Maternal anthropometry and infant feeding practices in Israel in relation to growth in infancy: the North African Infant Feeding Study[1,2]

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ABSTRACT Relations between maternal anthropometric status during pregnancy and infant feeding practices and growth from birth through the first 6 mo of life were examined in a cohort of 351 Israeli mother-infant pairs of North African descent. Maternal weight, height, and triceps skinfold thicknesses were determined at 6 and 9 mo of pregnancy, while infants' weights and lengths were measured at birth and at 1, 2, 3, and 6 mo of age with concurrent collection of age-specific maternal-reported infant feeding data. On the basis of multiple-linear-regression analysis that adjusted for potential covariates, mean maternal weight at the first prenatal visit and at 6 and 9 mo of pregnancy were positively associated with birth length (*P* for trend in all cases < 0.0001) and with linear growth between birth and 1, 3, and 6 mo of age. Maternal skinfold thickness at 9 mo of pregnancy and maternal height were also significantly associated with birth length. Moreover, maternal height, weight, and skinfold thickness at 6 and 9 mo of pregnancy were positively associated with mean birth weight. After adjustment for morbidity in the past month and other covariates, infants breast-fed exclusively had greater attained weight and weight gain in the first 3 mo compared with infants who were bottle-fed exclusively, breast-fed and bottle-fed, or solid-fed exclusively. These findings underscore the need for programs that improve the nutritional status of women before, during, and after pregnancy, and encourage exclusive breast-feeding of infants for at least the first 3 mo of life. *Am J Clin Nutr* 1997;65:1731–7.

KEY WORDS Anthropometry, height, skinfold thickness, breast-feeding, bottle-feeding, infants, weight, length, growth, pregnancy, humans

INTRODUCTION

Maternal nutritional status is a recognized determinant of fetal growth (1–3). Newborns with intrauterine growth retardation have higher rates of subsequent growth retardation in infancy and childhood (4, 5). Although the association of maternal nutritional status with birth weight has been examined in many studies (1–3), there are fewer studies examining the relations with birth length and infant growth (3, 6).

Infant feeding practices are determinants of infant growth. Breast-feeding is associated with reduced risks of growth retardation and of gastrointestinal and respiratory infections (7–10). The association of infant feeding practices, growth, and morbidity has been studied extensively in many countries, with less emphasis on ethnic-group specific research (7, 11).

Israel is a multiethnic country populated by individuals of European, Middle Eastern, and North African ancestry. Infant feeding research has focused primarily on infants of parents of European and Middle Eastern backgrounds, but not on those of North African heritage (9, 12). From 1982 to 1986, a cohort of pregnant women of North African descent, who resided in and around Beer Sheva, Israel, were followed from 6 mo of pregnancy through the infant's first 6 mo of life. The objectives of the North African Infant Feeding Study (NIFS) were *1*) to examine the relation among maternal nutritional status and pregnancy outcome, infant growth, and morbidity; *2*) to determine the relation among infant feeding, growth, and morbidity; and *3*) to assess the relation between anthropometric indicators of nutritional status and infant morbidity. In this paper we examine the independent contribution of maternal anthropometric status during pregnancy and infant feeding practices to infant anthropometric status. We examined the relation of these variables to length or weight at birth and at 1, 2, 3, and 6 mo of age and the change in these variables between birth and 1, 2, 3, and 6 mo of age.

SUBJECTS AND METHODS

All women who participated in the NIFS were of North African descent, with more than one-half of the women having immigrated to Israel. To be considered an individual of North African descent, either the woman or her mother had to have been born in Morocco, Tunisia, Algeria, or Libya. The women were residents of Beer Sheva or Dimona (a town adjacent to Beer Sheva) in the Negev region of Israel. At the time of the

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study, Jews of North African descent were the largest ethnic group in the Beer Sheva (42% in Beer Sheva and 60% in nearby towns). They were considered to be a low to lower middle class immigrant population in Israel.

From 1982 to 1986, all pregnant women of North African descent were identified when they applied for prenatal care in one of seven Maternal and Child Health (MCH) Centers: five in Beer Sheva and two in Dimona. Any woman who had a history of chronic disease (eg, endocrine, cardiac, or renal) was excluded from study enrollment. All participants signed informed consent forms that were approved by the Institutional Review Board of the Ben Gurion University Faculty of Health Sciences, Beer Sheva, Israel.

Data collection

In this cohort study, interview data were collected longitudinally at the seven MCH Centers by trained interviewers. The interviews during pregnancy (ie, at 6 and 9 mo) included questions about sociodemographic characteristics, reproductive and medical histories, maternal work status and plans to stop working pre- and postpartum, history of infant feeding practices and intended infant feeding practices for the index newborn, current smoking status, and use of vitamin-mineral supplements. Postpartum interviews took place at birth and at 1, 2, 3, and 6 mo of age and focused on smoking status, medication use, infant feeding practices (ie, breast-feeding status, including the frequency of breast-feeding in the prior 24 h; age of introduction of, type of, and frequency of intake of breast milk supplements and substitutes; as well as weaning practices), and maternal reporting of infant morbidity by service unit (Kupat Holim and Soroka Hospital) to identify morbidity episodes for medical record abstraction.

Of the 1172 women who were enrolled in the NIFS at 6 mo of pregnancy, 132 were excluded because of preterm deliveries, congenital malformations, multiple births, or attrition, thereby reducing the sample to 1040 mother-infant pairs at birth. Of these, 677 mother-infant pairs had complete infant feeding data from the time of the infant's birth to 6 mo of age, but had incomplete data on either maternal nutritional status during pregnancy, infant growth, or both. Because this study addresses the relations of both maternal anthropometric status during pregnancy and infant feeding practices to infant growth in the first 6 mo of life, only mother-infant pairs with data collected at 6 and 9 mo of pregnancy, at birth, and at 1, 2, 3, and 6 mo of infancy could be used in a longitudinal analysis. Three hundred fifty-one mother-infant pairs satisfied this criterion and formed the analytic subcohort in the longitudinal data analysis. In a comparison between the 677 mother-infant pairs with complete data from birth through 6 mo and the analytic subcohort (n = 351), rates of infant feeding practices over time were similar; for example, the rates of exclusive breast-feeding among the 677 compared with the 351 were as follows: 91.8% and 92.3% at birth, 33.5% and 35.9% at 1 mo, 18% and 19.6% at 2 mo, 5.3% and 7.3% at 3 mo, and 0.9% and 0.7% at 6 mo, respectively. Similarly, the rates of mixed breast and bottle (cow milk or formula) feeding for the two groups were 33.2% and 33.4% at 1 mo, 22.9% and 26.1% at 2 mo, 17.8% and 19% at 3 mo, and 8.3% and 11% at 6 mo, respectively. Thus, the analytic subcohort did not differ appreciably from the larger cohort on one of the major exposure variables of interest in this analysis. We also found that there were no significant differences in weight or length of the subcohort children at any age when compared with children of the same age but who were not available at the next follow-up time. For example, the birth weight and length of the subcohort children were not significantly different from those of children who were not available for the 1-mo measurement.

Anthropometric assessment and morbidity data collection

Maternal anthropometric data were collected during pregnancy and included height and weight at the first prenatal visit as well as weight and triceps skinfold thickness at 6 and 9 mo of pregnancy. Maternal weight gain during pregnancy was calculated from the mother's weight at the first and last prenatal visits.

Birth weight and length were abstracted from delivery records, whereas infant weight and length were routinely measured at 1, 2, 3, and 6 mo of age (± 3 wk) at the MCH Center. Infant height was measured to the nearest 0.1 cm by using the World Health Organization's measuring board. Infant weight was measured to the nearest 0.1 kg with beam-balance scales that were standardized and checked periodically against known weights. Infants were measured while wearing light clothes. Triceps skinfold thicknesses were measured to the nearest 0.2 cm with Harpenden (British Indicators, Ltd, London) skinfold calipers.

Trained fourth-year medical students from Ben Gurion University abstracted maternity and other hospital records as well as clinic records for information on morbidity over the infant's first 6 mo of life. A morbidity episode was defined as the occurrence of at least one episode of respiratory or gastrointestinal infection in a 1-mo period that had been diagnosed at the Kupat Holim Clinic.

Data analysis

In the first phase of the analysis the distributions of maternal weight, height, and skinfold thicknesses at 6 and 9 mo of pregnancy as well as maternal weight gain during pregnancy were examined. The distributions of weight-for-height, height-for-age, and weight-for-age in infancy were compared. Because very few children were of low birth weight (n = 14), wasted (n = 1 at 3 mo; n = 2 at 6 mo), or stunted (n = 8 at 3 mo; n = 9 at 6 mo) (13), the analysis focused on continuous endpoints of anthropometric status.

The one-sample rank-sign test was used to compare the median weight or length in NIFS children with the median measure of a comparable age and sex group in the National Center for Health Statistics (NCHS) population. Student's t test was used to compare mean weight and length at birth and at 1, 2, 3, and 6 mo of age by maternal anthropometric status during pregnancy and by infant feeding practices. Maternal anthropometric status included weight at the first prenatal visit and at 6 and 9 mo of pregnancy, triceps skinfold thickness at 6 and 9 mo of pregnancy, and height. All indicators of maternal anthropometric status were categorized into quartiles, with mothers in the lowest quartile of an anthropometric indicator compared with mothers in each of the top three quartiles. Infant feeding practices were classified into four categories on the basis of maternal reporting at each age-specific interview: *1*) breast-fed exclusively, *2*) bottle-fed exclusively, *3*) breast-fed and bottle-fed exclusively, and *4*) fed solids exclusively. Bottles contained cow milk or infant formula. Besides the analysis of infant feeding practices with concurrent age-specific weight and length, we also examined the relation of early infant feeding practices to growth in subsequent months. Student's t tests were used to compare mean growth differences between breast-feeding and other feeding groups.

In the second phase of the analysis, multiple-linear-regression models were created with mean birth weight or length as well as infant's weight or length at 1, 3, and 6 mo of age as the dependent variables. The main independent variables were maternal anthropometric status and age-specific infant feeding practices. The following variables were examined in the models as potential confounding factors: sex, birth length, birth weight (for models of infant's weight and length from 1 to 6 mo), infant morbidity in the month preceding measurement, maternal and paternal education, and maternal height. Parity and maternal smoking habits, either in the past or currently, were excluded from the analyses because they were not statistically significant predictors of infant growth. Adjustment for measurements at birth was in effect an examination of the growth velocity or gain in weight or length between birth and 1, 3, or 6 mo of age. Quartiles of maternal anthropometric status variables were included as dummy variables in regression models. Tests for trend across increasing quartiles were computed by including the anthropometric variable as a continuous variable in the model. The presence of statistical interaction between maternal anthropometric status and infant feeding was examined by including interaction terms in the models. Two-tailed t tests were used and all findings were considered statistically significant at a P value of ≤ 0.05. All data were analyzed by using SAS software (version 6.04; Statistical Analysis System Inc, Cary NC).

TABLE 1
Characteristics of the North African Infant Feeding Study (NIFS) subsample

Variable	Value
Maternal education	
< 9 y	40 [12][1]
9–12 y	260 [77]
≥ 13–7	37 [11]
Paternal education	
< 9 y	40 [12]
9–12 y	271 [80]
≥ 13 y	28 [8]
Maternal employment	
Yes	128 [37]
No	212 [63]
Maternal place of birth	
Israel	169 [49]
Morocco	143 [41]
Tunisia	27 [8]
Other	8 [2]
Prior births	
0	145 [42]
1	94 [27]
2	57 [16]
3	22 [6]
≥ 4	29 [8]
Weight gain during pregnancy (kg)	10 ± 5[2]
Weight at first prenatal visit (kg)	60 ± 10
Weight at 9 mo of pregnancy (kg)	70 ± 10
Triceps skinfold thickness at 6 mo of pregnancy (mm)	18 ± 6
Maternal height (cm)	159 ± 7

[1] n; percentage of subsample in brackets.
[2] $\bar{x}$ ± SD.

RESULTS

Among the analytic subcohort from the NIFS, 88% of mothers and fathers had received ≥ 9 y of education (**Table 1**). Thirty-seven percent of the women were working during pregnancy, 42% were nulliparous, and on average, women gained 10 kg between the first prenatal visit and the end of pregnancy. Forty-nine percent of the women were born in Israel and the remainder were immigrants from a North African country.

Compared with the median age- and sex-specific weights and lengths of infants in the referent population, NIFS boys and girls had significantly lower median lengths at birth and during the first 6 mo of life. NIFS boys had similar median weights at any point to those of the NCHS standard. Median birth weights of NIFS and NCHS girls were comparable; however, NIFS girls were significantly heavier at 2, 3, and 6 mo of age compared with the NCHS median (data not shown).

In the analysis of the relation between maternal anthropometric status and infant length, mean maternal weight at the first visit of pregnancy and at 6 and 9 mo of pregnancy were positively associated with birth length (P for trend in all cases < 0.0001) and with linear growth between birth and 1, 3, and 6 mo of age (**Table 2**). Maternal skinfold thickness at 9 mo, but not at 6 mo, was positively associated with birth length. Infants born to mothers in the top quartile of triceps skinfold thickness at 9 mo were 1 cm longer, on average, at birth than infants of mothers in the lowest quartile (P for trend = 0.02). Babies of mothers in the highest quartile of height were significantly longer at birth and at 1, 3, and 6 mo of age compared with infants of mothers in the lowest quartile of height.

We next examined the relation between maternal anthropometric indicators during pregnancy and infant's weight. Maternal weight at 6 and 9 mo of pregnancy were positively associated with infant's weight at birth and at 1, 3, and 6 mo of age (**Table 3**). A positive and significant trend was observed between quartiles of maternal skinfold thickness at 6 and 9 mo of pregnancy and birth weight. Maternal skinfold thickness at 6 mo was associated with a higher infant weight at 3 and 6 mo. Finally, compared with mothers in the lowest quartile of height, those in the two highest quartiles gave birth to significantly heavier babies (P for trend = 0.007).

The rates of exclusive breast-feeding during infancy declined precipitously from 34% at 1 mo to 18% at 2 mo, to 6% at 3 mo (**Table 4**). Because only two infants were breast-fed exclusively at 6 mo of age, analyses of feeding practices and growth were limited to the assessments of infant feeding in the first 3 mo. Infant feeding practices were not related to linear growth velocity in the first 3 mo (data not shown). The relation between infant feeding practices and attained weight at 1, 2, and 3 mo of age was adjusted for birth weight; hence, the models describe the relation of infant feeding to weight gain between birth and 1, 2, and 3 mo of age (Table 4). Infants who were breast-fed exclusively at any age up to 3 mo of age were heavier and gained more weight than did infants who were

TABLE 2
Relation of maternal anthropometric status during pregnancy to infant length (cm) in the North African Infant Feeding Study (NIFS)

Mother's status in quartiles	Length at birth		Length at 1 mo of age		Length at 3 mo of age		Length at 6 mo of age	
	$\bar{x}$ ± SD[1]	β[2]	$\bar{x}$ ± SD[1]	β[2]	$\bar{x}$ ± SD[1]	β[2]	$\bar{x}$ ± SD[1]	β[2]
Weight at first visit (kg)								
< 52.5 (*n* = 86)	48.6 ± 2.0	Ref	51.5 ± 1.9	Ref	58.7 ± 2.0	Ref	65.6 ± 4.2	Ref
52.5 to < 59 (*n* = 85)	49.3 ± 2.3	0.8	52.4 ± 2.5[3]	0.9[3]	59.8 ± 3.6[3]	1.2[3]	67.0 ± 3.5[3]	0.7
59 to < 65.2 (*n* = 85)	50.1 ± 2.2[3]	1.6[3]	53.4 ± 2.3[3]	1.3[3]	60.3 ± 2.2[3]	1.2[3]	66.9 ± 2.6[3]	0.4
≥ 65.2 (*n* = 90)	49.9 ± 2.0[3]	1.3[3]	52.8 ± 2.5[3]	0.8[3]	60.3 ± 2.0[3]	1.3[3]	67.3 ± 2.9[3]	1.0
P for trend[4]		0.0001		0.01		0.009		0.12
Weight at 6 mo of pregnancy (kg)								
< 58.5 (*n* = 83)	48.7 ± 2.1	Ref	51.6 ± 2.0	Ref	58.9 ± 2.3	Ref	65.6 ± 3.8	Ref
58.5 to < 65.5 (*n* = 87)	49.1 ± 2.2	0.6	52.5 ± 2.3[3]	1.0[3]	59.8 ± 3.3	0.8	67.0 ± 4.0[3]	1.4[3]
65.5 to < 71.7 (*n* = 89)	50.0 ± 2.2[3]	1.5[3]	53.1 ± 2.4[3]	0.9[3]	60.2 ± 2.2[3]	0.7	66.8 ± 2.4	0.4
≥ 71.7 (*n* = 87)	50.0 ± 1.9[3]	1.3[3]	52.9 ± 2.6[3]	0.6	60.2 ± 2.2[3]	0.8	67.4 ± 3.1[3]	1.3[3]
P for trend[4]		0.0001		0.12		0.15		0.09
Weight at 9 mo of pregnancy (kg)								
< 62.5 (*n* = 84)	48.6 ± 2.0	Ref	51.5 ± 2.0	Ref	58.9 ± 2.3	Ref	65.6 ± 3.9	Ref
62.5 to < 70.0 (*n* = 80)	49.7 ± 2.0[3]	1.2[3]	52.7 ± 2.2[3]	0.5	60.0 ± 3.2[3]	0.5	66.9 ± 3.4[3]	0.6
70.0 to < 76.7 (*n* = 92)	49.9 ± 2.4[3]	1.4[3]	53.1 ± 2.6[3]	1.1[3]	60.3 ± 2.1[3]	0.9	66.7 ± 2.4	0.6
≥ 76.7 (*n* = 72)	50.0 ± 1.5[3]	1.5[3]	53.1 ± 2.2[3]	0.7[3]	60.2 ± 2.2[3]	1.0	67.5 ± 3.3[3]	1.3
P for trend[4]		0.0001		0.02		0.04		0.04
Skinfold thickness at 6 mo of pregnancy (cm)								
< 13.5 (*n* = 86)	49.3 ± 2.2	Ref	52.4 ± 2.1	Ref	59.5 ± 2.3	Ref	66.1 ± 4.3	Ref
13.5 to < 17 (*n* = 82)	49.3 ± 2.1	0.2	52.5 ± 2.4	0.2	59.6 ± 2.3	0.3	67.0 ± 3.5	1.3
17 to < 22 (*n* = 85)	49.4 ± 2.3	0.2	52.4 ± 2.7	0.6	59.7 ± 2.4	0.4	66.5 ± 2.5	0.9
≥ 22 (*n* = 77)	49.8 ± 2.1	0.7	52.9 ± 2.3	0.5	60.3 ± 2.4	0.6	67.0 ± 2.5	0.5
P for trend[4]		0.09		0.07		0.09		0.46
Skinfold thickness at 9 mo of pregnancy (cm)								
< 14.0 (*n* = 84)	48.9 ± 2.2	Ref	52.1 ± 2.4	Ref	59.7 ± 3.3	Ref	66.5 ± 4.7	Ref
14.0 to < 17.45 (*n* = 87)	49.9 ± 1.7	1.1[3]	52.8 ± 2.0	0.3	59.9 ± 2.0	−0.5	66.4 ± 2.5	−1.2[3]
17.45 to < 22 (*n* = 80)	49.7 ± 2.1[3]	1.0[3]	52.8 ± 2.1	0.4	59.9 ± 2.2	0.1	67.1 ± 2.6	0.1
≥ 22 (*n* = 60)	49.8 ± 2.3[3]	0.9[3]	52.9 ± 2.8	0.6	60.2 ± 2.3	−0.02	66.6 ± 2.2	−0.9
P for trend[4]		0.02		0.12		0.70		0.58
Height (cm)								
< 154 (*n* = 70)	49.0 ± 2.0	Ref	51.6 ± 2.2	Ref	59.2 ± 2.5	Ref	66.2 ± 3.3	Ref
154 to < 160 (*n* = 98)	49.4 ± 2.5	0.4	52.3 ± 2.1	0.2	59.3 ± 2.2	−0.4	66.4 ± 3.2	−0.2
160 to < 165 (*n* = 91)	49.5 ± 2.2	0.4	52.9 ± 2.7[3]	0.8[3]	60.0 ± 2.4	0.2	66.6 ± 4.0	0.3
≥ 165 (*n* = 84)	49.9 ± 1.8[3]	0.6	53.0 ± 2.2[3]	0.5	60.7 ± 3.0[3]	0.8	67.5 ± 2.9[3]	0.8
P for trend[4]		0.12		0.05		0.03		0.11

[1] Means among the highest three categories of maternal anthropometric status were compared with the baseline category by using *t* test.
[2] β Coefficients are from linear-regression models including sex, morbidity in previous month (yes or no), maternal and paternal education (continuous, three levels), and maternal anthropometric status (three dummy variables). Models of length at ages 1, 3, and 6 mo also included birth length; models for height also included weight at first prenatal visit. Ref, reference or comparison category.
[3] $P < 0.05$.
[4] Obtained from a linear-regression model with anthropometric status as a continuous variable.

bottle-fed, breast- and bottle-fed, or solid-fed exclusively. Specifically, compared with the infants breast-fed exclusively at 1 mo, those who were breast- and bottle-fed or bottle-fed exclusively had lower weights at 1 mo and were likely to gain ≈200 g less in the first month of life, whereas infants who were fed a solid diet gained ≈400 g less during the same period. Likewise, infants who were breast- and bottle-fed, bottle-fed exclusively, or solid-fed exclusively had lower weights at 3 mo than those breast-fed exclusively and they gained significantly less weight between birth and 3 mo of age. Also, infant feeding at 1 mo was associated with greater weight at 2 and 3 mo of age. However, there was apparently no association between infant feeding practices in the first 3 mo of life and weight or length at 6 mo of age. The relations of infant feeding practices and infant growth were not modified by measures of maternal anthropometric status.

DISCUSSION

We examined the relations between maternal anthropometric status during pregnancy and infant growth in an analytic subcohort of 351 mother-infant pairs using data from 6 mo of pregnancy through the first 6 mo of infancy. Maternal anthropometric status at 6 and 9 mo of pregnancy was significantly associated with infant growth. Mean maternal weight at 6 and 9 mo of pregnancy and maternal height were significantly associated with birth length and weight as well as with the velocity of linear growth and

TABLE 3

Relation of maternal anthropometric status during pregnancy to infant weight (g) in the North African Infant Feeding Study (NIFS)

Mother's status in quartiles	Weight at birth		Weight at 1 mo of age		Weight at 3 mo of age		Weight at 6 mo of age	
	$\bar{x}$ ± SD[1]	β[2]	$\bar{x}$ ± SD[1]	β[2]	$\bar{x}$ ± SD[1]	β[2]	$\bar{x}$ ± SD[1]	β[2]
Weight at first visit (kg)								
< 52.5 (n = 86)	3052 ± 365	Ref	3855 ± 474	Ref	5584 ± 676	Ref	7420 ± 1070	Ref
52.5 to < 59 (n = 85)	3188 ± 465	156[3]	4031 ± 542	89	5913 ± 867[3]	264[3]	7696 ± 1024	88
59 to < 65.2 (n = 85)	3357 ± 409[3]	338[3]	4205 ± 513[3]	133	5986 ± 733[3]	207	7786 ± 868[3]	142
≥ 65.2 (n = 90)	3394 ± 379[3]	369[3]	4186 ± 505[3]	50	6062 ± 640[3]	217	7934 ± 906[3]	207
P for trend[4]		0.0001		0.44		0.14		0.21
Weight at 6 mo of pregnancy (kg)								
< 58.5 (n = 83)	3057 ± 380	Ref	3891 ± 510	Ref	5607 ± 718	Ref	7401 ± 965	Ref
58.5 to < 65.5 (n = 87)	3180 ± 426	146[3]	4003 ± 489	10	5881 ± 835[3]	259[3]	7662 ± 1124	231
65.5 to < 71.7 (n = 89)	3371 ± 432[3]	344[3]	4170 ± 548[3]	31	6007 ± 711[3]	148	7870 ± 813[3]	170
≥ 71.7 (n = 87)	3382 ± 385[3]	355[3]	4211 ± 500[3]	24	6051 ± 663	197	7904 ± 943[3]	291
P for trend[4]		0.0001		0.69		0.25		0.13
Weight at 9 mo of pregnancy (kg)								
< 62.5 (n = 84)	3045 ± 376	Ref	3863 ± 475	Ref	5591 ± 727	Ref	7414 ± 1001	Ref
62.5 to < 70.0 (n = 80)	3229 ± 431[3]	216[3]	4008 ± 513	5	5873 ± 810[3]	197	7599 ± 1006	41
70.0 to < 76.7 (n = 92)	3405 ± 393[3]	401[3]	4260 ± 502[3]	157[3]	6070 ± 717[3]	222	7846 ± 799[3]	167
≥ 76.7 (n = 72)	3384 ± 385[3]	393[3]	4200 ± 492[3]	44	6048 ± 656[3]	260	7963 ± 995[3]	349[3]
P for trend[4]		0.0001		0.24		0.06		0.04
Skinfold thickness at 6 mo of pregnancy (cm)								
< 13.5 (n = 86)	3195 ± 459	Ref	4023 ± 515	Ref	5814 ± 749	Ref	7484 ± 1090	Ref
13.5 to < 17 (n = 82)	3210 ± 421	47	4015 ± 516	−35	5816 ± 704	57	7601 ± 880	238
17 to < 22 (n = 85)	3254 ± 426	78	4108 ± 501	30	5843 ± 643	43	7794 ± 946	464[3]
≥ 22 (n = 77)	3328 ± 381	160[3]	4160 ± 554	75	6085 ± 693[3]	213	7963 ± 828[3]	502[3]
P for trend[4]		0.02		0.18		0.08		0.0004
Skinfold thickness at 9 mo of pregnancy (cm)								
< 14.0 (n = 84)	3119 ± 408	Ref	3900 ± 513	Ref	5791 ± 948	Ref	7586 ± 1146	Ref
14.0 to < 17.45 (n = 87)	3347 ± 427[3]	244[3]	4172 ± 505[3]	89	5899 ± 631	−144	7661 ± 826	−175
17.45 to < 22 (n = 80)	3315 ± 377[3]	229[3]	4164 ± 435[3]	145[3]	5952 ± 645	64	7730 ± 886	−60
≥ 22 (n = 60)	3310 ± 411[3]	222[3]	4174 ± 561[3]	127	6016 ± 749	3	7829 ± 848	−49
P for trend[4]		0.002		0.06		0.54		0.40
Height (cm)								
< 154 (n = 70)	3102 ± 432	Ref	3913 ± 549	Ref	5664 ± 712	Ref	7510 ± 1139	Ref
154 to < 160 (n = 98)	3213 ± 428	126	4064 ± 538	5	5853 ± 726	111	7696 ± 1090	−16
160 to < 165 (n = 91)	3296 ± 432[3]	160[3]	4095 ± 521	−76	5902 ± 765	22	7672 ± 914	−120
≥ 165 (n = 84)	3356 ± 378[3]	198[3]	4176 ± 479[3]	4	6110 ± 752[3]	264[3]	7892 ± 763	38
P for trend[4]		0.007		0.81		0.09		0.93

[1] Means among the highest three categories of maternal anthropometric status were compared with the baseline category by using t test.

[2] β Coefficients are from linear-regression models including sex, morbidity in previous month (yes or no), maternal and paternal education (continuous, three levels), and maternal anthropometric status (three dummy variables). Models of weight at ages 1, 3, and 6 mo also included birth weight; models for height also included weight at first prenatal visit. Ref, reference or comparison category.

[3] $P < 0.05$.

[4] Obtained from a linear-regression model with anthropometric status as a continuous variable.

weight at 1, 3, and 6 mo. These findings may be related to the biological pathway from adequate maternal nutritional status during pregnancy to larger size at birth and greater resistance to disease, and in turn to rapid linear growth in infancy. On the other hand, these associations may be confounded by socioeconomic status, which may be an independent determinant of infant growth. Greater maternal height may be an indicator for higher socioeconomic status, which would lead to better infant growth through better sanitation, resulting in reduced infant illness, more resources to purchase better-quality supplemental infant foods, and better child care (14). Relations between maternal weight at 6 and 9 mo of pregnancy and infant growth were the same even after adjustment for infant morbidity, maternal height, and indicators of socioeconomic status, namely maternal and paternal education. However, there is a possibility that residual confounding may still explain the results reported.

Newborns or infants of mothers in the upper quartiles of maternal height were significantly longer and heavier at birth and over the first 6 mo of life than were infants of mothers in the lowest quartile of height. To account for the possibility that the influence of height on birth or infant length or weight was simply a reflection of total maternal body mass (15), the analyses were adjusted for maternal weight at the first prenatal visit, and the associations with maternal height persisted. These findings agree with those from previous research on birth weight (3) and infant growth (9, 16–18).

We found that maternal weight during pregnancy was associated with higher weight at birth and during the first 6 mo of

TABLE 4
Relation of infant feeding practices to infant weight (g) in the North African Infant Feeding Study (NIFS)

Feeding practice	Measurement at 1 mo of age			Measurement at 2 mo of age			Measurement at 3 mo of age		
	$\bar{x}$ ± SD[1]	Model 1	Model 2	$\bar{x}$ ± SD[1]	Model 1	Model 2	$\bar{x}$ ± SD[1]	Model 1	Model 2
1 mo of age									
Breast-fed (n = 118)	4245 ± 522	Ref	Ref	5113 ± 645	Ref	Ref	5981 ± 749	Ref	Ref
Breast- and bottle-fed (n = 106)	4050 ± 475[3]	−161[3]	−158[3]	5060 ± 574	46	21	5948 ± 798	152	70
Bottle-fed (n = 102)	3899 ± 526[3]	−191[3]	−191[3]	4890 ± 570[3]	−57	−75	5725 ± 709[3]	−85	−14
Solids only (n = 25)	3915 ± 594[3]	−365[3]	−357[3]	4753 ± 532[3]	−419[3]	−401[3]	5710 ± 754	−276	−148
2 mo of age									
Breast-fed (n = 63)				5182 ± 580	Ref	Ref	6053 ± 735	Ref	Ref
Breast and bottle-fed (n = 72)				5107 ± 630	−40	−72	5921 ± 753	−48	−65
Bottle-fed (n = 127)				4978 ± 573	−118	−94	5893 ± 792	−97	−43
Solids only (n = 86)				4831 ± 589[3]	−189[3]	−214[3]	5673 ± 681[3]	−224	−154
3 mo of age									
Breast-fed (n = 21)							6275 ± 810	Ref	Ref
Breast and bottle-fed (n = 58)							5997 ± 744	−197	−153
Bottle-fed (n = 126)							5808 ± 832[3]	−311	−253[3]
Solids only (n = 145)							5829 ± 672[3]	−174	−234

[1] Means among breast-fed children were compared with other categories of infant feeding by using t test.
[2] Models are linear-regression models. Model 1 included weight at birth, sex, maternal height (continuous in four quartiles), weight at first prenatal visit (continuous in four quartiles), morbidity in previous month (yes or no), maternal and paternal education (continuous, three levels), and infant feeding (three dummy variables). Model 2 included length at the same age and all variables in model 1. Ref, reference or comparison category.
[3] $P \leq 0.05$.

life. The relations between maternal weight gain during pregnancy and birth length and weight as well as infant growth are not reported here because most findings were not significant. The only significant finding was a direct association between pregnancy weight gain and birth weight, which agrees with the findings of other research (14, 17). Maternal weight gain during pregnancy was estimated incorrectly given that maternal weight was initially measured at the first prenatal visit rather than in the prepregnancy period. This estimate of maternal weight gain may have reduced the ability to detect an association when indeed one may have existed. A combination of low prepregnancy weight and low weight gain during pregnancy probably presents the highest risk of low birth weight (15).

Of all the indicators of maternal anthropometric status during pregnancy, maternal skinfold thickness is a measure of maternal energy reserves. In this study, maternal triceps skinfold thicknesses at 6 and 9 mo were positively associated with birth length and weight. Maternal skinfold thickness was not associated with length at various points in the first 6 mo of life. At 6 mo of pregnancy, maternal reserves can be mobilized in the third trimester of pregnancy to enhance fetal weight velocity. These results agree with those from a study from the Philippines in which maternal arm fat area and arm muscle mass were associated with birth length and weight (16). However, in the Nutrition Collaborative Research Support Program carried out in Egypt, Kenya, and Mexico, measures of maternal fatness were not associated with infant growth (weight or length) whereas measures of maternal lean body mass were (19). The relation between various components of body composition and newborn and infant nutritional status needs to be examined further. Maternal diet is probably another important factor in determining infant nutritional status (19); the role of various dietary factors, including energy and micronutrient intakes, should also be examined.

Exclusive breast-feeding at 1, 2, and 3 mo of age was associated with higher mean weight at each respective age compared with infants who were bottle-fed exclusively, breast-fed and bottle-fed, or solid-fed exclusively. Exclusive breast-feeding was also associated with greater weight gain in the first 3 mo of life compared with the other feeding practices. These findings were adjusted for morbidity to reduce the potential association between bottle-feeding and solid-feeding and infection from contamination of these food sources. They were also adjusted for sex, maternal height, parental education, and length at the same age. These findings agree with those of some (9, 20–24) but not of other (16) studies, possibly because of different timing of and types of breast milk supplements and substitutes used and because the adequacy of breast milk composition in mothers from different populations varied. In a study carried out among mothers with high educational and socioeconomic status (25), children breast-fed exclusively had a weight velocity in the first 3 mo of life similar to that of formula-fed children, but they started gaining weight less rapidly thereafter, although these slower growth rates were not associated with any harmful consequences such as higher morbidity or lower activity. In the NIFS, infants who were fed breast milk and bottle milk or solids probably had a higher risk of infection, clinical as well as subclinical, that may have resulted in a slower weight velocity.

Although maternal nutritional status and infant feeding were independently associated with infant growth, there was no interaction between these two sets of variables. Fat or obese mothers have higher breast milk lipid concentrations; however, this does not seem to be the mechanism through which maternal nutrition enhances infant growth. Breast milk lipid concentration is not associated with infant growth, suggesting that infants of obese mothers regulate their intake and thus consume a smaller volume of milk but the same amount of energy as infants of mothers whose milk is low in fat (26). Adequate maternal nutrition may improve infant growth by increasing breast-feeding duration (27) and hence lead to better infant growth.

The data from this study were longitudinally collected from midpregnancy through the first 6 mo of an infant's life. Age-specific infant feeding and growth data were collected, with interviewers regularly retrained in anthropometric collection of maternal and infant weight and height. Although the study had certain methodologic strong points, the major limitation was the small sample size of the subcohort with complete longitudinal data for data analysis (n = 351 mother-infant pairs). Therefore, the findings cannot necessarily be interpreted at the population level. Nevertheless, there were no significant differences in infant feeding practices and infant's weight and length at birth and at 1, 3, and 6 mo of life between children in the analytic subcohort and the other children.

In summary, a subsample of women of North African descent in Israel were followed from 6 mo of pregnancy through the first 6 mo of their infant's life to examine the relations of maternal anthropometric status during pregnancy, infant feeding, and infant growth. Neither the women nor their infants were considered malnourished according to recognized standards (13, 15), yet maternal weight, height, and triceps skinfold thickness during pregnancy were important predictors of fetal and infant growth. Compared with other feeding practices, breast-feeding exclusively for the first 3 mo of life increased weight and weight gain during early infancy. Breast-feeding has also been shown to be associated with reduced severity of diarrheal and other infections in infancy (10, 28). Guidelines that encourage exclusive breast-feeding are not necessarily promoted among ethnic groups like the North Africans in Israel where hygienic conditions are apparently adequate and health services are largely used for prenatal and infant care. These findings underscore the need to consider programs that improve the nutritional status of women before, during, and after pregnancy, and encourage exclusive breast-feeding of infants for at least the first 3 mo of life.

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