Original Article

Maternal nutrition in rural Kenya: health and socio-demographic determinants and its association with child nutrition

Constance A. Gewa*, Monica Oguttu† and Nanette S. Yandell*

*Department of Global & Community Health, College of Health & Human Services, George Mason University, Fairfax, Virginia 22030, USA, and

†Kisumu Medical and Education Trust, PO Box 6805-40103, Kisumu, Kenya

Abstract

High levels of food insecurity and human immunodeficiency virus (HIV) infection place most breastfeeding mothers in Kenya at high risk of malnutrition. We examined the role of selected socio-economic, demographic and health factors as determinants of nutritional status among HIV-infected and HIV-uninfected mothers in rural Kenya and further examined the interrelationship between maternal nutritional and child nutritional status within this population. A cross-sectional design was used to collect data from non-pregnant mothers with children ages 4–24 months in Kisumu District, Kenya. Over 80% of the mothers were breastfeeding at the time of the study. Mean maternal body mass index (BMI) (21.60 ± 3.15) and percent body fat (22.29 ± 4.86) values were lower than among lactating mothers in other Sub-Sahara African countries. Maternal HIV status was not significantly associated with any of the maternal nutritional indicators assessed in the study. Breastfeeding, recent severe illness and having multiple children below 2 years of age were negatively associated with maternal nutritional status, while higher maternal age, socio-economic status and household food security were each positively associated with maternal nutritional status. Significant positive association was reported between maternal weight, height, BMI, mid-upper arm circumference (MUAC), body fat and fat-free mass estimates, and children's height-for-age, weight-for-age, weight-for-height and MUAC-for-age z-score. This analysis identifies determinants of maternal nutritional status in rural Kenya and highlights the importance of interventions that address malnutrition in both HIV-infected and HIV-uninfected mothers in rural Kenya. Significant association between maternal and child nutritional status stresses the importance of addressing maternal and young child nutritional status as interrelated factors.

Keywords: maternal malnutrition, HIV, Kenya.

Correspondence: Constance A. Gewa, Department of Global & Community Health, College of Health & Human Services, George Mason University, 4400 University Drive, MS 5B7, Fairfax, VA 22030, USA. E-mail: cgewa@gmu.edu

Introduction

Maternal nutritional status plays an important role in women and children's health. Previous studies have documented the importance of adequate maternal nutritional status on milk production and maternal and child health outcomes including amount and concentration of breast milk energy and fat (Brown *et al.*

1986). Among human immunodeficiency virus (HIV)-infected mothers, adequate maternal nutritional status has been associated with lower maternal morbidity and mortality, child mortality, reduced risk of disease progression and HIV transmission through breastfeeding (Taha *et al.* 2006; Mehta *et al.* 2007). Poor maternal nutritional status may also impact a mother's ability to seek and utilize services aimed at

improving her welfare and that of the child. Maternal malnutrition remains a burden to many communities in Africa (Lartey 2008). A recent analysis demonstrated the presence of multiple nutrient deficiencies among HIV-infected and HIV-uninfected lactating mothers in rural South Africa (Papathakis *et al.* 2007). The energy and nutrient burden associated with lactation may be more aggravating especially for mothers who often start their pregnancy in poor nutritional and health status as is often seen in low socio-economic communities (Allen *et al.* 1994). High levels of food insecurity and HIV infection in Kenya place most breastfeeding mothers in this country at high risk of malnutrition [United Nations Human Settlements Programme (UN-HABITAT) 2006; National AIDS and STI Control Programme (NASCOP) 2009; International Food Policy Research Institute (IFPRI) 2010]. Despite this, few studies have highlighted the nutritional status of mothers with infants and young children in Kenya (Ettyang *et al.* 2003, 2005). Furthermore, information on determinants of maternal nutritional status at post-partum in Kenya is generally lacking. It is imperative that these determinants be examined in order to effectively implement prevention and intervention programmes and policies that directly address the health outcomes of children and mothers. In this analysis, we examined the role of selected socio-economic, demographic and health factors as determinants of nutritional status among HIV-infected and HIV-uninfected mothers in rural Kenya and further examined the interrelationship between maternal nutritional and child nutritional status within this population.

Subjects and methods

Methods

Mother-child (singleton) pairs were recruited through two post-natal Maternal & Child Health (MCH) clinics in the rural parts of Winam Division located in Kisumu East District in Kenya. Kisumu East District reports relatively high levels of poor health outcomes including high infant, under-five and mortality and high levels of child malnutrition and food insecurity [UN-HABITAT 2006; Ministry of Public Health & Sanitation (MOPHS 2009)]. The study area is predominantly inhabited by the Luo tribe and is served by two main Catholic mission area hospitals that are located to serve populations in the upper zone and lower zone of the division. The study inclusion criteria were non-pregnant mothers with children ages 4–24 months who resided within the study location. Maternal HIV status was noted from the clinic records, and separate sampling frames were created for HIV-infected and HIV-uninfected mothers. Because of their low numbers, all eligible HIV-infected mothers were approached and requested to participate in the study. A computer-generated simple random sample of eligible HIV-uninfected mothers was created using SAS Version 9.1 (SAS Institute, Cary, NC, USA). All HIV-infected and randomly selected HIV-uninfected mothers were visited at their home and requested to participate in the study. Community health workers (CHWs), with a minimum of high school level of education, were trained to recruit, take body measurements, conduct interviews and record data as per the study protocol.

Key messages

- BMI and percent body fat estimates among post-partum HIV-infected and HIV-uninfected mothers in rural Kenya are lower than that documented among lactating mothers in Sub-Saharan Africa.
- Maternal HIV status was not significantly associated with maternal nutritional status estimates among post-partum mothers in rural Kenya.
- Breastfeeding, having multiple children under 2 years old, severe illness, maternal age, food security and SES were significantly associated with maternal nutritional status.
- Study documents presence of positive association between maternal and young children's nutritional status.
- Children of HIV-infected mothers had significantly lower HAZ, WAZ and HCAZ values compared with children of HIV-uninfected mothers.

A total of 53 HIV-infected and 115 HIV-uninfected mothers were recruited through the upper zone clinic, and a total of 33 HIV-infected and 145 HIV-uninfected mothers were recruited through the lower zone clinic bringing the numbers to 86 and 260 for HIV-infected and HIV-uninfected mothers, respectively. Participation rates varied by maternal HIV status (66% among HIV-positive mothers and 89% among HIV-negative mothers) and by zones (80% in the upper zone and 85% in the lower zone) giving an overall participation rate of 82%. Data collection began in July 2009 and lasted 2 months. All communication with the respondents was carried out in the local *Dholuo* language. Human subjects approval was obtained for the research study from the George Mason University and Kenya Medical Research Institute. Health officers and the local community leaders were informed in detail about the aim and procedures of the study. Informed written and verbal consent and assent by mothers of study children was obtained before the study.

Anthropometry

Anthropometric measurements were assessed at the research office based within the clinic precincts. Mothers were asked to remove their shoes and to change into standard lightweight clothes (sleeveless shirt and skirt) provided by the research team before any anthropometric assessments were taken. All measurements were taken to ensure privacy of the study participants. Two separate measures were taken by a pair of trained CHWs. A second set of measures were taken if the difference between the first set of measures were beyond set points: 0.1 kg for weight, 0.5 cm for height, 0.2 cm for mid-upper arm circumference (MUAC) and 2 mm for skinfolds. All anthropometric measurements followed the procedures described in Lohman *et al.* (1988). Body weight was measured using a portable electronic scale (Pelstar LLC, Bridgeview, IL, USA). Mother's height was measured using a portable adult/infant measuring unit (Perspective Enterprises, Portage, MI, USA). The height measurement was read to the nearest 0.1 cm once correct positioning was confirmed. Maternal body mass index (BMI) was com-

puted as weight in kilograms divided by the square of height in meters. The MUAC was measured on the left arm to the nearest 0.1 cm using a MUAC insertion tape (Abbott Laboratories Inc., Columbus, OH, USA). The 'Lange' brand calipers (Beta Technology, Santa Cruz, CA, USA) was used to measure skinfold thickness to the nearest millimetre. Skinfold measurements included triceps, biceps, subscapular suprailiac and abdomen. Triceps, biceps, subscapular and suprailiac skinfolds were measured on the left side of the body. Maternal body density was estimated from the sum of skinfolds at the triceps, biceps, subscapular and suprailiac and by using the age-appropriate Durnin & Womersley equations, and percent body fat was estimated using the Siri equation (Durnin & Womersley 1974; Gibson 2005).

Children's clothes and shoes were removed before any anthropometric measurements were taken. Mothers were asked to hold the children while standing on the electronic weighing scale, and the children's body weight was taken by the difference method. Their length was measured using a horizontally placed portable adult/infant measuring unit. Head circumference, MUAC and skinfold thickness were measured with the child seated and supported in an upright position on the mother's lap. Both head circumference and MUAC were measured to the nearest 0.1 cm using an insertion tape. Skinfold thickness assessment included measurements at the triceps, biceps and subscapular locations. MUAC and skinfold measurements were made on the left side of the body. The World Health Organization (WHO) 2006 growth reference standards, which uses the WHO Multicenter Growth Reference Study population, was used to transform children's measurements into sex- and age-specific *z*-scores: length-for-age *z*-score (LAZ), weight-for-age *z*-score (WAZ), weight-for-length *z*-score (WLZ), MUAC-for-age *z*-score (MCAZ) and head circumference-for-age *z*-score (HCAZ) (WHO 2007). Stunting was defined as LAZ below $-2SD$, underweight was defined as WAZ below $-2SD$, wasting was defined as WHZ below $-2SD$, low MUAC was defined as MCAZ below $-2SD$ while low head circumference was defined as HCAZ below $-2SD$.

Food-related factors

Household food insecurity was assessed using the household food insecurity access scale (HFIAS) version 3 (Coates *et al.* 2007). The scale has been shown to be a valid and reliable tool in measuring household food insecurity among poor households in rural Tanzania (Knueppel *et al.* 2010). The HFIAS questions focus on the household food security situation in the previous 4 weeks and places households into four ordinal levels showing increasing household food insecurity at successive levels: food secure, mildly food insecure access, moderately food insecure access and severely food insecure access. Food secure and mildly food insecure access categories were merged to create 'food secure' category, while 'moderately food insecure access and severely food insecure access categories were merged to create 'food insecure' category. Child's breastfeeding status at the time of study was noted as part of a questionnaire on child-feeding practices. Breastfeeding duration was later calculated from the information provided.

Maternal morbidity

Mothers were asked about illness/morbidity experience in the last 7 days using open-ended and probing questions and a structured questionnaire. The questionnaire was based on a similar questionnaire previously used in Kenya and included a list of illnesses/diseases commonly found in the study area and population (Neumann *et al.* 2003). The questionnaire was administered by trained CHWs during the mothers' visit to the research offices. Signs, symptoms, changes in activity and food intake were ascertained by specific probing questions. Signs and symptoms in the questionnaire were organized by general, non-specific and specific categories, which comprised a diagnosis or illness category. Medications and visits to a health facility were verified by clinic or hospital cards when available. A morbidity score was defined to identify those with mild or severe forms of illness. Mild illness included fever without chills, chills without fever, cold/sore throat, ear problems, eye problems, mouth sore or toothache, skin rash/sores, diarrhoea, painful urination and trouble with arms or legs. Severe

illness included malaria; tuberculosis; typhoid; pneumonia; asthma; meningitis; epilepsy; measles; whooping cough; jaundice; fever and chills; combination of bed ridden, poor appetite and any of the mild conditions; combination of bed ridden and swollen/painful joint(s); combination of bed ridden and accident/injury; poor appetite and mouth sores; bloody diarrhoea and painful urination with bloody urine.

Child's birthweight/size

Child's weight at birth was either recorded from the child health cards or self-reported by the mother. In addition, mothers were asked to indicate the child's size at birth ranging from the following values: 'very small', 'smaller than average', 'average', 'larger than average' and 'very large'. 'Very small' and 'smaller than average' were merged to form 'smaller' category during analysis, while 'larger than average' and 'very large' were merged to form 'larger' category. About 20% of the children had missing information on their birthweights.

Household demographics and socio-economic status (SES)

Information on household membership was collected using questionnaires with the mother being the respondent. Information included birth dates, marital status, religion, tribe and gender of household members, and highest class attained. Household size and number of 'under-tuos' (mother's biological children under 2 years of age) within the household, maternal education level and maternal age were defined from the census data. Education levels included primary school, secondary school and post-secondary. Because of the low numbers of mothers in the post-secondary category, secondary and post-secondary education categories were merged into one 'post-primary school' category.

Information on the household SES was collected through interviews with the mothers in each household. The SES questionnaire, which has been previously used among populations in rural Kenya (Neumann *et al.* 2003), included both social and economic factors and accounted for employment,

income, land ownership and usage, education and literacy, household possessions and expenditures, types of houses, and involvement of parents in leadership and community positions. All variables were weighted, based on ranking by community leaders, and a composite SES score was developed by adding up the points, whereby a higher score represents a higher level of SES.

Data analysis

SAS Version 9.1 was used for data analysis. Twenty-five per cent of the mothers were HIV-infected. The *t*-test and chi-square procedures were utilized to make comparisons across maternal HIV status categories. The association between potential determinants and each of the maternal nutritional status indicators (BMI, MUAC, abdominal skinfold and body fat, and fat-free mass estimates) was analysed using simple regression analysis. Determinants that showed significant association with at least one of the nutritional status indicators were included in the final multiple linear regression model. Predictor variables in the multiple linear regression models included maternal HIV status indicator, maternal age and morbidity status, household SES score, multiple 'under-tuos' indicator, HFIAS, breastfeeding status and child's age. All models were assessed for goodness-of-fit, violation of regression assumptions and for presence of multicollinearity.

Multiple linear regression analysis was also used to examine the relationship between each maternal nutritional status (BMI, MUAC, abdominal skinfold and body fat, and fat-free mass estimates) and child nutritional status while adjusting for maternal HIV status and age, household SES and children's age and sex. Each reported beta value came from separate regression models between a pair of each maternal nutritional status indicator and each child nutritional status indicator. In addition, multiple logistic regression analysis was used to examine the relationship between each maternal nutritional status and the odds of a child being underweight, wasted, stunted and having low MCAZ and low HCAZ. These sets of analysis adjusted for maternal HIV status and age, household SES and children's

age and sex as well. All models were assessed for goodness-of-fit and violation of regression assumptions. Each reported odds ratio (OR) value came from separate regression models between a pair of each maternal nutritional status indicator and each child nutritional status indicator.

Results

Mean maternal age was 26.4 ± 6.2 years. Household SES ranged from 28 to 128 points with a mean of 61.6 ± 16.6 and a median of 61 points. Median household size was 5 and 84% of the mothers were married. Over 26% of them reported severe illness and over 16% of the mothers had more than one child under the age of 2 years. A majority of the households had experienced food insecurity in the previous 4 weeks. HIV-infected mothers were older, and higher percentage of them was not breastfeeding at the time of the survey compared with the HIV-uninfected mothers (Table 1).

Mean BMI was 21.6 ± 3.2 (Table 2), which is within the normal BMI range. The overall prevalence of underweight was 10%, 78% were within the normal BMI range and 12% were overweight or obese. Mean BMI, skinfold measures, MUAC, body fat mass and fat-free mass estimates did not significantly differ by maternal HIV status.

Determinants of maternal nutritional status

Increase in maternal age and household SES and household food security were each associated with significantly higher levels of maternal BMI, MUAC and body fat estimates (Table 3). Maternal BMI, MUAC and body fat estimates were significantly higher in food secure households compared with those that were food insecure. Maternal BMI, abdominal skinfold and body fat mass estimates were each significantly lower among mothers who were breastfeeding at the time of the study compared with those who were not. Maternal BMI, MUAC, abdominal skinfold and body fat and fat-free mass estimates were each significantly lower among mothers with multiple 'undertuos' compared with those with only one child under the age of 2 years, and abdominal

Table 1. Socio-economic and demographic characteristics: all and by maternal HIV status^{†‡}

	All estimate	HIV-positive estimate	HIV-negative estimate
Maternal age ^{§¶}	26.4 (6.2)	28.2* (6.0)	26.8 (6.1)
Married**	290 (84.3)	69 (80.2)	221 (85.7)
Breastfeeding**	283 (82.3)	55 (64.0)*	227 (88.0)
Severe illness**	90 (26.2)	19 (22.1)	72 (27.9)
Multiple 'U2s'*	58 (16.9)	14 (16.3)	43 (16.7)
Child's age ^{§¶}	12.1 (5.7)	12.6 (6.2)	11.9 (5.6)
Male child**	169 (49.1)	45 (52.3)	124 (48.1)
Child's size at birth**			
Smaller	44 (12.7)	9 (10.5)	35 (13.5)
Same	268 (77.9)	71 (82.5)	197 (76.3)
Larger	32 (9.4)	6 (7.0)	26 (10.2)
Household size [¶]	5.5 (2.1)	5.3 (1.8)	5.6 (2.1)
SES [¶]	61.6 (16.6)	59.6 (15.9)	62.4 (16.8)
Food insecure**	333 (96.8)	85 (98.8)	248 (96.1)

HIV, human immunodeficiency virus; SES, socio-economic status; U2s, untwos. *Mean values significantly different between maternal HIV status categories: *P*-value < 0.05. [†]*n* = 344 for all, *n* = 86 for HIV+ mothers, *n* = 258 for HIV- mothers. [‡]Estimates are number and percent unless indicated. [§]Mothers age in years; child's age in months. [¶]Estimate is mean (SD). **Estimate is number (percent).

Table 2. Maternal nutritional status: all and by maternal HIV status*

	All mean (SD)	HIV-positive mean (SD)	HIV-negative mean (SD)
BMI	21.6 (3.2)	21.2 (3.0)	21.7 (3.2)
Triceps skinfold (mm)	11.6 (4.2)	11.1 (4.4)	11.7 (4.1)
Biceps skinfold (mm)	6.0 (3.0)	5.5 (2.7)	6.2 (3.1)
Subscapular skinfold (mm)	9.5 (3.8)	9.1 (3.7)	9.7 (3.8)
Suprailiac skinfold (mm)	9.9 (4.7)	9.1 (4.4)	10.2 (4.8)
Abdominal skinfold (mm)	7.9 (3.4)	7.6 (3.4)	8.0 (3.4)
Body-fat (kg)	13.1 (4.9)	12.8 (4.8)	13.2 (5.0)
% body-fat	22.3 (4.9)	21.7 (5.0)	22.5 (4.8)
Fat-free body mass (kg)	44.3 (5.7)	44.7 (5.6)	44.2 (5.7)
MUAC (cm)	26.8 (3.6)	26.7 (3.3)	26.9 (3.6)

BMI, body mass index; HIV, human immunodeficiency virus; MUAC, mid-upper arm circumference; SD, standard deviation. **n* = 344 for all, *n* = 86 for HIV-positive mothers, *n* = 258 for HIV-negative mothers.

skinfold values were significantly lower among mothers who reported severe illness in the last 7 days compared with those who did not. Maternal HIV was not significantly associated with any of the nutritional indicators assessed in the study.

Interrelationship between maternal and child nutrition status

Children of HIV-infected mothers had significantly lower mean LAZ, WAZ and HCAZ values. A higher

percentage of children of HIV-infected mothers were undernourished compared with children of HIV-uninfected mothers: 35% vs. 19% for stunting (*P*-value = 0.003), 20% vs. 9% for underweight (*P*-value = 0.006) and 7% vs. 1% for low HCAZ (*P*-value = 0.035). No differences were noted in the mean WLZ and MCAZ values (Table 4).

Children's WAZ significantly increased with an increase in all of the maternal anthropometric measures with the exception of the maternal abdominal skinfolds (Table 5). Higher maternal MUAC

Table 3. Association of study variables and maternal anthropometric measures using multiple linear regression†

	BMI		MUAC		Abdominal skinfold		Body fat mass		Fat-free mass	
	Beta	CI	Beta	CI	Beta	CI	Beta	CI	Beta	CI
HIV+	-0.72	(-1.51, 0.08)	-0.56	(-1.40, 0.28)	-0.61	(-1.47, 0.25)	-1.04	(-2.27, 0.19)	0.07	(-1.42, 1.55)
Maternal age [§]	0.06*	(0.01, 0.11)	0.09**	(0.03, 0.15)	-0.05	(-0.11, 0.01)	0.15**	(0.07, 0.24)	0.08	(-0.02, 0.18)
Breastfeeding	-1.00*	(-1.96, -0.05)	-0.63	(-1.63, 0.38)	-1.50**	(-2.53, -0.47)	-1.73*	(-3.24, -0.21)	-1.53	(-3.36, 0.29)
Multiple 'U2s'	-0.94*	(-1.83, -0.06)	-1.42**	(-2.35, -0.48)	-1.64**	(-2.61, -0.67)	-2.03**	(-3.45, -0.61)	-1.71*	(-3.41, -0.01)
SES	0.03*	(0.01, 0.05)	0.02*	(0.01, 0.04)	0.02	(-0.01, 0.05)	0.04*	(0.01, 0.07)	0.03	(-0.01, 0.047)
Severe illness	-0.55	(-1.33, 0.22)	-0.72	(-1.54, 0.10)	-1.07*	(-1.92, -0.23)	-0.91	(-2.12, 0.29)	0.22	(-1.23, 1.67)
Food secure	2.72**	(0.72, 4.73)	2.69*	(0.65, 4.72)	1.44	(-0.65, 3.53)	3.22*	(0.15, 6.30)	2.28	(-1.42, 5.98)
Child's age [§]	0.01	(-0.05, 0.07)	0.03	(-0.03, 0.10)	0.01	(-0.06, 0.07)	0.05	(-0.05, 0.15)	0.03	(-0.09, 0.15)

Breastfeeding at time of survey; BMI, body mass index; CI, confidence interval; HIV, human immunodeficiency virus; MUAC, mid-upper arm circumference; SES, socio-economic status; U2s, under-twos. Beta estimate values are significant: * P -value < 0.05, ** P -value < 0.01. † n = 344 for all, n = 86 for HIV-positive mothers, n = 258 for HIV-negative mothers. ‡Each column represents results from one multiple linear regression model that includes maternal HIV status, age, breastfeeding status, severe illness, child's age and household SES and food security status as independent variables. §Mothers age in years; child's age in months.

Table 4. Children's nutritional status: all and by maternal HIV status†

	All mean (SD)	HIV-positive mean (SD)	HIV-negative mean (SD)
LAZ	-0.93 (1.50)	-1.19 (1.75)	-0.79* (1.31)
WAZ	-0.55 (1.29)	-0.80 (1.40)	-0.46* (1.25)
WLZ	-0.05 (1.37)	-0.15 (1.18)	-0.02 (1.42)
HCAZ	0.11 (1.17)	-0.18 (1.27)	0.21* (1.12)
MCAZ	0.22 (1.08)	0.14 (1.14)	0.25 (1.06)

HCAZ, head circumference-for-age z-score; HIV, human immunodeficiency virus; LAZ, length-for-age z-score; MCAZ, mid-upper arm circumference-for-age z-score; WAZ, weight-for-age z-score; WLZ, weight-for-length z-score; SD, standard deviation. *Mean values significantly different between maternal HIV status categories: P -value < 0.05. † n = 344 for all, n = 86 for those children of HIV-positive mothers, n = 258 for children of HIV-negative mothers.

{OR = 0.87 [confidence interval (CI): 0.77–0.99]} and body fat [OR = 0.91 (CI: 0.83–0.99)] were significantly associated with lower odds of child being underweight.

WHZ significantly increased with an increase in all of the maternal anthropometric measures with the exception of maternal height and abdominal skinfold values. Children's MCAZ significantly increased in all of the maternal anthropometric measures with the exception of the maternal height and fat-free mass values. However, not one of the maternal anthropometric measures were significantly associated with odds of children being wasted or having MCAZ < -2.

LAZ significantly increased with an increase in maternal weight, height, body fat and fat-free mass. Higher maternal weight [OR = 0.96 (CI: 0.93–0.99)], height [OR = 0.95 (CI: 0.91–0.99)], body fat [OR = 0.91 (CI: 0.86–0.98)] and fat-free mass [OR = 0.93 (CI: 0.88–0.98)] were each associated significantly lower odds of child stunted. HCAZ significantly increased with an increase in maternal weight and body fat mass. However, none of the maternal anthropometric measures were significantly associated with odds of children having HCAZ < -2. A majority of the significant associations were maintained even after excluding mothers with severe illness.

Discussion

HIV-infected and HIV-uninfected mothers were similar in most aspects assessed in the study with the

Table 5. Association of maternal nutritional indicators and child nutritional status using multiple linear regression^{†‡§}

	LAZ		WAZ		WLZ		HCAZ		MCAZ	
	Beta	CI	Beta	CI	Beta	CI	Beta	CI	Beta	CI
Weight	0.02**	(0.01, 0.04)	0.03**	(0.01, 0.04)	0.02**	(0.01, 0.04)	0.01*	(0.01, 0.03)	0.02**	(0.01, 0.03)
Height	0.03**	(0.01, 0.06)	0.03**	(0.01, 0.05)	0.01	(−0.01, 0.04)	0.01	(−0.01, 0.03)	0.01	(−0.01, 0.03)
BMI	0.04	(−0.01, 0.09)	0.07**	(0.02, 0.11)	0.07**	(0.02, 0.11)	0.03	(−0.01, 0.07)	0.05**	(0.01, 0.09)
MUAC	0.04	(−0.01, 0.08)	0.06**	(0.02, 0.10)	0.05*	(0.01, 0.049)	0.02	(−0.01, 0.06)	0.06**	(0.03, 0.09)
Abdominal skinfold	0.01	(−0.04, 0.05)	0.01	(−0.04, 0.04)	0.01	(−0.04, 0.05)	0.01	(−0.03, 0.04)	0.05**	(0.01, 0.08)
Body fat mass	0.04*	(0.01, 0.07)	0.05**	(0.02, 0.08)	0.05**	(0.02, 0.08)	0.03*	(0.01, 0.05)	0.04**	(0.02, 0.07)
Fat-free body mass	0.04**	(0.01, 0.07)	0.05**	(0.02, 0.07)	0.04**	(0.01, 0.06)	0.02	(−0.01, 0.04)	0.02	(−0.01, 0.04)

BMI, body mass index; CI, confidence interval; HCAZ, head circumference-for-age z-score; LAZ, length-for-age z-score; MCAZ, mid-upper arm circumference-for-age z-score; MUAC, mid-upper arm circumference; SES, socio-economic status; WAZ, weight-for-age z-score; WLZ, weight-for-length z-score. Beta estimate values are significant: **P*-value < 0.05, ***P*-value < 0.01. [†]*n* = 344 for all, *n* = 86 for those children of HIV-positive mothers, *n* = 258 for children of HIV-negative mothers. [‡]Adjusted for maternal HIV status and age, household SES and children's age and sex.

[§]Each beta comes from a separate full regression model.

exception of age and breastfeeding status at the time of the study. In addition, a majority of mothers considered their children's birth size to be similar to those of other children in the community and a large percentage of the households suffered food insecurity in the previous 4 weeks. However, a higher percentage of the HIV-uninfected mothers reported severe illness although the difference was not statistically significant.

Mean maternal anthropometric measurements did not differ by maternal HIV status, indicating that there are other overarching factors that influence maternal nutritional status beyond HIV status. This finding is similar to that reported among lactating women in South Africa (Papathakis *et al.* 2005). Mean maternal BMI was within the normal BMI range with only 10% of the mothers having low BMI values. The mean BMI reported in this study is similar to that reported among lactating mothers in Nandi district of Kenya and higher than that reported among mothers in Pokot district of Kenya (Ettyang *et al.* 2003, 2005). However, the mean BMI was lower than that reported among breastfeeding mothers in Nigeria and among HIV-infected and HIV-uninfected lactating mothers in South Africa (Papathakis *et al.* 2005; Ijarotimi 2010). Percentage of body fat was lower than that among mothers in Nandi district of Kenya, lactating mothers in South Africa and among HIV-uninfected women in Zaire (Kotler *et al.* 1999; Ettyang *et al.* 2003; Papathakis

et al. 2005). Comparing HIV-infected women across Africa findings indicate that fat mass and percent body fat among the HIV-infected mothers was higher in our study than reported among HIV-infected women in Zaire but lower than reported among HIV-infected lactating mothers in South Africa (Kotler *et al.* 1999; Papathakis *et al.* 2005).

Having multiple children under the age of two and breastfeeding at the time of study were associated with significantly lower values of a majority of the maternal anthropometric measure included in this study. Multiple children under the age of two may indicate relatively short birth intervals between the respective children and a possible overlap of breastfeeding and pregnancy. A recent review on birth spacing and maternal nutrition showed mixed results with studies in both developed and developing nations reporting a positive, negative and non-significant association between maternal nutrition and various measures of birth spacing (Dewey & Cohen 2007). The review attributed such varied results to differences in study designs, variable definitions and types of outcomes assessed. Despite the results, short birth intervals may interfere with the mother's ability to build up required nutrient stores especially in the presence of limited food and health resources.

Breastfeeding at the time of the study was associated with significantly lower values of a majority of the maternal anthropometric measure. Over 80% of the mothers enrolled in the study were still breast-

feeding. Lactation is associated with higher energy and nutrient demands on mothers which if not met, may lead to poor maternal nutritional status (Otten *et al.* 2006). Such an impact will vary based on breastfeeding duration and intensity in addition to maternal nutritional stores, supplies and other demands (Butte & Hopkinson 1998). Studies on the role of lactation on maternal nutritional status have been mixed with some studies showing positive and negative effects and even non-significant results. Despite these differences, a review of the literature concluded that lactation in itself appears to be a minor contributor to the overall variability noted in the post-partum weight change (Butte & Hopkinson 1998). In addition, women may gain their weight back once they stopped breastfeeding. However, the extent to which women may gain or lose weight is likely to depend on the availability of supportive resources. Filipino and Bangladeshi mothers were reported to lose weight while breastfeeding and to start gaining weight once they had stopped breastfeeding (Winkvist & Rasmussen 1999). Studies on lactation and maternal nutritional status in the presence of HIV infection have shown mixed results as well. An earlier clinical trial among HIV-infected Kenyan women suggested presence of weight loss among breastfeeding mothers, and a more recent trial among HIV-infected Kenyan women reported significantly higher BMI decline among current breastfeeders at each follow-up time point compared with mothers who never breastfed (Nduati *et al.* 2001; Otieno *et al.* 2007). On the other hand, an observational study among HIV-infected Tanzanian mothers reported no significant association between breastfeeding status and weight loss of more than 10% (Sedgh *et al.* 2004). Such mixed results may arise from differences in study design as well as outcome definition. Overall, more consistent results have been noted with respect to body fatness and composition with mothers in most low-income countries as a decrease in skinfold thickness and/or body fatness during lactation (Dorea 1997; Winkvist & Rasmussen 1999). The current study shows a negative association between current breastfeeding and body composition as measured by BMI, abdominal skinfold measure and body fat levels, thus highlighting the importance of assessing maternal nutritional status

during the lactation period. Inadequate maternal nutritional status has been associated with poor breast milk indicators and maternal and child health outcomes and should be prevented or treated in a timely manner (Miranda *et al.* 1983; Brown *et al.* 1986; Taha *et al.* 2006; Mehta *et al.* 2007).

Presence of severe illness in the last week was significantly associated with lower abdominal skinfold values. Severe illness impacts nutritional status through reduced intake and/or increased nutrient losses, thus decreasing nutrient supplies while increasing demands on maternal nutrient stores and leading to poor nutritional status (Semba & Bloem 2008). A previous study of Filipino lactating mothers indicated the presence of severe respiratory morbidity associated with significantly lower maternal weight (Adair & Popkin 1992). Maternal age was associated with higher body fat estimates and MUAC values indicating an increase in fat stores among older mothers. The associations between maternal age and body fat and MUAC were in the expected direction. MUAC and body composition measures such as BMI and skinfolds among adults have been shown to increase with age (Durnin & Womersley 1974; Adair & Popkin 1992; Gibson 2005).

Food secure households were associated with significantly higher levels of maternal BMI, MUAC and body fat mass compared with food insecure households. Household food insecurity has been associated with inadequate energy and nutrient intake and malnutrition among household members (Oldewage-Theron *et al.* 2006; Knueppel *et al.* 2010). Households that suffer high levels of food insecurity are also more likely to lack other resources including adequate sanitation and health care resources. Household SES was associated with significantly higher values in three of the five anthropometric measures included in the current study. Malnutrition has been shown to be disproportionately higher among those of lower SES within different countries (Van de Poel *et al.* 2008). Low household SES is often associated with limited access to resources known to influence nutritional status such as food and health care. Because the current analysis has controlled for household food insecurity and illness severity, the reported SES effect goes beyond these two factors and may represent a

broader and more long-term effect of SES on maternal nutritional status in the study area.

This study demonstrated the presence of significant positive association between maternal anthropometric status and child nutritional status independent of maternal HIV status and age, household SES and children's age and sex. This interrelationship could be a result of both genetic and/or environmental factors. A majority of children in this study were still breastfeeding, and thus depended on a significant amount of their nutrient intake from breast milk. Children in developing countries consume a significant percentage of their daily energy intake from breast milk (Brown *et al.* 1998). However, the shared environment would impact a child's nutritional status through a number of factors including breastfeeding practices, access to quality foods and health care resources. Although we did not have any information on children's HIV status, shared maternal and child HIV status are likely to contribute to the reported significant associations. The significant interrelationship between maternal and child nutritional status is similar to that shown between mothers and their children in Bangladesh, Ethiopia and Brazil (Rahman *et al.* 1993; Engstrom & Anjos 1999; Girma & Genebo 2002; Silveira *et al.* 2010). The nutrition Collaborative Research Support Program (CRSP) studies reported significant positive correlations between maternal lean mass and infant weight and length, and between maternal BMI and infant length at 3–6 months post-partum (Allen *et al.* 1994). The current analysis shows the presence of a positive relationship between multiple maternal body size and composition indicators and child nutritional status indicators. Children of HIV-infected mothers had significantly lower HAZ, WAZ and HCAZ values compared with children of HIV-uninfected mothers. Such differences should be further examined to provide a better understanding of child nutritional status in the presence of maternal HIV infection.

The strength of the current analysis lies in our ability to control for multiple factors including maternal HIV status and age, household SES and children's age and sex. The study's limitation lies in the lack of adjustment of pre-pregnancy weight or BMI and

pregnancy weight gain (Allen *et al.* 1994) and lack of adjustment for children's HIV status when examining the interrelationship between maternal and child nutritional status. Timely paediatric HIV diagnosis is still lacking in many low-income nations as a result of low levels acceptance by parents and limited resources among other possible reasons (Vreeman *et al.* 2010), while inclusion of pregnancy nutrition status from a rural Kenyan population would be best achieved through a longitudinal study design.

This analysis adds to the literature on maternal nutritional status in rural communities in low-income nations. It demonstrates the presence of acute undernutrition as shown by the low BMI, skin-folds and body composition values among mothers in the study's population and shows that inadequate maternal nutritional status is present among both HIV-infected and HIV-uninfected mothers in this area. It contributes to the understanding of determinants of maternal nutrition in rural Kenya. Presence of interrelationship between maternal nutritional measures and child nutritional status stresses the importance of addressing maternal nutritional status with the aim of improving both maternal and child health outcomes. Poor nutritional status among HIV-infected and HIV-uninfected mothers highlights the importance of interventions that can address malnutrition in both HIV-infected and HIV-uninfected mothers in this region. The study sample was restricted to mothers who had visited the MCH clinics for delivery or post-partum infant care. Mothers who may not have access to these services are expected to have poorer nutritional status, and efforts should be made to reach them as well.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

Contributions

CAG was the Principal Investigator for research study, was responsible for the study design, conducted the research and was responsible for statistical analysis and writing of the manuscript. MO conducted the research and was responsible for writing of the manuscript. NSY was responsible for statistical analysis and writing of the manuscript. All authors read and approved the final manuscript.

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