Midupper Arm Circumference (MUAC) Changes in Late Pregnancy Predict Fetal Growth in Twins

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The objective of the study was to test the hypothesis that changes in arm anthropometry can be used to determine the risk of faltering growth in twin gestations. Serial data on midupper arm circumference (MUAC) and maternal weight gain were collected from a sample of 156 mothers. Changes in MUAC were monitored from 20 to 34 weeks. Women with a large loss of MUAC (greater than 1.5 cm), particularly when it occurred within two to four weeks of delivery, were significantly heavier, had higher pregravid Body Mass Indexes (BMIs), but gained less weight than mothers with no change in MUAC. In analysis of covariance models adjusting for length of gestation, black ethnicity, males per twin pair, monochorionicity, and baseline MUAC at 20 weeks, a large loss of MUAC was associated with significantly lower birthweight (2263 g vs. 2499 g) and birthweight *z*-score (–0.92 SDU vs. –0.39 SDU). Changes in MUAC from 20 to 34 weeks, and especially near delivery, are significantly associated with fetal growth in twin pregnancies. A positive change may indicate that the mother has adequate dietary intake or nutrient stores to continue to accrue lean body mass and support fetal growth, while a loss of MUAC indicates that dietary intake or nutrient stores may be inadequate. This simple, relatively precise, measure of change in maternal body composition during pregnancy may be useful in identifying twin pregnancies at risk for faltering intrauterine growth, particularly among overweight or obese women.

Midupper arm circumference (MUAC) is a clinical indicator of nutritional status frequently used in famine relief because of its correlation with body mass index (BMI) and because it is not affected by edema (Boss et al., 1994; Collins, 1996; Collins & Myatt, 2000; Spiegel et al., 2004). MUAC reflects both past and present nutritional status and is less responsive than body weight to short-term changes in health and nutritional status (WHO, 1995). Because it is relatively stable throughout pregnancy, even when measured late in gestation, MUAC may be more reflective of nutritional status than body weight (Krasovec & Anderson, 1991).

Optimally, MUAC should increase slightly in pregnancy, reflecting at first the accretion of maternal fat and lean body mass and, in the third trimester, an increase in lean body mass alone. A change in MUAC may be particularly useful as a nutritional indicator in twin pregnancy since large maternal weight gains may mask a loss of maternal lean body mass and the inability to support optimal fetal growth. A large decrease in MUAC, as assessed through serial measures, is more likely to indicate a loss of maternal lean body mass. MUAC may also be a better indicator than weight gain for overweight and obese women, among whom twinning is more common and the recommendations for weight gain less clear. The objective of this study was to determine if changes in arm anthropometry (MUAC) could be used as a proxy for weight gain and to determine the risk of faltering growth in twin gestations.

Subjects and Methods

The sample consisted of 156 women participating in a nutritionally enhanced program of prenatal care that included: (1) twice-monthly prenatal visits to a registered dietitian and nurse practitioner team in addition to regular prenatal visits with the woman's primary care physician; (2) additional maternal education; (3) modification of maternal activity; (4) individualized dietary prescription; (5) multimineral supplementation; and (6) serial monitoring of nutritional status (Luke et al., 2003). Any woman pregnant with twins and enrolling for care at the University of Michigan could

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be referred to the program by any member of their healthcare team, as well as self-referral. Each program participant received a dietary assessment on entry to the program, based on a 24-hour dietary recall, and, if needed, recommendations were made to bring the diet to between 3000 and 4000 kcal per day depending on pregravid BMI, as 20% of calories are obtained from protein, 40% of calories are obtained from carbohydrate and 40% of calories are obtained from fat. At each subsequent program visit, the dietary assessment was repeated, and additional recommendations were made as needed. Based on the system of diabetic exchanges, this diet translated into three meals and three snacks per day. In cases of nausea and vomiting, antiemetics were prescribed and guidelines were given to maintain hydration and avoid ketosis, resuming a full diet as soon as possible. Program participants were advised to include a daily mineral supplement of calcium and magnesium with zinc, totaling 3 g of calcium carbonate, 1.2 g of magnesium oxide, and 45 mg of zinc oxide, in three equally divided doses at breakfast, dinner and bedtime. In addition, program participants were advised to include a multivitamin containing 100% of the nonpregnant Recommended Dietary Allowances (RDAs), increasing to two pills per day after 20 weeks' gestation. Participants were questioned about compliance and use of correct dosage at each visit.

Each program visit included measurements of maternal weight, blood pressure, midupper arm circumference (MUAC), fundal height and fetal heart tones, urinary assessment for leukocytes, protein, ketones, and glucose. The rates of maternal weight gain were estimated from regression curves fit to measured prenatal weights over time. From the regression equations, the rate of maternal weight gain was predicted before and after 20 weeks' gestation. These gestational periods have been shown in prior studies on weight gain in twin pregnancies to be more important for fetal growth than traditional trimesters (Luke et al., 1997, 1998). Ultrasonographic measures of fetal growth were obtained at 18 to 20 weeks, and again at 24, 28 and 32 weeks' gestation. This study was approved by the Institutional Review Board of the University of Michigan.

A total of 156 of the 190 women (82.1%) participating in the program were measured serially for MUAC. The MUAC was determined according to the method suggested by Frisancho (1990). The MUAC was measured using a paper tape at the midpoint of the upper right arm between the acromion (the bony protrusion on the posterior of the upper shoulder) and the olecranon process of the elbow. The circumference was measured to the nearest 0.1 cm. Study participants were divided into two groups depending on the change in MUAC over 2 to 4 weeks at the end of the pregnancy, with large loss defined as more than a 1.5 cm loss.

The outcomes evaluated were average twin pair birthweight and z-score based on gender-specific reference values for singletons (Kramer et al., 2001). Comparisons between women with and without a large loss in MUAC for background and pregnancy characteristics were made by Student's t test for continuous variables and using the χ^2 distribution for discrete characteristics. Comparisons of birthweight outcomes with and without a large loss in MUAC were made using analyses of covariance controlling for length of gestation, black ethnicity, males per twin pair, monochorionicity, and baseline MUAC at 20 weeks' gestation. Results are presented as least square means (± standard error of the estimate, *SEE*).

To determine the clinical utility of a large loss in MUAC, the sensitivity and specificity of a large loss in MUAC were calculated for average twin-pair birthweight z-scores of less than −0.50 standard deviation units (SDU), −0.75 SDU and −1.0 SDU. A z-score of less than −2 SDU (or below the 95th percentile) would be a better indicator, particularly in developing countries, but because this group of women was relatively well nourished and under good prenatal care, the prevalence of cases below this cutoff (n = 5) was too low for analysis.

Results

A summary of the characteristics of the study population is given in Table 1. MUAC, measured at program entry, was highly correlated with pregravid BMI (r = .91, p < .0001). Women in the large loss group were significantly heavier before conception, but averaged lower gestational weight gain both before and after 20 weeks' gestation. The rate of maternal weight gain was significantly correlated with MUAC changes (total rate, r = .46; rate 0 to 20 weeks, r = .33; and rate 20 to 34 weeks, r = .43, all at p < .01).

Models for the twin birthweight and z-scores are given in Table 2. Controlling for length of gestation, black ethnicity, males per twin pair, monochorionicity, and baseline MUAC at 20 weeks' gestation, both average twin-pair birthweight and z-score were significantly lower with a large loss in MUAC by −236 g and −0.53 SDU, respectively (p < .02).

Sensitivity and specificity calculated for average twin-pair birthweight z-scores of less than −0.50 SDU, −0.75 SDU, and −1.0 SDU demonstrated that a large loss in MUAC was generally an insensitive indicator of poor fetal growth (i.e., sensitivity for −1.0 SDU with a large loss in MUAC = 9.1%), but that it was a highly specific measure (specificity for −1.0 SDU with a large loss in MUAC = 94.3%). Sensitivity and specificity for the other cut-off levels were nearly identical.

Discussion

These findings indicate that a large loss in MUAC of more than −1.5 cm toward the end of a twin pregnancy is associated with reduced fetal growth. Women with a large loss in MUAC after 20 weeks' gestation

Table 1

Characteristics of Program Mothers and Twin Pregnancies

	MUAC change	
	Large loss	No loss
	n = 10	*n* = 146
	Mean (*SD*)	Mean (*SD*)
Age (y)	30.9 (3.5)	32.2 (5.4)
Height (cm)	164.3 (7.2)	165.9 (6.0)
Height (in)	64.7 (2.8)	65.3 (2.4)
Weight (kg)	78.6 (18.5)*	66.8 (15.0)
Weight (lb)	172.9 (40.7)*	147.0 (33.0)
BMI (kg/m²)	29.1 (6.3)**	24.3 (5.5)
Total gain (lb)	33.3 (14.4)**	46.6 (15.1)
Total rate of weight gain (lb/wk)	0.94 (0.41)*	1.31 (0.41)
Rate of weight gain 0–20 wks (lb/wk)	0.65 (0.42)*	1.02 (0.50)
Rate of weight gain 20–34 wks (lb/wk)	1.31 (0.64)*	1.76 (0.64)
MUAC @ 20 wk (cm)	33.7 (5.3)**	29.7 (4.0)
Entry to prenatal care (wk)	14.6 (4.1)	15.4 (5.2)
Program visits (#)	7.7 (2.3)	6.4 (2.2)
Gestation (wks)	35.6 (1.3)	35.4 (2.5)
Birthweight (gm)	2387 (359)	2491 (518)
z-score (SDU)	–0.75 (0.74)	–0.40 (0.70)
White, non-Hispanic (%)	70.0	84.9
Primipara (%)	50.0	56.2
Obese (%)	50.0*	15.8

Note: Significantly different at $p < .05$*, at $p < .01$**.

were more likely to be overweight or obese and to have larger infants, even with lower levels of weight gain. Nevertheless, a large loss in MUAC was associated with decreased fetal growth. These findings suggest that serial measurements of MUAC in obese women, poorly nourished women, or in the developing world where weight monitoring is more difficult could be used as a proxy for weight gain to determine risk for faltering fetal growth in singleton pregnancies.

Numerous studies, mostly in developing countries or with high-risk populations, have tested the utility of the MUAC in evaluating risks of adverse pregnancy outcomes. Mahomed et al. (1998) reported that Zimbabwean women with the highest MUAC in the highest quintile (28–39 cm) were 4.4 times more likely to develop preeclampsia than women with MUAC values in the lowest quintile (21–23 cm). Hediger et al. (1994) found that women who gained upper arm fat late in pregnancy had the largest gestational weight gains but significantly smaller infants. Verhoeff et al. (2001) reported an 80% increased risk of prematurity in singleton births with a MUAC below 23 cm in Malawi women. Karim and Mascie-Taylor (1997) reported high correlations of MUAC and low birthweight among women in Bangladesh.

We were unable to evaluate satisfactorily the clinical utility (sensitivity and specificity) of a large loss in MUAC with respect to birthweight outcomes as the sample size with a large loss was so small in this cohort, and there was no clear clinical endpoint to use as outcome. The use of birthweight as an outcome is also problematic because birthweight is only a surrogate for a number of processes, including genetic, maternal, lifestyle and nutritional factors. The points –0.5 SDU, –0.75 SDU, and –1.0 SDU for average twin birthweight *z*-score all yielded very high specificity (~95%), but very low sensitivity (~10%). A *z*-score of less than –2 SDU (or below the 95th percentile) would have been a better indicator and might have improved the sensitivity, but because this group of women is relatively well-nourished and under good prenatal care, the prevalence of cases below this cut-off was very low. Nevertheless, the fact that the specificity of a large loss in MUAC with respect to fetal growth is so high may mean that serial monitoring of MUAC may be useful to rule out cases for further testing or follow-up.

Maternal weight gain during pregnancy is positively associated with fetal growth, and reflects the development of the maternal reproductive tissues, and the increase in blood volume, extracellular fluid, and maternal energy stores as healthy maternal adaptations to reproduction. Maternal fat stores are believed to be important energy reserves for the latter half of pregnancy and lactation, when demands are greatest. Our results are in line with those of Challis et al. (2003) and Liljestrand and Bergström (1991), who reported a strong correlation of MUAC with maternal BMI. Our findings confirm those of Piperata et al. (2002), who also reported better outcomes with little or no change in MUAC throughout pregnancy. Our findings extend this association by demonstrating the link with maternal weight gain, maintenance of the MUAC and improved birthweight. Serial assessments of maternal MUAC during pregnancy may be particularly useful in developed countries where maternal obesity is on the rise and prenatal measurement of maternal weights has fallen out of favor, as in the United Kingdom.

Table 2

Average Twin Birthweight and *z*-Score by MUAC Change From 20 to 34 Weeks

	MUAC change	
	Large loss	No loss
	n = 10	*n* = 146
	LS Mean (*SEE*)	LS Mean (*SEE*)
Average twin birthweight (g)	2263 (90)*	2499 (23)
Average twin *z*-score (SDU)	–0.92 (0.21)*	–0.39 (0.05)

Note: *Significantly lower ($p < .05$) in models adjusted for gestation, black ethnicity, males/twin pair, monochorionicity, and baseline MUAC at 20 weeks.

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