. 2009). Informed consent was obtained from all participants in writing or by thumb printing prior to enrolment.

Procedures

Anthropometric measurements for each child were obtained directly at the time of enrolment by a trained research worker throughout the study period. Weight was measured with a digital scale (10 g increments) (Tanita Baby Scale, Model 1583, Tanita Corporation, Tokyo, Japan). Length was measured supine using graduated polyurethane plastic mats (1-mm increments) (Child Growth Foundation, London, UK). Although mid-upper arm circumference is considered as the most practicable and least expensive indicator for severe malnutrition especially in resource-poor settings, its use in infants younger than 6 months is constrained by the lack of internationally acceptable reference standards for this age group (Berkley *et al*. 2005; Myatt *et al*. 2006; Fernández *et al*. 2010). The nutritional indices of interest in this study, therefore, were weight for age (WAZ), height/length for age (HAZ), weight for height/length (WHZ) and body mass index for age (BMI-*z*) expressed as *z*-scores based on the latest WHO Multicentre Growth Reference (WHO-MGR) (WHO 2006). Each *z*-score represents the difference between the weight or length of a child and the median weight or length of a reference population (for the same age and sex) divided by the standard deviation (SD) of the reference population used by WHO-MGR. The three main outcome measures were severe underweight, stunting and wasting defined as *z*-scores for WAZ, HAZ and BMI-*z* of less than –3, respectively. While it is heuristic to characterize the nutritional status of a growing child with reference to a growth standard, these nutritional indices essentially reflect undernourished physical status and may also, to a lesser degree, be related to non-nutritional factors.

BMI-z was chosen in place of WHZ as the outcome variable for wasting because of the larger number of missing data with WHZ resulting from the exclusion of all infants whose height fell below 45 cm in the WHO-MGR. Additionally, as BMI-z is based on age-specific centiles, it would appear to be conceptually more useful than WHZ in infancy (Nash *et al*. 2008).

In order to reflect the co-morbidity of all the three nutritional deficits, a composite index termed 'any severe undernutrition' defined as WAZ, HAZ and/or BMI-z < –3 SD was further introduced (Nandy *et al*. 2005; Berger *et al*. 2008). The composite index provides a more broad-based signal of multiple anthropometric failures and the need for timely intervention to improve breastfeeding practices before the weaning period. All severely undernourished infants based on the composite nutritional index were regarded as cases. Controls were chosen from among infants without any malnutrition as defined by the z-scores within the range of ± 2.00 SD for all the nutritional indices. All preterm infants with gestational age below 37 weeks were excluded from our analysis. Gestational age was based on the number of days between the first day of the last menstrual period (LMP) as reported by mothers and the date of delivery expressed in completed weeks after LMP. The places of delivery consisted of hospitals (publicly owned or private owned) and non-hospitals (traditional maternity homes run by traditional birth attendants, participant's residence, church premises or born before arrival in hospital).

Data management and statistical analysis

Gender-specific z-scores for the three nutritional indices were obtained from the macro provided by the WHO (2006). Default settings in the software regarding cut-offs for out-of-range or biologically improbable values were used in the data analysis and all such values were recorded as missing data. A descriptive overview of the pattern of severe undernutrition in the study population based on the individual nutritional indices was first presented. Thereafter, the association between place of delivery and 'any severe undernutrition' was explored with Pearson χ^2 test. OR and the corresponding 95% CI were estimated using both conditional and unconditional logistic regression analyses to ascertain the robustness of the results. Factors associated with the conventional indices were also explored separately and compared with the results from the composite index. The potential confounding variables of interest were guided by evidence from this study population and the literature and included maternal age, parity, education, occupation, type of housing (with or without shared sanitation), antenatal care, multiple gestation, hyperbilirubinaemia requiring phototherapy and hospital admission for neonatal illness (Espo *et al*. 2002; Rahman *et al*. 2009; Olusanya *et al*. 2010). Variables entered into the logistic model were those with two-sided critical level of approximately $P \leq 0.10$ in the univariate analysis. Model calibration was verified with the Hosmer–Lemeshow test. SPSS for Windows version 16.0 (SPSS Inc, Chicago, IL, USA) was used for all statistical analyses.

Results

Of the 7075 eligible mother–infant pairs, a total of 5990 infants (mean age 16.7 ± 18.3 days) with complete anthropometric data were enrolled for this study. After excluding all preterm infants and those with biologically implausible data, a total of 918 severely undernourished infants (mean age 23.5 ± 21.3 days) were enlisted as cases, more than half (549 or 59.8%) of whom were female. Some 53 (5.8%) were severely undernourished by all three nutritional deficits, 180 (19.6%) by any two deficits and 685 (74.6%) by only one deficit. Of the cases, 301 (32.8%) were severely underweight, 693 (75.5%) were severely stunted and 210 (22.9%) were severely wasted. A total of 1836 infants without any form of undernourishment were selected as controls and matched by age and gender. The maternal and infant characteristics of the cases and their controls are shown in Table 1. Majority or more than half of the mothers of both cases and controls were multiparous, self-employed usually in small-scale trading activities, lived in housing with shared sanitation, attended antenatal care clinics and delivered outside hospitals. Almost all mothers (approximately 99%) of both cases and controls reported that their infants were

Table 1. Characteristics of infants with any severe undernutrition compared with non-malnourished infants

Profile	Cases $n = 918$	Controls $n = 1836$	Unadjusted odds ratios (95% CI)	
			Unmatched	Matched
Maternal factors				
Maternal age (Years) [a]				
<20	45 (4.9)	48 (2.6)	1.92 (1.27–2.91)**	1.93 (1.27–2.93)**
20–35	800 (87.3)	1640 (89.5)	Reference	Reference
>35	71 (7.8)	144 (7.9)	1.01 (0.75–1.36)	1.02 (0.76–1.37)
Parity				
Primiparous	414 (45.1)	707 (38.5)	Reference	Reference
Multiparous	504 (54.9)	1129 (61.5)	0.76 (0.65–0.90)**	0.76 (0.65–0.89)**
Education				
None	29 (3.2)	46 (2.5)	Reference	Reference
Primary/secondary	768 (83.7)	1499 (81.6)	0.81 (0.51–1.30)	0.81 (0.50–1.31)
Post-secondary	121 (13.2)	29 (41.8)	0.66 (0.40–1.10)	0.66 (0.39–1.10)
Occupation				
None	123 (13.4)	232 (12.6)	Reference	Reference
Informal	591 (64.4)	1202 (65.5)	0.93 (0.73–1.18)	0.93 (0.73–1.18)
Formal/regular	204 (22.2)	402 (21.9)	0.96 (0.73–1.26)	0.96 (0.72–1.27)
Antenatal care				
Yes	909 (99.0)	1800 (98.0)	Reference	Reference
None	9 (1.0)	36 (2.0)	0.50 (0.24–1.03)	0.49 (0.24–1.03)
House with shared sanitation				
None	84 (9.2)	215 (11.7)	Reference	Reference
Yes	834 (64.4)	1621 (88.3)	1.32 (1.01–1.72)*	1.34 (1.02–1.76)*
Place of delivery				
Hospital	406 (44.2)	866 (47.2)	Reference	Reference
Outside hospital	512 (55.8)	970 (52.8)	1.13 (0.96–1.32)	1.13 (0.96–1.32)
Infant factors				
Gestational type				
Singleton	878 (95.6)	1815 (98.9)	Reference	Reference
Multiple	40 (4.4)	21 (1.1)	3.94 (2.31–6.72)***	3.93 (2.30–6.74)***
Hospital admission after birth				
No	891 (97.1)	1761 (95.9)	Reference	Reference
Yes	27 (2.9)	75 (4.1)	0.71 (0.46–1.11)	0.70 (0.44–1.11)
Hyperbilirubinaemia				
No	849 (92.5)	1777 (96.8)	Reference	Reference
Yes	69 (7.5)	59 (3.2)	2.45 (1.71–3.50)***	2.46 (1.72–3.53)***

CI, confidence interval. Missing data: [a] = 6 (0.2%). *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

exclusively breastfed. In both the unmatched and matched analyses, there were statistically significant differences in maternal age, parity, housing sanitation type, gestational type and hyperbilirubinaemia between cases and controls. There was no significant difference between infants born outside hospitals as a group compared with those born in hospitals ($P = 0.144$). However, a significant difference ($P < 0.001$) between cases and controls was observed when place of delivery was disaggregated into the various types. The differences between the two groups on education ($P = 0.124$), antenatal care ($P = 0.056$) and hospital admission for illness ($P = 0.134$) were considered of borderline significance at $P \leq 0.10$ and enlisted as additional adjustment variables for the regression modelling.

A comparison of cases and controls based on various places of delivery is presented in Table 2. Delivery in traditional maternity homes was the most common among mothers in both groups accounting for at least 40% of all deliveries or 75% on non-hospital delivery. Private hospitals accounted for over half of those who delivered in health facilities. Infants delivered at residential homes compared with public

Table 2. Severe malnutrition associated with place of delivery after conditional logistic regression analysis

Place of delivery	Cases $n = 918$ (%)	Controls $n = 1836$ (%)	Severe underweight $n = 301$	Severe stunting $n = 693$	Severe wasting $n = 210$	Any severe undernutrition
			Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)
Hospital						
Publicly owned	177 (19.3)	423 (23.0)	Reference	Reference	Reference	Reference
Privately owned	229 (24.9)	443 (24.1)	1.08 (0.66–1.76)	1.38 (1.03–1.69)*	1.11 (0.62–1.97)	1.23 (0.95–1.59)
Outside hospital						
Traditional maternity homes	385 (41.9)	777 (42.3)	1.35 (0.86–2.14)	1.17 (0.88–1.56)	1.24 (0.73–2.10)	1.21 (0.95–1.54)
Residential homes	82 (8.9)	90 (4.9)	2.98 (1.51–5.88)**	2.33 (1.50–3.60)***	2.90 (1.32–6.37)**	2.17 (1.49–3.17)***
Church premises	40 (4.4)	98 (5.3)	1.13 (0.51–2.50)	0.89 (0.53–1.47)	1.55 (0.65–3.72)	0.95 (0.62–1.46)
Born before arrival in hospital	5 (0.5)	5 (0.3)	1.26 (0.11–14.31)	0.35 (0.04–3.32)	–	2.00 (0.53–7.61)
Hosmer–Lemeshow test			$P = 0.217$	$P = 0.971$	$P = 0.795$	$P = 0.634$

CI, confidence interval. $*P < 0.05$; $**P < 0.01$; $***P < 0.001$. All models adjusted for maternal age, parity, education, type of housing sanitation, antenatal care, multiple gestation, hospital admission for neonatal illness and hyperbilirubinaemia requiring phototherapy.

hospitals had twofold odds of being severely undernourished after adjusting for maternal age, parity, education, housing sanitation type, antenatal care, multiple gestations, hospital admission for neonatal illness and hyperbilirubinaemia in the conditional logistic regression. Further breakdown showed that these infants had almost threefold odds of being severely underweight ($P = 0.002$) or severely wasted ($P = 0.008$) and over twofold odds of being severely stunted ($P < 0.001$). Infants delivered in private hospitals were also at increased risk of severe stunting ($P = 0.032$). All the logistic models were satisfactorily calibrated based on the selected covariates.

An overview on the pattern of severity among the cases across the place of birth is presented in Table 3. Severe stunting was the most prevalent, while traditional maternity homes accounted for at least one-third of infants with all nutritional deficits. The more severe undernutrition (z-score <4.00) was most common among infants born in traditional maternity homes. No infant had severe wasting with z-score <–5.00 across all places of birth.

Discussion

Against the backdrop of the commonly reported problem of late presentation and case finding in developing countries, this study has demonstrated that home delivery is an important marker for infants who are likely to suffer severe acute and chronic malnutrition in early infancy, while infants born in private hospitals were also at an increased risk of severe stunting. Perhaps more notably, the study has also demonstrated that beyond the well-documented maternal and perinatal mortality risks commonly associated with home delivery (Lawn *et al*. 2005; Ronsmans *et al*. 2006), the surviving infants are still at risk of severe malnutrition. However, a good proportion of such infants can be detected early when they attend community-based clinics for routine childhood immunization. These findings complement an earlier report on the prevalence and risk factors for moderate-to-severe undernutrition that was limited to merely comparing infants delivered outside hospitals with those delivered in hospitals (public and private) as a group (Olusanya *et al*. 2010). Additionally, in this earlier

Table 3. Severity of malnutrition in early infancy across place of delivery

Place of delivery	Total $n = 918$	WAZ			HAZ			BMI-*z*		
		A (%)	B (%)	C (%)	A (%)	B (%)	C (%)	A (%)	B (%)	C (%)
Hospital										
Publicly owned	177	36 (20.3)	13 (7.3)	3 (1.7)	95 (55.2)	26 (15.1)	14 (8.1)	34 (19.9)	4 (2.3)	–
Privately owned	229	47 (20.5)	15 (6.6)	8 (3.5)	130 (58.6)	41 (18.5)	14 (6.3)	34 (15.2)	12 (5.4)	–
Outside hospital										
Traditional maternity homes	385	88 (22.9)	34 (8.8)	11 (2.9)	198 (52.5)	64 (17.0)	16 (4.2)	67 (18.6)	22 (6.1)	–
Residential homes	82	18 (22.0)	13 (15.9)	0 (0.0)	45 (54.9)	19 (23.2)	2 (2.4)	13 (16.5)	8 (10.1)	–
Church premises	40	10 (25.0)	2 (5.0)	1 (2.5)	21 (52.5)	6 (15.0)	1 (2.5)	10 (27.0)	2 (5.4)	–
Born before arrival in hospital	5	2 (40.0)	0 (0.0)	0 (0.0)	1 (20.0)	0 (0.0)	0 (0.0)	3 (60.0)	1 (20.0)	–
Missing data		0			20 (2.2%)			42 (4.6%)		

z-score categories: A = –4.01 to –3.01; B = –5.00 to –4.01; C = –6.00 to –5.01.

study, which is one of the very few that have reported the prevalence of severe undernutrition in early infancy, the prevalence of severe underweight was 5.4%, severe stunting was 12.5% and severe wasting was 3.7% of the overall population.

The findings in the current study are not entirely surprising but are seldom recognized as potential indicators for high-risk infants. The vast majority of mothers who are economically disadvantaged and are unable to afford delivery in hospitals or even in traditional maternity homes are likely to deliver at home. The average delivery fee paid as reported by mothers in this population is the local equivalent of US$88 for private hospital, US$66 for government hospital, US$42 for herbal homes and US$32 for delivery at church premises (data not shown). This excludes other essential expenses that must be borne for the care of the newborn and the often elaborate traditional naming ceremony. One study from Bangladesh also found that children delivered at home were 1.5 times more likely to be moderately wasted than those born in hospital (Rahman *et al*. 2009). This (Bangladesh) study may have been less sensitive in linking severe malnutrition because of methodological differences such as the use of weight for height and the WHO/National Center for Health Statistics (NCHS) reference population. Moreover, the WHO-MGR has been shown to classify up to eight times more children as severely malnourished with fewer medical complications and requiring shorter durations of treatment compared with WHO/NCHS (Isanaka *et al*. 2009). Another study from rural Malawi only established an association between home delivery and severe stunting (Espo *et al*. 2002).

Mothers who deliver at home lack access to a range of post-delivery health talks and support on newborn care including feeding practices mostly provided in hospitals which may also account for the observed malnutrition in early infancy underpinned by suboptimal feeding. This may be exacerbated by the quest to earn a living through informal activities with irregular work hours besides the possible impact of delayed initiation of breastfeeding, insufficient breast milk, unsuccessful lactation and illness episodes in mother or child and poor living conditions. Poverty is a well-established cause of severe acute malnutrition and can be addressed effectively by improved economic well-being and dietary inputs without the need for clinical intervention if not accompanied by serious medical complications commonly attributable to infections (Collins *et al*. 2006; Bhutta *et al*. 2008; Black *et al*. 2008). Home births in developed countries may not necessarily have a similar outcome as in developing countries as they are more likely to be driven by maternal preference or the logistics of access to hospitals especially in rural/remote areas rather than financial constraints. The association between delivery in private hospitals and severe stunting is less clear and rarely investigated. It is, however, important to mention that private hospitals in this setting vary

considerably in terms of the range, quality and cost of services offered and thus warrant further studies.

Community-based management of severe malnutrition can be conducted in designated nutritional rehabilitation centres, existing primary health care or well-child clinics or the homes of the affected infants (Collins *et al*. 2006). Home-based therapeutic care is uniquely suited for treating infants delivered at home and has the advantage of eliminating the common barrier of physical, financial and social access to care. Studies have demonstrated the effectiveness of home-based administration of ready-to-use therapeutic food (RUTF) recommended by WHO (Ashworth 2006; WHO 2007). RUTF is an energy-dense food enriched with minerals and vitamins, with a comparable nutrient composition but greater energy and nutrient density than F100, which is the therapeutic diet commonly used in hospital settings (Collins *et al*. 2006; WHO 2007). It is soft and crushable without the need for adding water or refrigeration and can be used in areas where hygiene conditions are not optimal. The production process is simple and can be made from local crops with basic technology that is readily available in resource-poor countries and has greatly facilitated home-based care of severe malnutrition (Collins *et al*. 2006). It should therefore be possible to use the platform of routine immunization clinics to supply RUTF to mothers who deliver at home as a special risk group for severe malnutrition and to monitor the impact of this intervention at subsequent visits based on the schedule for routine immunization. Although exclusive breastfeeding is recommended in the first 6 months of life (Kramer & Kakuma 2002; WHO 2007), complementary feeding with RUTF may be required before the usual starting age of 6 months in view of the overriding economic circumstances of most of the mothers.

One notable feature of the current study is the strength of the evidence derived from its case–control design, careful selection of controls exclusively from well-nourished infants, adequately-powered sample size, adjustment for important confounders, satisfactory model calibration and narrow CI. In addition, the case definition based on the composite index of all three nutritional indices rather than sole reliance on the conventional index of weight-for-height *z*-scores allowed for a more realistic recognition of the co-morbidity of nutritional deficits among severely malnourished infants especially in resource-poor countries. Undoubtedly, different forms of malnutrition may be underpinned by different causes, thus requiring different treatments. For example, a severely wasted infant with acute malnutrition would require more proactive management with highly intensive treatment regimes of short duration, whereas severely stunted infants are likely to be associated with prolonged episodes of undernutrition prenatally which can only be effectively addressed through a broader nutritional intervention targeting both the mother during pregnancy and the infant over a longer duration (Bhutta *et al*. 2008). While underweight may be considered as a composite indicator of both acute and chronic malnutrition, it cannot distinguish between the two nutritional states. The case definition used in this study should therefore facilitate the timely initiation of appropriate (rehabilitative) intervention for all severely malnourished infants regardless of the distinct etiological profile and biological processes. However, the implication of the higher number of severely malnourished infants identified by this method would need to be balanced with available resources to undertake effective intervention programmes for the affected infants. Moreover, sole reliance on the composite index may miss some subtle but significant associations as exemplified by the observation between delivery in private hospitals and severe stunting.

Acute undernutrition in early infancy may also be a precursor of an imminent prolonged/chronic malnutrition in early childhood. This study has demonstrated the utility of well-child clinics for routine immunization for the timely identification of severely malnourished infants who, otherwise, would have presented late with or without medical complications. Routine childhood immunization services in primary care centres are offered at no charge to parents, thus accounting for a good uptake among mothers who delivered at home. As a result, a good proportion of high-risk infants can be readily identified using this platform by simply eliciting information on maternal place of delivery. Some study limitations are worth noting. For example, the enrolment criteria in this

retrospective cross-sectional study were prone to selection bias which may affect the external validity. However, to our knowledge there are no reasons to suggest that the findings would be materially different in comparable settings in Africa and South Asia given the fairly large sample size of the primary population. As a community-based study, clinically proven exposure variables could not be explored. Considering that undernutrition is a product of a complex web of interactions ranging from the molecular and microbiological level to the cultural and socioeconomic environment, the possibility of residual confounding could therefore not be ruled out. Moreover, it is pertinent to mention that given the variable onset of growth faltering beyond the first 3 months of life, the results of this study must necessarily be complemented with ongoing growth monitoring throughout childhood. Future prospective studies are also warranted to ascertain the performance of place of delivery as a screening tool for case finding as well as the practice implications of targeting infants delivered at home, especially in rural communities barring the challenges of routine anthropometry in this age group (Myatt *et al*. 2006).

Conclusions

In highly disadvantaged regions such as South Asia and sub-Saharan Africa, which account for a disproportionate burden of severe malnutrition worldwide, the vast majority of births occur outside hospitals. This study has demonstrated that beyond the mortality risks commonly associated with home delivery, surviving infants delivered at home in urban settings and, to a lesser degree, those delivered in private hospitals are at increased risks of severe malnutrition from early infancy. This finding would also suggest that the predominant home births in rural areas in these two regions are potentially at an elevated risk of severe malnutrition. Opportunity exists for a home-based therapeutic nutritional intervention within the framework of community-based management of severe malnutrition recommended by WHO. Existing well-child clinics for routine immunization provide a valuable platform for the timely detection of affected infants and possible monitoring of the therapeutic programme to complement primary prevention strategies for reducing the incidence and overall burden of severe malnutrition.

Acknowledgements

The support of Professor Linda Luxon and Professor Sheila Wirz of the University College London and Great Ormond Street Hospital for Children NHS Trust, UK on the substantive project that preceded this work is acknowledged.

Source of funding

None.

Conflicts of interest

The authors declare that they have no conflicts of interest.

Contributions

BOO designed the study and drafted the manuscript with contributions from JKR on data analysis, interpretation and intellectual content. Both authors reviewed and approved the final manuscript.

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