A standard of fetal growth for the United States of America

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The appropriate interpretation of monitored fetal growth throughout pregnancy in individual patients and populations is dependent upon the availability of adequate standards. There is no adequate standard of fetal weight throughout pregnancy that is suitable for patients in the U. S. A. To determine such a standard for infants delivered at about sea level the 10th, 25th, 50th, 75th, and 90th percentiles of fetal weight for each menstrual week of gestation were calculated from 430 fetuses at 8 to 20 menstrual weeks' gestation aborted with prostaglandins and from 30,772 liveborn infants delivered of patients at 21 to 44 menstrual weeks' gestation. Median fetal crown-to-rump lengths and crown-to-heel lengths were derived from measurements of 496 aborted fetuses of 8 to 21 weeks' gestation. Fetal weight correction factors for parity, race (socioeconomic status), and fetal sex were calculated. The derived fetal growth curves are useful for clinical, public health, and investigational purposes. (AM. J. OBSTET. GYNECOL. 126: 555, 1976.)

WITH THE ADVENT of new monitoring techniques, fetal and maternal condition can be better evaluated throughout pregnancy. Although assessment of fetal growth is an important aspect of fetal monitoring, the expected ranges of fetal weight and growth throughout pregnancy have not been adequately determined. Accurate knowledge of fetal growth is clinically important for at least three reasons: (1) to identify the effects of pathologic pregnancies on fetal size, (2) to aid in the evaluation of diagnostic measurements of fetal growth, and (3) to identify potentially abnormal children in the antepartum or immediately postpartum periods.

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Available data on fetal size and growth throughout pregnancy are not adequate for many clinical purposes. Streeter[1] conducted the most comprehensive study of embryo and fetal growth in early pregnancy and reported values for formalin-fixed and embalmed specimens. Although his measurements of sitting height, head size, and head-to-foot length are similar to those of nonpreserved specimens, fetal weights differ significantly. Since the weight change caused by formalin is dependent upon several factors, there is no reliable way to determine the weight of the nonpreserved from the preserved fetus.

Fetal weight and some of the parameters that appear to be associated with differential rates of fetal growth in the latter part of the second trimester and throughout the third thrimester in specific patient populations have been reported by several investigators. Unfortunately, either these studies pertain to selected populations who are not representative of all subgroups in the U. S. A. or the studies are too small to permit accurate determination of fetal growth percentiles. The importance of evaluating the relationships between fetal growth and such variables as fetal sex, and maternal race, socioeconomic factors, and parity has been previously reported.[2, 3]

One of the most frequently used standards of fetal growth is the one reported by Lubchenco and associ-

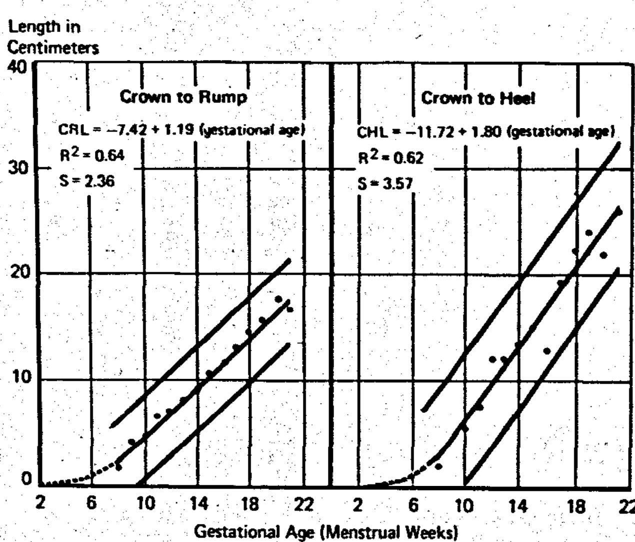

Fig. 1. Fetal length: left, crown-to-rump; right, crown-to-heel. Regression of crown-to-rump length *(CRL)* and crown-to-heel length *(CHL)* with 90 per cent confidence limits on a future CRL and CHL are graphed from data derived from 496 prostaglandin-induced abortions. Each dot represents the mean CRL and CHL for a given gestational age, *(S)* is the estimated standard deviation about the regression line, *(R^2)* is the multiple correlation coefficient, and the dashed line is an extrapolation to 0 cm. at 2 menstrual weeks' gestation.

Table I. Selected patient characteristics

8-21 weeks' gestation			*21-44 weeks' gestation*		
Characteristic	*No.*	*%*	*Characteristic*	*No.*	*%*
Age (yr.):			*Age (yr.):*		
20	169	34.1	20	6,216	20.2
20-29	297	59.9	20-29	17,755	57.7
30-39	27	5.4	30-39	6,401	20.8
40+	3	0.6	40	400	1.3
Parity:			*Parity:*		
0	280	56.4	1	10,032	32.6
1-2	168	33.9	2	7,836	25.5
3-4	41	8.3	3-4	8,893	28.9
5+	7	1.4	5+	4,009	13.0
Race:			*Race:*		
White	252	50.8	White	16,401	53.3
			Private	15,077	49.0
			Staff	1,324	4.3
Non-white	244	49.2	Nonwhite	14,371	46.7
			Private	1,723	5.6
			Staff	12,648	41.1

ates,[4] derived from deliveries at 24 to 42 menstrual weeks' gestation. Their study was based on relatively few (5,635) selected infants born to Caucasian mothers of low socioeconomic status at a high elevation (5,280 feet). Their derived fetal growth rates may be inappropriate for other areas of the United States, since fetal growth may be affected by altitude, and these other areas may have populations with different races, socioeconomic, and parity compositions. Fetal growth standards for the past generations,[5] for other countries,[6-12] and for other specific U. S. A. groups[13-15] may not be representative of present-day fetal growth standards in the U. S. A.

To determine the "normal" (expected) range of fetal weight throughout pregnancy at sea level for most U. S. A. patient types, the association of selected variables with fetal weight and fetal length in early pregnancy, pertinent data from 31,268 prostaglandin-induced abortions and deliveries after spontaneous labor at 8 to 44 menstrual weeks' gestation were analyzed.

Materials and methods

To determine fetal growth from 8 to 21 menstrual weeks' gestation, 641 fetuses aborted with prostaglandins (PG's) were weighed and measured. All abortions were legally approved and performed in the Clinical Research Unit of the Memorial Hospital, University of North Carolina at Chapel Hill (elevation 513 feet), during the period of 1972 to 1975. Abortions were induced with PG's according to investigational protocols; $PGF_{2\alpha}$ by the intra-amniotic and vaginal routes, PGE_2 by the vaginal route, 15(S)-15-methyl $PGF_{2\alpha}$ by the intra-amniotic and intramuscular routes, and 15(S)-15-methyl PGE_2 by the intramuscular route. Neither the systemic nor intrauterine administration of any of these prostaglandins is known to cause effects in the fetus that would change either its weight or size. Fetal weights and crown-to-rump and crown-to-heel lengths from intact fetuses were obtained within 30 minutes of delivery with a Mettler electronic scale and ruler.

Gestational age for the abortions was "estimated" by a combination of the physician's estimate based on uterine size and the patient's stated last normal menstrual period (LNMP). Neither of the two estimates of gestional age alone was satisfactory. Therefore, only data from 496 of the 641 pregnancies where the LNMP estimate and the physician's estimate of gestional age differed by no more than 2 weeks were analyzed for fetal length. Fetal weights were derived from 430 fetuses at 8 to 20 weeks' gestation.

Fetal weight from 21 to 44 menstrual weeks' gestation was determined with the use of data from 30,772 deliveries during the period from 1962 to 1969 at MacDonald House, University Hospitals of Cleveland, Ohio (elevation 660 feet). Data were analyzed from single births with the infant living at the onset of labor among pregancies not complicated by pre-eclampsia, breech, erythroblastosis, diabetes mellitus, or congenital abnormalities. Subsets of some of these data have been previously reported.[2, 3, 16, 17] Gestational age was calculated to the nearest week of gestation from the

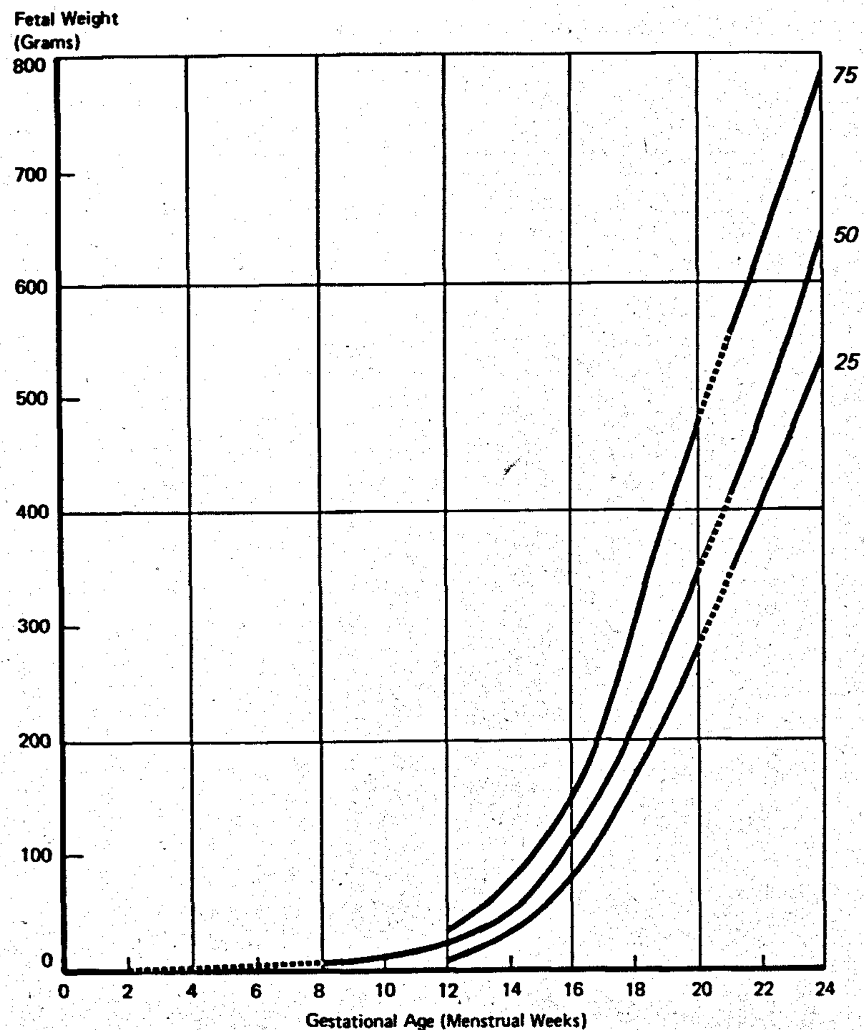

Fig. 2. Fetal weight during early pregnancy. The 50th (median), 25th, and 75th percentiles of fetal weight in grams during the initial 24 menstrual weeks of pregnancy as calculated from 430 prostaglandin-induced abortions at ≤20 weeks' and 30,772 "spontaneous" deliveries from 21 to 44 weeks' gestation are graphed. Dashed lines are extrapolations between the data sets and to 0 Gm. at 2 menstrual weeks' gestation.

patient's LNMP. Infants were weighed on a balance scale immediately after delivery.

Fetal weight percentiles were calculated from the data at each week of gestation. The resulting 10th, 25th, 50th, 75th, and 90th percentile curves for fetal weight were then smoothed with two-point weighted means. Simple linear regression techniques were used for the analyses of crown-to-heel and crow-to-rump lengths. Whenever statistical tests were used, only the p value—the significance level of the test—is presented.

Subjects. Although the race distribution for patients in the 8 to 21 week group was similar to that of those in the 21 to 44 week group, the distributions of age and parity differed (Table I). In both groups 98 per cent of the nonwhite patients were blacks. Patients in the 21 to 44 weeks' group were classified as staff or private, depending on their ability to pay private physician costs, whereas patients in the 8 to 21 weeks' group were not so classified. Since 90.5 per cent of the staff patients were nonwhite and 89.7 per cent of the private patients were white, the effects of these two variables, race and socioeconomic status, on fetal growth could not be adequately separated.

Results

Fetal length (8 to 21 weeks' gestation). The relationship of both crown-to-rump (CRL) and crown-to-heel (CHL) lengths to gestational age appears to be linear during this period of gestation (Fig. 1). The calculated regressions of the CRL and CHL on gestational age are given by:

$$\text{CRL} = -7.42 + 1.19\ (\text{gestational age}) \quad s = 2.36 \text{ cm.}$$
$$\text{CHL} = -11.72 + 1.80\ (\text{gestational age}) \quad s = 3.57 \text{ cm.}$$

In the range of 8 to 21 menstrual weeks' gestation the expected CRL and CHL are calculated from the

Table II. Fetal weight percentiles throughout pregnancy

Gestational age (menstrual weeks)	*No. of women*	*Smoothed percentiles*				
		10	*25*	*50*	*75*	*90*
8	6	—	—	6.1*	—	—
9	7	—	—	7.3*	—	—
10	15	—	—	8.1*	—	—
11	13	—	—	11.9*	—	—
12	18	—	11.1	21.1	34.1	—
13	43	—	22.5	35.3	55.4	—
14	61	—	34.5	51.4	76.8	—
15	63	—	51.0	76.7	108	—
16	59	—	79.8	117	151	—
17	36	—	125	166	212	—
18	58	—	172	220	298	—
19	31	—	217	283	394	—
20	21	—	255	325	460	—
21	43	280	330	410	570	860
22	69	320	410	480	630	920
23	71	370	460	550	690	990
24	74	420	530	640	780	1,080
25	48	490	630	740	890	1,180
26	86	570	730	860	1,020	1,320
27	76	660	840	990	1,160	1,470
28	91	770	980	1,150	1,350	1,660
29	88	890	1,100	1,310	1,530	1,890
30	128	1,030	1,260	1,460	1,710	2,100
31	113	1,180	1,410	1,630	1,880	2,290
32	210	1,310	1,570	1,810	2,090	2,500
33	242	1,480	1,720	2,010	2,280	2,690
34	373	1,670	1,910	2,220	2,510	2,880
35	492	1,870	2,130	2,430	2,730	3,090
36	1,085	2,190	2,470	2,650	2,950	3,290
37	1,798	2,310	2,580	2,870	3,160	3,470
38	3,908	2,510	2,770	3,030	3,320	3,610
39	5,413	2,680	2,910	3,170	3,470	3,750
40	10,586	2,750	3,010	3,280	3,590	3,870
41	3,399	2,800	3,070	3,360	3,680	3,980
42	1,725	2,830	3,110	3,410	3,740	4,060
43	507	2,840	3,110	3,420	3,780	4,100
44	147	2,790	3,050	3,390	3,770	4,110

*Median fetal weights may be overestimated. They were derived from only a small proportion of the fetuses delivered at these weeks' gestation.

above equations. The 95 per cent confidence limits on a future CRL or CHL for gestations over 10 weeks are approximated by the expected CRL ±3.9 cm. and by the expected CHL ±6.0 cm. The relationship of fetal length to age is curvilinear in the very early pregnancy.

Fetal weight. The 25th, 50th, and 75th percentiles of fetal weight during the initial 24 weeks' gestation are portrayed in Fig. 2. The continuity of the percentiles of the two data sets [(1) abortions at Chapel Hill and (2) neonates at Cleveland] is apparent.

The 10th, 25th, 50th, 75th, and 90th percentiles of fetal weight throughout pregnancy are portrayed in Fig. 3 and detailed in Table II. These percentiles are not adjusted for fetal sex or maternal parity and race.

Growth rate expressed as the median fetal weight gain per week increased progressively until 34 to 36 weeks' gestation, after which the weekly fetal weight increment decreased (Fig. 4). In contrast, when growth rate (weight gain) is expressed as the percentage increase in weight over the previous week, the maximum percentage increase in weight is in early pregnancy and progressively decreases throughout pregnancy (Fig. 5).

Variables associated with differences in fetal weight. Maternal parity and race (socioeconomic) and fetal sex are associated with significant ($p < 0.10$) differences in median fetal weights in the latter part of pregnancy (Fig. 6). After 34 to 38 weeks' gestation, median fetal weights were significantly different (p

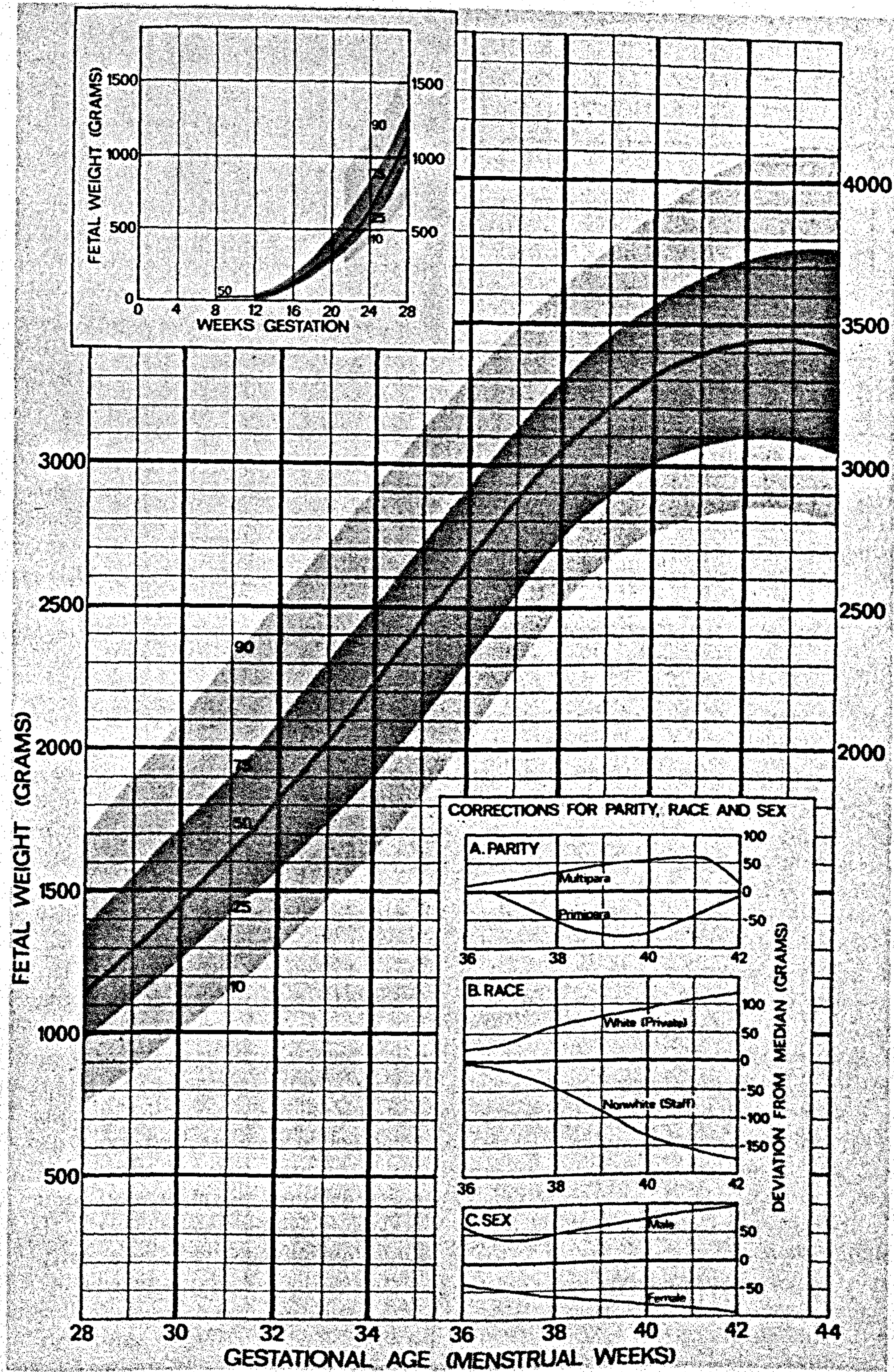

Fig. 3. Fetal weight. The 50th (median), 10th, 25th, 75th, and 90th percentiles of fetal weight in grams throughout pregnancy and correction factors for parity, race (socioeconomic), and sex derived from 31,202 prostaglandin-induced abortions and "spontaneous" deliveries are graphed.

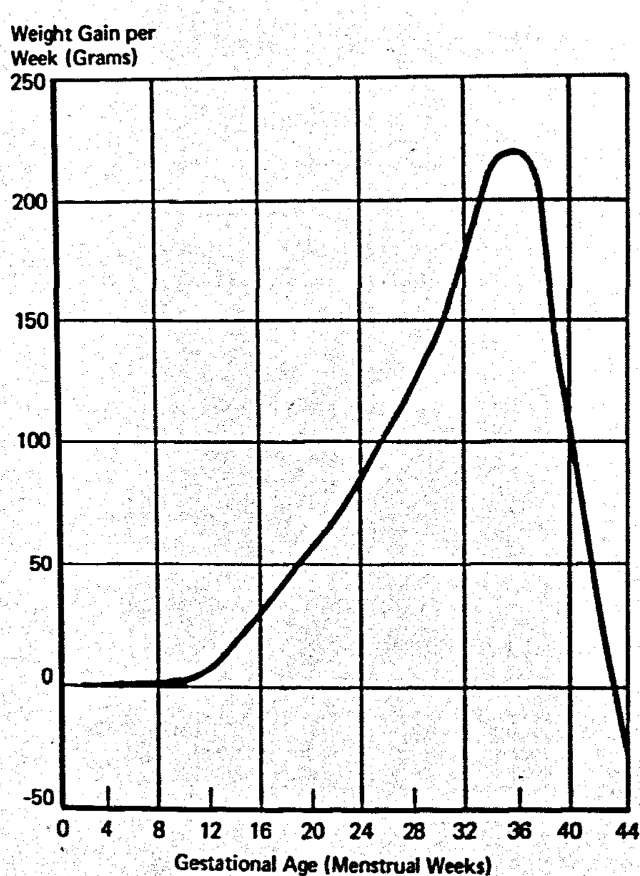

Fig. 4. Weekly fetal weight gain throughout pregnancy. The median weight gain in grams each week throughout pregnancy among 31,202 prostaglandin-induced abortions and "spontaneous" deliveries are graphed.

<0.10) for primiparas and multiparas, for whites (private) and nonwhites (staff), and for male and female fetuses. Distributions of fetal weights about the median weights at each week after the 34th week for each of the above variables were similar. Before 34 weeks' gestation, median fetal weights were not significantly different ($p > 0.10$) for these variables.

At each gestational age after 36 weeks' the median weights were plotted in Fig. 6 and deviations from the median were plotted in Fig. 3 for patients of different parities and races (socioeconomic) and fetal sexes. Analyses indicated that the effects of these variables on median fetal weight could be considered additive. From Fig. 3 the expected fetal weight (EFW) adjusted for sex, and/or parity, and/or race (socioeconomic) can be determined within ±50 grams. For a selected maternal gestational age the adjustment is made by adding to the median fetal weight the grams' deviation for the effects of sex, parity, and race (socioeconomic). For example, the expected fetal weight (EFW) for a singleton delivery to a white private primigravid patient at 39 weeks' gestation is obtained by adding to the uncorrected median weight for 39 weeks' gestation (3,170 grams) the correction factors at 39 weeks' for primigravidas (−65 grams) and for white patients (private (+75 grams) [EFW = 3,170 − 65 + 75 = 3,180 grams]. If the fetal sex is known, the EFW can be further adjusted by adding the fetal sex correction factor.

Comment

A U. S. A. standard of fetal weight throughout pregnancy for singleton uncomplicated pregnancies delivered at about sea level has been determined for male and female fetuses, nulliparas, and multiparas and for whites and nonwhites. Although median weight of specific U. S. A. populations may vary from these medians, with appropriate corrections for sex, parity, and race, the derived median fetal weights at each gestational age will probably be accurate enough for clinical and investigational purposes. Other variables such as maternal smoking habits, diseases, abnormal presentations, nutrition, and addictions which may affect fetal weight were not evaluated in this study. It was the objective of this study to evaluate fetal growth for "normal" pregnancies rather than for *pathologic* and *nutritional conditions* and personal habits that may be altered and/or may depend upon local conditions.

The validity of using fetal weights from deliveries after spontaneous labor ("spontaneous" deliveries) during the late second and early third trimesters had been questioned, since a large proportion of these pregnancies may have been abnormal and resulted in fetal weights that are not representative of "normal" growth. Because there was good continuity in the fetal weight percentile curves derived from prostaglandin-induced abortions and from fetuses born after "spontaneous" labor, it appears that the fetal weight percentiles derived from "spontaneous" deliveries in the late second and third trimesters are valid for interpreting "*normal*" (usual) fetal growth.

Mean crown-to-rump length (CRL) (sitting height) and crown-to-heel length (CHL) at each week of gestation reported in this study were similar to those previously reported.[1, 18] From 8 to 21 weeks' gestation the relationship to fetal length was linear in all of these studies. In contrast, Haase's rule, a commonly used calculation for determining the expected CHL, yields a curvilinear growth rate during the initial 20 weeks' gestation and a linear relationship thereafter. Haase's rule: The expected CHL in centimeters for the initial five lunar months of pregnancy is determined by dividing the number of menstrual weeks' gestation by four and squaring the quotient; after the fifth lunar month the expected CHL is determined by dividing the number of menstrual weeks' gestation by four and

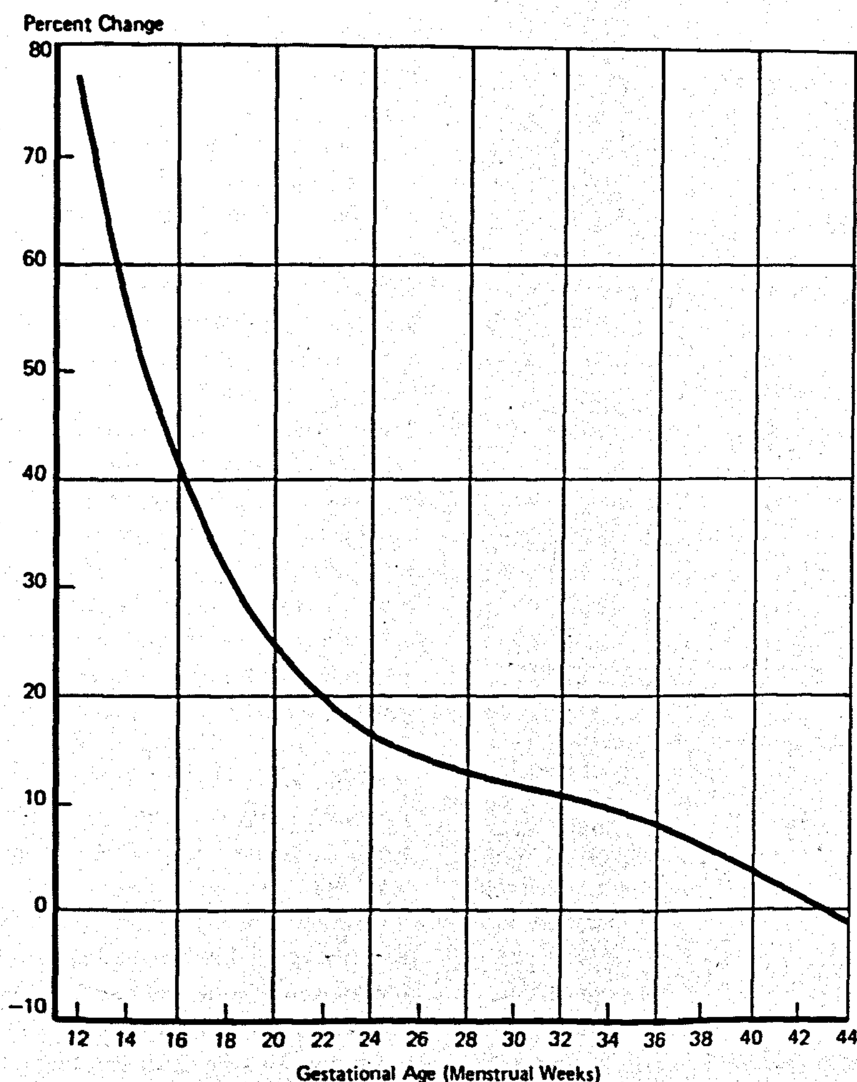

Fig. 5. Percentage increase in weight over previous week throughout pregnancy. Throughout pregnancy, the median percentage increase in fetal weight during the week prior to the plot among 31,202 prostaglandin-induced abortions and "spontaneous" deliveries is graphed.

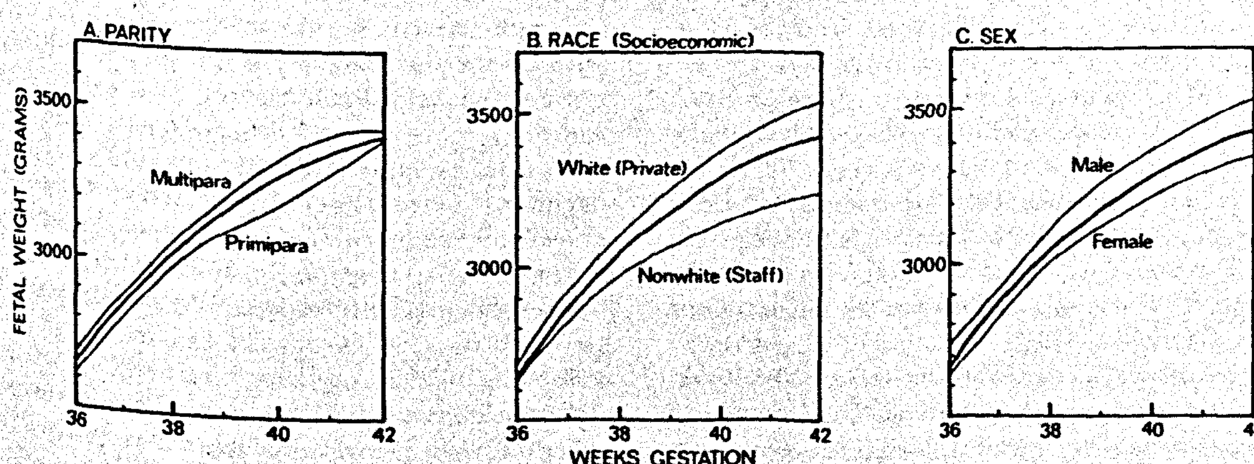

Fig. 6. Median fetal weight by parity, race, (socioeconomic) and sex. The median fetal weight in grams during 36 to 42 menstrual weeks' gestation derived from 31, 202 prostaglandin-induced abortions and "spontaneous" deliveries (central unmarked line) are graphed with fetuses of different sexes and born to mothers of different parities and races (socioeconomic). Deviations prior to 36 weeks' gestation were not significant (p >0.10).

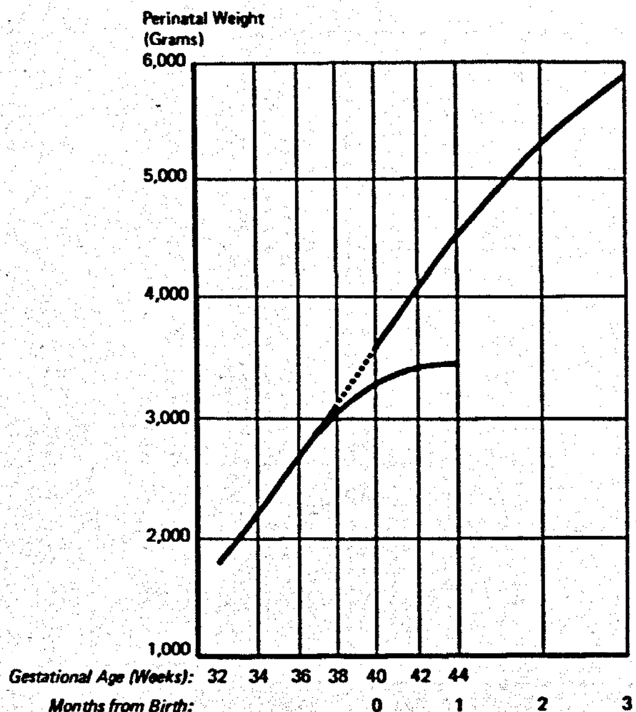

Fig. 7. Median perinatal weight. Graphed are the median weight in grams throughout the latter part of pregnancy derived from 30,772 "spontaneous" deliveries, and the media weight throughout the initial 3 months of life as reported by H. C. Stuart, M.D., and associates.[23] The dashed line is an extrapolation of the best fitting line to indicate similar rates of growth.

multiplying the quotient by five.[19] Although Haase's rule may be useful for rough determinations of expected fetal lengths, it should not be used as a standard for fetal lengths or for determining rates of fetal growth.

Fetal weights for use as clinical standards must be derived from recently delivered, nonmacerated, nonfixed specimens with an accurately determined gestational age. To obtain estimates of fetal size at 8 to 28 weeks' gestation for use by embryologists, Streeter[1] used 704 formalin-fixed or embalmed specimens in different conditions and states of preservation obtained from many sources over a period of several years. The gestational ages were derived by several methods. He derived the estimates of the expected formalin-fixed fetal weight at 28 to 40 weeks' gestation by adding 5 per cent (an estimate of the amount added by embalming) to the mean weights reported by Zangemeister.[5] However, formalin fixing and embalming do not add a consistent amount or percentage of weight and the amount of weight added depends upon several factors.[20] In our study the median weights at each week's gestation were from 0 to 40 grams higher at 14 to 26 weeks' and from 0 to 200 grams higher at 27 to 30 weeks' gestation than those reported by Streeter.[1] Unfortunately, it is not always made clear in textbook presentations that Streeter's data are for the embryologist's use to estimate gestational age from the weight of a fixed specimen and not for clinicians dealing with nonfixed specimens.

Many of the values reported for fetal weight and growth during the latter part of pregnancy are not satisfactory for use in today's U. S. A. population. Fetal weights derived many years ago[5] were lower and therefore are unsatisfactory for today's standards. Median weights in India[6] and Singapore[7] were consistently lower, and those in Sweden,[9] Holland,[8] and Scotland[11] were higher, whereas those reported from Canada,[12] parts of the U. S. A.,[13-15] and Austria[10] were similar to subgroups in this study. National standards change and periodically need revision. Some methods, such as use of birth certificate data and the inclusion of weights of dead fetuses or only fetuses that live throughout the neonatal period, result in inaccurate fetal weight standards.

Standards for fetal weight derived from very specific populations are usually satisfactory for only that population. Among the indigents in Atlanta, Negroes had lower male and female birth weights at each gestational age after 37 weeks' gestation than did Caucasians.[13] The median birth weights of Negroes were similar to only the nonwhite subpopulation in our study. Probably the most frequent standard of fetal weight used in the U. S. A. is the one reported by Lubchenco and associates.[4] Using various "corrections," they reported combined weights of infants born to 5,635 indigent Spanish American patients in Denver, Colorado (elevation 5,280 feet). Their 90th, 50th, and 10th percentile weights after 30 weeks' gestation were about 100 grams less than those reported in our study.

Growth curves are potentially useful for several purposes in the clinical practice of obstetrics and gynecology and pediatrics as well as in public health and the social sciences. Adequate fetal growth standards may be used as a basis for more informed clinical judgments and for better interpretation of the results of fetal monitoring. For example, in complicated pregnancies, when evaluating the best time for delivery, determination of the expected fetal weight at the present gestational age and the expected weight gain with each duration of delay may be helpful. Serial determinations of fetal growth by ultrasound and other methods, if correlated with fetal weight, could be used to assess growth retardation and the effects of different therapies. Although neonates weighing less than 3.5 pounds and/or with "severe intrauterine growth retardation" have higher rates of mortality and attenuated somatic, psychological, and intellectual growth as compared to their peers,[21, 22] better definition of the high- and low-risk neonate groups may be possible with the availability of accurate growth standards.

Growth curves may be useful for selecting groups that might benefit from specific public health and educational programs and for partially evaluating the effects of such programs. Nutritional and special educational and psychological adjustment programs for the very premature and severely growth-retarded infants may decrease their mortality rate, improve their psychological adjustment, and promote their maximum somatic and intellectual growth. More appropriate and successful treatment and education programs may be devised if concentrated follow-up programs of high-risk children are created to detect neurological, speech, hearing, eye, and behavior problems. The effects on fetal growth of genetic factors, illnesses, and personal habits such as smoking, diet, and addiction can be evaluated so that potential parents can be counseled and effective public health programs can be initiated. Serial fetal growth rate curves over several years could be used to partially evaluate specific nutritional, medical care, and educational programs.

Large, controlled, long-term comparative studies of various methods of managing pregnancies with intrauterine growth retardation from different causes and at various stages of gestation need to be conducted. The most frequently used method of managing the growth-retarded fetus is either by the continued observation of the pregnancy until spontaneous labor occurs, or by effecting early delivery if there is presumptive evidence that continuation of the pregnancy will permanently injure the mother or there is a high probability that fetal death is imminent. However, there are reasons for believing that this approach rather than earlier delivery and adequate neonatal nutrition may result in less than optimal development in some fetuses.

Reduced intrauterine growth rate is probably associated with suboptimal fetal development. After a transient decrease in fetal growth while adapting to the extrauterine environment, the neonate gains[23] weight at a rate similar to the maximum rate noted during intrauterine development (Fig 7). Intrauterine growth retardation appears frequently to stem from a deficient intrauterine environment rather than an abnormality in the fetus since (1) after birth, low-birth-weight neonates often gain weight at a more rapid rate than their normal or high birth weight peers[24]; (2) the intrauterine growth rate of each fetus in multiple pregnancies is negatively related to the number of fetuses[25]; (3) fetuses of malnourished mothers[3, 26, 27] and/or pre-eclamptic mothers[16] have attenuated growth; and (4) in some populations the maximum rate of fetal growth continues into the latter part of pregnancy.[9]

The anatomical and functional effects of human intrauterine growth retardation are unknown. However, the decreased fetal brain growth that has been reported in animals when there are maternal nutritional deficiencies in the latter part of pregnancy may also occur in some growth-retarded human fetuses.[26, 27] Defects resulting from undernutrition during development may not be repaired even if adequate nutrition is later resumed. Fetuses of undernourished bitches and mice have smaller brains and a decreased number of central nervous system neurons than the offspring of well-nourished animals.[26, 27] This decrease in neurons persists into later life even though there has been good neonatal nutrition.[26, 27] Some investigators believe that this decrease in anatomical growth does not imply a functional deficiency.[28]

Although intrauterine growth retardation results potentially in less than the optimal neurologic and somatic development, the functional deficit may not always be demonstrable by the use of standardized tests for "normal" populations. Although the mean somatic size and intellectual and behavioral ratings of intrauterine growth–retarded infants are within "normal" ranges by 5 years of age, they are consistently less than those of their "peers."[21] Neurological deficiencies stemming from intrauterine growth retardation may not be adequately defined by IQ scores. Of 96 children born with "severe" growth retardation after 38 weeks' gestation, the mean IQ was 95 for males and 101 for females, but 50 per cent of males and 36 per cent of females had "poor" school performance; 59 per cent of males and 69 per cent of females had speech defects; 1 per cent had cerebral palsy; 6 per cent had convulsions; and 25 per cent had evidence of cerebral dysfunction.[22]

In consideration of such findings it appears that delivery of the growth-retarded fetus at a time when there is a high probability of extrauterine survival may result in less permanent damage to the infant than does the present practice of continued observation until there is evidence of maternal danger or impending fetal death. However, appropriate studies will be necessary to determine the best method of managing patients at different gestational ages with different degrees of intrauterine growth retardation from different causes and for managing the growth-retarded neonate.

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