Maternal anthropometry as a risk predictor of pregnancy outcome: the Nutrition CRSP in Kenya

C. Neumann,[1] L. Ferguson,[1] & N.O. Bwibo[2]

Background

A longitudinal study on food intake and human function in three countries, within the Nutrition Collaborative Research and Support Program (CRSP), enabled us to follow 247 Embu households in rural Kenya. Food intake, nutritional status, morbidity and a number of household and environmental characteristics were studied longitudinally for one to two years during the period, January 1984 to March 1986. From the available data it was possible to determine whether or not maternal anthropometric indicators had predictive values for identifying the risk of poor maternal pregnancy and infant outcomes. If this was so, then village health workers and traditional midwives would be able to detect women at risk for poor pregnancy outcomes and promote early intervention and referral to more expert treatment.

The 60-sq.km study area was on the south-east slope of Mount Kenya and subject to periodic drought and food shortages. As a result of seasonal food shortages and the need to sell food crops for cash, energy intake was found to be less than two-thirds of the recommended level. Animal protein intake was very low, resulting in vitamin B_{12}, zinc and iron deficiencies. The latter two were worsened by high phytate, fibre, and tea intake. Calcium and vitamin A intakes were also less than two-thirds of the recommended dietary allowance (RDA). Folic acid intake was low in 23% of the pregnant women although requirements were probably greater because of the pregnancy and malaria. Iodine deficiency was also present, with 24% of pregnant women noted to have a goitre. Biochemical evidence of low thyroid hormones was also found.

Anaemia due to nutritional deficiencies was prevalent, with endemic malaria and hookworm contributing heavily to this condition. Some 37–40% of all the women were found to be anaemic (haemoglobin <11 g/dl), with serum ferritin low in 35% of the women (cut-off point ≤10 mg/ml). Macrocytic anaemia was seen in 8.4% of the women and vitamin B_{12} levels in breast milk were found to be extremely low in the lactating women.

[1] University of California Los Angeles, School of Public Health, Los Angeles, CA, USA.

[2] University of Nairobi, Kenya.

Methodology

A sample of 290 Embu households was selected from a total of 2059 households in the study area, as determined by aerial survey and mapping. Criteria for enrolment were based on acquiring an adequate number of nuclear and intact families with the required family member types — toddlers, school-age children, and both biological parents residing continuously in the household. Also, at least 100 women were needed who would be likely to become pregnant early enough in the study so that they could be followed for at least 6 months following the birth of the infant. Of the 290 households, 247 completed the study; of these, 138 women were studied during pregnancy and lactation. Pre-pregnancy data were available for 83 out of 183 women. A total of 97 women were followed during all three trimesters, 199 were followed during the 2nd and 3rd trimesters, and 19 during the 3rd trimester only. There were 2 stillbirths, 3 perinatal deaths, and 3 miscarriages, leaving 130 women and infants to be followed during lactation and from birth till 6 months old.

Height, weight, mid-upper-arm circumference (MUAC), and six skinfolds were measured once per month. If a woman was enrolled in the first trimester of pregnancy, pre-pregnancy weight was considered to be the same as the weight at the time of enrolment, given the finding that women gained no weight and even lost some weight (on average, 0.2 kg) during the first trimester. Data on women more advanced in their pregnancies at the time of study enrolment were excluded from analyses requiring pre-pregnancy or first trimester weights.

Young women with the equivalent of a U.S. high school education were trained to carry out anthropometric measurements by the senior investigators, with special emphasis on height, MUAC and skinfold measurements. Training aimed at developing a high level of skill and accuracy for the complete range of measurements, interactions with household members, equipment maintenance and calibration, and data collection. Periodic standardization tests and retraining sessions were carried out throughout the life of the project, with a 50% validation check of all measurements performed.

Pregnancy "monitors" visited the homes once a month to inquire about signs and symptoms of pregnancy based on menstrual history, lactation, and clinical signs and symptoms of early pregnancy. Pregnancy tests were performed, on request, on over 50% of women. To determine gestational age of the newborn, Dubowitz testing was carried out on all newborns by a physician and/or trained neonatal nurse from immediately after birth till 72 hours at the latest. The majority were tested within the first 24 hours.

Study variables

Predictor variables included the following anthropometric measurements which were made during the pre-pregnancy period and during each of the trimesters of pregnancy (monthly measurements were averaged): height, weight, body mass index (BMI), and MUAC. Other predictor variables used in this analysis were maternal age, reproductive history, and haemoglobin level.

Infant outcomes included low birth weight (LBW), prematurity, intrauterine-growth retardation (IUGR), stillbirth, perinatal death, and infant growth from birth to 6 months. The definitions used are the same as those used in the meta-analysis. Infant growth was measured in terms of length, weight, and MUAC from birth to 6 months.

Maternal outcomes included delivery complications, mainly caesarean section and breech presentation, and maternal nutritional status in lactation. Pregnancy and lactation weight and fat changes were also calculated for the purpose of comparing women of different initial sizes.

Results

Low birth weight. Of the total live births, 10% of the neonates were classified as LBW. Of these, 77% were IUGR and 23% were preterm.

Table 1: **Odds ratios for low birth weight (both IUGR and pre-term), based on maternal anthropometry**

	Percentile	Cut-off	No.	OR	95% CI
Weight (kg):	25	45.0	56	9.1	1.4–57.6
Trimester 1	25	45.8	96	4.2	1.0–17.1
Trimester 2	50	52.0	115	5.3	1.1–25.3
Trimester 3	50	55.2	138	5.6	1.2–26.3
MUAC (cm):					
Trimester 2	25	23.7	115	3.5	1.0–11.8
Trimester 2	50	25.3	115	12.6	1.6–101.2
Trimester 3	25	23.6	138	2.8	0.9–9.1
Trimester 3	50	25.1	138	5.8	1.2–27.1

Odds ratios calculated from simple contingency tables indicated that both maternal weight and MUAC are potential predictors of LBW. Women below the 25th percentile in weight (approximately 45 kg) during pre-pregnancy and the first trimester of pregnancy showed an increased risk of having LBW infants. By the 2nd and 3rd trimesters women below the 50th percentile were at more than fivefold risk of a LBW infant than those who were above the 50th percentile (Table 1).

Low fat stores and muscle mass as indicated by MUAC also appeared to be risk factors for underweight infants. Increased odds ratios ranging from 3.5 to 12.6 were found for the women with smaller MUAC during the 2nd and 3rd trimesters (Table 1). Maternal height was not significantly predictive of LBW. The earlier in pregnancy a significant risk of LBW can be detected, the earlier an intervention can be initiated. Both weight and MUAC measurements are useful in this respect.

Stratified analyses of maternal weight and MUAC as risk factors for LBW, controlling for the effects of maternal height, age, and parity, indicated no significant differences between the strata. Logistic regression analyses were used to further control for the effects of non-anthropometric factors. The final model indicated that the joint effects of maternal BMI, parity, socioeconomic status, and haemoglobin, significantly affects the odds of the birth of a LBW infant. In each case a lower value of the maternal characteristic increases the odds of such a birth (Table 2). The predictive value of MUAC is subsumed when all of these other determinants can be considered, but this does not invalidate its use as a simple predictive measure.

Table 2: **Logistic regression model to predict the birth of low-birth-weight infants**

Outcome	Variable	Parameter estimate	Standard error	P (chi-squared)
LBW (n = 110)	Intercept	14.8	7.25	0.04
	BMI (trimester 2)	−0.54	0.31	0.07
Chi-sq.[a] = 21.0	MUAC (trimesters 1 and 2)	−0.02	0.30	0.95
P< 0.001 (6 df)	Parity <3	1.57	0.86	0.07
Concordance 86%	Haemoglobin	−0.34	0.20	0.10
	Socioeconomic status	−0.06	0.03	0.08
	Maternal age	0.09	0.07	0.18

[a] Chi-squared for log likelihood ratio, statistically significant.

In another set of analyses investigating changes in maternal weight and fat stores during pregnancy, it was found that the loss of fat during late pregnancy was correlated with higher birth weights and lengths, and infant MUAC. This was attributed to the ability of better nourished women to use their stores as a source of energy for the fetus during the final stages of pregnancy. These women may have lost upper-arm mass, but would still be in the upper quartiles of MUAC, given their initial size advantage.

Intrauterine growth retardation. Sixteen percent of infants were classified as IUGR. The risk factors determined from contingency tables were small maternal stature and small MUAC. Odds ratios calculated from the unstratified sample show a twofold risk of IUGR for infants born to mothers in the lower half of the sample with respect to height <154.5 cm. Insufficient pre-pregnancy fat stores were the most predictive of IUGR. Women in the lowest quartile (MUAC <24.4 cm) were at an eightfold risk of giving birth to an IUGR infant. By the 1st trimester the lowest quartile (MUAC <24.2 cm) had an odds ratio of 2.8, and during the second trimester the lower half (MUAC <25.3 cm) had an odds ratio of 2.5 compared with women with larger arm circumferences. As with the incidence of low birth weight, stratified analyses revealed no differences in risk to women of differing height, age, or parity (Table 3).

The logistic regression model for IUGR confirms the role of height in predicting this outcome. The model also includes significant parameter estimates for maternal weight, parity, number of previous stillbirths, and haemoglobin.

Table 3: **Odds ratios for intrauterine growth retardation (IUGR), based on maternal anthropometry**

	Percentile	Cut-off	No.	OR	95% CI
Height (cm):					
Pre-pregnancy	50	154.5	137	2.2	0.9–5.5
MUAC (cm):					
Pre-pregnancy	25	24.4	56	8.4	1.9–37.5
Trimester 1	25	24.2	94	2.8	0.9–8.6
Trimester 2	50	25.3	114	2.5	0.9–7.2

Table 4: **Logistic regression model to predict the birth of intrauterine-growth-retarded infants**

Outcome	Variable	Parameter estimate	Standard error	P (chi-squared)
IUGR (n = 91)	Intercept	−18.61	14.39	0.20
	Height	0.18	0.09	0.06
Chi-sq.[a] = 21.3	Weight (trimester 2)	−0.30	0.13	0.03
P = 0.006 (8 df)	MUAC (trimester 2)	0.30	0.30	0.32
Concordance 86%	Wt. change (trimester 2)	0.22	0.18	0.22
	Parity	−0.50	0.22	0.02
	Previous stillbirths	1.36	0.74	0.07
	Haemoglobin	−0.35	0.17	0.04
	Age	0.09	0.07	0.22

[a] Chi-squared for log likelihood ratio, statistically significant.

Preterm birth. Maternal anthropometry did not predict an increased risk for the birth of a preterm infant.

Maternal complications. The model for delivery complications, mainly caesarean section and breech presentation, shows that socioeconomic status, the number of previous stillbirths, and parity significantly affect the risk of problems at delivery. Decreasing maternal height and increasing maternal age also predict complications, but less strongly than socioeconomic status, previous stillbirths, and parity (Table 5).

Table 5: **Logistic regression model to predict maternal complications at delivery**

Outcome	Variable	Parameter	Standard	P
Maternal delivery complications	Intercept	12.52	12.6	0.32
	Height	−0.11	0.08	0.15
Chi-sq.[a] = 10.4	Age	0.09	0.07	0.19
P <0.03 (4 df)	Previous stillbirths	1.22	0.53	0.02
Concordance 84%	Parity	−0.28	0.17	0.08

[a] Chi-squared for log likelihood ratio, statistically significant.

Owing to the small number of complicated deliveries (n = 11), a simple analysis comparing maternal infant characteristics of complicated births versus normal births was also carried out. Statistical tests (the t-test) indicated significant differences (α = 0.5) between the mothers with regard to the number of previous abnormal deliveries, height, and net pregnancy weight gain. The infants born of complicated deliveries were also heavier and more likely to be male.

Stillbirths and miscarriages. Because the number of stillbirths, miscarriages, and abortions was small (n = 5) comparisons of relevant factors were made with normal pregnancy outcomes. Statistical tests (the t-test) were performed to see if the proportions of women with histories of poor reproductive outcomes and other visible risk factors was higher among those women with current pregnancy wastage than among those with current normal outcomes. Variables included history of stillbirths, abortion, or miscarriage; number of previous abnormal deliveries; visible goitre; and use of non-iodinated salt. Despite the small number of abnormal outcomes, statistically significant differences (α = 0.05) were found for all variables other than goitre, which was of borderline significance. A history of previous poor pregnancy outcomes was an excellent warning for a poor outcome in the current pregnancy.

Perinatal deaths. The number of perinatal deaths was only five. The striking characteristics of these infants included LBW, twin birth, prematurity, high maternal parity, and maternal weight loss during pregnancy.

Differential pregnancy weight gain in larger versus smaller women. Recent recommendations reflect the concept that higher energy intake and weight gain would seem to be indicated in malnourished women compared with normal women, to ensure normal-weight newborns and to prevent further maternal depletion. The following analyses examined pregnancy weight gain among women of different pre-pregnant size. This stratification scheme is relevant to the high prevalence of short stature and underweight women in developing countries.

Smoothed (using running medians) weight and MUAC change curves were generated for maternal weight and MUAC at the 25th, 50th and 75th percentiles for pre-pregnancy values. Included were only women giving birth to full-term, normal-weight infants (≥3000 g).

The lighter and leaner the women, the more weight they gained and less fat they lost late in pregnancy. When stratifying by maternal height, the weight gain was greatest for the shortest women, i.e., under 151 cm (25th percentile); and least for those ≥158 cm (75th percentile). This pattern was also true for BMI. In addition, the taller women experienced a larger decrease in MUAC in late pregnancy than did the shorter women. Furthermore, those taller mothers whose MUAC (presumably fat stores) decreased the most in late pregnancy gave birth to the infants with the largest weights, lengths, and MUAC. This is not contradictory to what was found in an earlier analysis on the non-stratified sample, which showed that maternal fat gain in the 2nd and 3rd trimester was positively associated with pregnancy weight and birth weight (Table 6). The beneficial fat loss occurred later in pregnancy, ostensibly providing a source of energy for the growing fetus.

Table 6: **Relationship between change in MUAC during pregnancy and infant size at birth**

Women	Infant	No.	r^a	P
Net MUAC loss during pregnancy	vs. birth weight	64	−0.29	0.02
	vs. birth length	93	−0.23	0.03
	vs. birth MUAC	62	−0.41	0.001

[a] Pearson correlation, two-tailed.

Infant growth from birth to 6 months. The mother's size upon entry into pregnancy determined, in large measure, the child's growth from birth to 6 months and the attained size. Maternal height, pre-pregnancy weight, weight during all trimesters and lactation, and BMI during pregnancy and lactation correlated positively and significantly with infant weight, length, and MUAC (except for height with infant MUAC). Regression analysis indicated that maternal height and weight each accounted for 14% of the variance in infant weight and length at 6 months. Genetic factors and a shared environment probably contribute to this correlation.

Maternal fat stores (sum of six skinfolds and MUAC) during both pregnancy and lactation also correlated positively with infant weight, length, and MUAC. More interesting were the correlations between changes in maternal stores and infant growth during the first 6 months of life. A negative relationship between MUAC change in pregnancy and subsequent infant growth in length and weight from birth to 6 months was seen. The mothers who had the largest decrease in skinfolds and MUAC during pregnancy and the first 5 months of lactation had infants who gained the least weight, fat and length from birth to 6 months of age. During lactation a gain in MUAC in the mother was associated with fatter and heavier infants. Thus, it is seen that maternal fat stores in the pre-pregnancy period and maternal fat deposition in pregnancy and lactation support infant growth. Presumably, the better nourished the mother, the better the ability to lactate.

Positive infant growth was predicated by maternal pregnancy and lactation weight, height, BMI, and MUAC. Decreases in maternal fat stores during pregnancy and lactation are represented by decreases in MUAC, a useful field measure. As with birth weight and intrauterine growth retardation, maternal anthropometry can predict infant growth outcomes.

Summary

Overall, the analyses validate the use of simple maternal anthropometric measurements to predict potential poor infant outcomes from birth to 6 months of age. The addition of a few questions about a mother's reproductive history, age, and visible medical conditions such as goitre allow for the prediction of delivery complications, pregnancy wastage, and perinatal deaths. The analyses also confirmed the need for differential nutritional and pregnancy weight-gain recommendations for women of varying pre-pregnant size. While larger and better nourished women may be able to withstand low energy intakes and loss of body fat and protein during pregnancy and lactation, shorter, leaner women with good infant outcomes demonstrate higher pregnancy weight gains and less fat loss during late pregnancy and lactation.

Reference

1. **Newmann C, Ferguson L.** *Analysis of maternal anthropometry as predictors of risk for adverse pregnancy outcome. Final report of Kenya CRSP Project.* Washington DC, USAID, 1993.