Customised antenatal growth charts are designed to facilitate better supervision of fetal growth. The chart is printed out in early pregnancy, after confirmation of pregnancy dates, and allows serial plotting of fundal height measurement as well as ultrasound derived estimated fetal weight. Their use increases the antenatal detection of growth problems while reducing the number of unnecessary (false positive) investigations (Gardosi & Francis, 1999)

A. Evidence for an individually adjustable standard to assess birth weight:

1. Large proportion of population are currently misclassified (SGA, LGA)

    Gardosi J et al. (1992). "Customised antenatal growth charts." Lancet 339: 283-287, **Abstract**.

2. Adjusted birth weight percentiles are better correlated with neonatal morphometry

    Sanderson DA et al. (1994). The individualized birth weight ratio: a new method of identifying intrauterine growth retardation." Br J Obstet Gynaecol 101: 310-314, **Abstract**.

3. Adjusted birth weight percentiles are better correlated with adverse pregnancy events

    Sciscione AC et al. (1996). Adjustment of birth weight standards for maternal and infant characteristics improves the prediction of outcome in the small-for-gestational-age infant. Am J Obstet Gynecol 175: 544-7, **Abstract**.

    de Jong CLD et al. (1998). "Application of a customised birthweight standard in the assessment of perinatal outcome in a high risk population." Br J Obstet Gynaecol 105: 531 - 35, **Abstract**.

    Clausson B et al. (2001). Perinatal outcome in SGA births defined by customised versus population based birthweight standards. Br J Obstet Gynaecol 108: 830-4, **Abstract**.

    McCowan L, Harding JE, Stewart AW. Customised birthweight centiles predict SGA pregnancies with perinatal morbidity. Br J Obstet Gynaecol 2005;112:1026-1033, **Abstract**.

B. Evidence for an individually adjusted standard to assess fetal growth:

1. Growth curves reproduce birth weight differences in physiological categories in low risk pregnancies

    Mongelli M and Gardosi J (1995). Longitudinal study of fetal growth in subgroups of a low risk population. Ultrasound in Obstetrics & Gynecology 6: 340-344, **Abstract**.

2. Growth curves reproduce birth weight differences in physiological categories in high risk pregnancies

    de Jong CLD et al (1998). Fetal weight gain in a serially scanned high-risk population. Ultrasound in Obstetrics & Gynecology 11: 39-43, **Abstract**.

3. Customised limits for fetal weight gain reduce false-positive 'IUGR' in a normal population

    Mongelli M and Gardosi J (1996). "Reduction of false-positive diagnosis of fetal growth restriction by application of customized fetal growth standards". Obstetrics & Gynecology 88: 844-848, **Abstract**.

C. Pilot study of feasibility of using customised charts for growth screening

    Customised limits for fundal height improve the detection of small for gestational babies and reduce unnecessary investigations

    Gardosi J & Francis A (1999). Controlled trial of fundal height measurement plotted on customised antenatal growth charts. Br J Obstet Gynaecol 106: 309-17, **Abstract**.

D. Editorial

Leeson S and Aziz N (1997). "Customised fetal growth assessment." British Journal of Obstetrics & Gynaecology 104: 648-651, **Abstract**.

Gardosi J (1998). The application of individualised fetal growth curves. J Perinatal Med 26: 137-42, **Abstract**.

A. Evidence for an individually adjustable standard to assess birth weight:

1. Large proportion of population are currently misclassified (SGA, LGA)

Gardosi J et al. (1992). "Customised antenatal growth charts." Lancet 339: 283-287,

Lancet 1992 Feb 1;339(8788):283-7

Comment in:

- Lancet. 1992 Apr 4;339(8797):878-9.
- Lancet. 1992 Apr 4;339(8797):878; discussion 879.
- Lancet. 1992 Apr 4;339(8797):878; discussion 879.

Customised antenatal growth charts.

Gardosi J, Chang A, Kalyan B, Sahota D, Symonds EM.

Department of Obstetrics and Gynaecology, Queen's Medical Centre, Nottingham, UK.

Charts for fetal growth do not take physiological variables into account. We have therefore designed a computer-generated antenatal chart that can be easily "customised" for each individual pregnancy, taking the mother's characteristics and birthweights from previous pregnancies into consideration. The adjusted birthweight range expected at 40 weeks' gestation is combined with a standard, longitudinal ultrasound-derived curve for intrauterine weight gain. Review at the Queen's Medical Centre, Nottingham, UK, of 4179 pregnancies with ultrasound-confirmed dates showed that, in addition to gestation and sex, maternal weight at first antenatal-clinic visit, height, ethnic group, and parity were significant determinants of birthweight in our population. Correction factors were calculated for each of these variables and entered into a computer program to adjust the normal birthweight centile limits. With adjusted centiles we found that 28% of babies conventionally designated small for gestational age (less than 10th centile) and 22% of those designated large (greater than 90th centile) were in fact within normal limits for the pregnancy. Conversely, 24% and 26% of babies identified as small or large, respectively, with adjusted centiles were "missed" by conventional unadjusted centile assessment. Adjustment for physiological variables will make assessment of fetal growth more precise and reduce unnecessary investigations, interventions, and parental anxiety.

PMID: 1346292

2. Adjusted birth weight percentiles are better correlated with neonatal morphometry

Sanderson DA et al. (1994). The individualized birth weight ratio: a new method of identifying intrauterine growth retardation." Br J Obstet Gynaecol 101: 310-314

The individualised birthweight ratio: a new method of identifying intrauterine growth retardation.

Sanderson DA, Wilcox MA, Johnson IR.

Department of Obstetrics and Gynaecology, City Hospital, Nottingham, UK.

OBJECTIVE: To assess the effectiveness of the newly developed individualised birthweight ratio in identifying growth retarded infants. DESIGN: Prospective observational study.

SETTING: Obstetric unit, City Hospital Nottingham.

SUBJECTS: Two thousand eight hundred and thirty-five women delivered between December 1991 and July 1992 and the infants of 616 of these selected by virtue of their birthweight for gestation and individualised birthweight ratio centile positions.

MAIN OUTCOME MEASURES: Skinfold thickness and ponderal index measurements, occurrence of abnormal fetal heart rate patterns, operative delivery due to fetal distress and the need for neonatal resuscitation.

RESULTS: Using an individualised birthweight ratio less than the 10th centile as a cut-off results in 25% of those less than the 10th centile of birthweight for gestation being reclassified as normally grown. A slightly larger group are reclassified as small; significantly more of these infants have abnormal ponderal indices and skinfold thicknesses, suffer abnormal fetal heart rate patterns, operative delivery for fetal distress and need neonatal resuscitation than do those who are reclassified as normally grown.

CONCLUSION: The individualised birthweight ratio combines the simplicity of birthweight measurement with the accuracy of clinical measurements in the identification of the growth retarded baby.

PMID: 8199077

3. Adjusted birth weight percentiles are better correlated with adverse pregnancy events

Sciscione AC et al. (1996). Adjustment of birth weight standards for maternal and infant characteristics improves the prediction of outcome in the small-for-gestational-age infant. Am J Obstet Gynecol 175: 544-7

Am J Obstet Gynecol 1996 Sep;175(3 Pt 1):544-7

Adjustment of birth weight standards for maternal and infant characteristics improves the prediction of outcome in the small-for-gestational-age infant.

Sciscione AC, Gorman R, Callan NA.

Department of Gynecology and Obstetrics, Johns Hopkins University School of Medicine, Baltimore, Maryland, USA.

OBJECTIVE: Birth weight is a function of gestational age. Various maternal and infant characteristics also affect birth weight. This study sought to adjust for these factors to better define abnormal growth.

STUDY DESIGN: Maternal and infant characteristics from normal pregnancies were correlated with birth weight. A formula was developed and applied to a second group in which we compared perinatal outcomes in normally grown infants with those who were small for gestational age. We compared outcomes between small-for-gestational-age infants defined by the formula with those defined by conventional tables.

RESULTS: Infants defined by the formula as small-for-gestational-age were more likely to have morbidity and mortality than those who were normally grown ($p < 0.001$). Small-for-gestational-age infants defined by the formula had more deaths and adverse outcomes than those defined by gestational age.

CONCLUSION: Adjusting birth weight standards for maternal and infant characteristics may improve the prediction of adverse outcomes.

PMID: 8828411

de Jong CLD et al. (1998). "Application of a customised birthweight standard in the assessment of perinatal outcome in a high risk population." Br J Obstet Gynaecol 105: 531 - 35

Br J Obstet Gynaecol 1998 May;105(5):531-5

Application of a customised birthweight standard in the assessment of perinatal outcome in a high risk population.

de Jong CL, Gardosi J, Dekker GA, Colenbrander GJ, van Geijn HP.

Department of Obstetrics and Gynaecology, University Hospital, Vrije Universiteit, Amsterdam, The Netherlands.

OBJECTIVE: Physiological as well as pathological variables influence birthweight. The aim of the present study was to examine perinatal outcome in relation to birthweight centiles applying a customised birthweight standard.

METHODS: Two hundred and seventeen babies from high risk pregnancies were evaluated and classified as small or not small for gestational age according to two standards: 1. conventional Dutch birthweight centiles and 2. customised centiles which adjust individually for physiological variables like maternal booking weight, height and ethnic origin.

RESULTS: Customisation of the weight standards resulted in identification of an additional group of infants who were small for gestational age, but not by the Dutch standards. These babies were associated with significantly more adverse perinatal events than those who were not small for gestational age as defined by a customised standard.

CONCLUSIONS: Adjustment of birthweight centiles for physiological variables significantly improves the identification of infants who have failed to reach the expected birthweight and who are at increased risk for adverse perinatal events.

PMID: 9637123

Clausson B et al. (2001). Perinatal outcome in SGA births defined by customised versus population based birthweight standards. Br J Obstet Gynaecol 108: 830-4,

Perinatal outcome in SGA births defined by customised versus population-based birthweight standards.

Clausson B, Gardosi J, Francis A, Cnattingius S.

Department of Women's and Children's Health, Uppsala University, Sweden.

OBJECTIVE: To determine whether customised birthweight standard improves the definition of small for gestational age and its association with adverse pregnancy outcomes such as stillbirth, neonatal death, or low Apgar score.

DESIGN: Population based cohort study.

POPULATION: Births in Sweden between 1992-95 (n = 326,377).

METHODS: Risks of stillbirth, neonatal death, and Apgar score under four at five minutes were calculated for the lowest 10% birthweights according to population-based and customised standards, and were compared with the data from the group with birthweights over this limit. Population attributable risks for stillbirth using various birthweight centile cutoffs were calculated for the two standards.

OUTCOME MEASURES: Odds ratios and 95% confidence intervals for stillbirth, neonatal death and Apgar score under four at five minutes, and population attributable risks for stillbirth at different birthweight centiles.

RESULTS: Risks of stillbirth, neonatal death, and Apgar score under four at five minutes and population attributable risks of stillbirth were consistently higher if 'small for gestational age' was classified by a customised rather than by the population-based birthweight standard. Compared with infants who were not small for gestational age by both standards, the odds ratio for stillbirth was 6.1 (95% CI 5.0-7.5) for small for gestational age by customised standard only, whereas it was 1.2 (95 % CI 0.8-1.9) for small for gestational age by population standard only.

CONCLUSIONS: Compared with the population-based birthweight standard, a customised birthweight standard increases identification of fetuses at risk of stillbirth, neonatal death and Apgar score under 4 at 5 minutes, probably due to improved identification of fetal growth restriction.

PMID: 11510708

McCowan L, Harding JE, Stewart AW. Customised birthweight centiles predict SGA pregnancies with perinatal morbidity. Br J Obstet Gynaecol 2005;112:1026-1033

Customized birthweight centiles predict SGA pregnancies with perinatal morbidity

McCowan LM, Harding JE, Stewart AW

Department of Obstetrics and Gynaecology, National Women's Hospital, University of Auckland, New Zealand

OBJECTIVE: To determine the following: (1) the proportion of babies reclassified as small or appropriately grown using customized and population centiles; and (2) the relative risks of perinatal morbidity, including abnormal umbilical Doppler studies, in babies classified as small for gestational age (SGA) and appropriate for gestational age (non-SGA) using the two centile calculations.

DESIGN: Cohort study in SGA and general hospital populations.

POPULATION: A cohort of SGA pregnancies (n= 374) and a general obstetric population (n= 12,879).

METHODS: Pregnancy outcomes were compared between 'non-SGA both' (> or =10th% by population and customized centiles) and those who were 'SGA both' (<10th% by population and customized centiles), 'SGA customized only' (SGA by customized but non-SGA by population centiles) and 'SGA population only' (SGA by population but non-SGA by customized centiles).

OUTCOME MEASURES: Maternal and newborn morbidity and perinatal death.

RESULTS: In the SGA cohort 271 (72%) babies were 'SGA both', 27 (7%) were 'SGA customized only', 32 (9%) were 'population SGA only' and 44 (12%) were 'non-SGA both'. In the general obstetric population 863 (6.7%) babies were 'SGA both', 445 (3.5%) were 'customized SGA only', 285 (2.2%) were 'population SGA only' and 11,286 (88%) were 'non-SGA both'. Perinatal death and newborn morbidity including nursery admission and long hospital stay were increased and comparable between 'SGA both' and 'customized SGA only' in both study populations. Newborn morbidity was low and comparable between 'population SGA only' and 'non-SGA both'. No perinatal deaths occurred in 'population SGA only' babies. Abnormal Doppler studies were more common in 'SGA both' or 'customized SGA only' but not in 'population SGA only' groups compared with 'non-SGA both'.

CONCLUSIONS: Customized birthweight centiles identified small babies at risk of morbidity and mortality. Use of customized centiles is likely to detect more babies at risk of perinatal morbidity and mortality than would be detected by population centiles.

PMID: 16045513

B. Evidence for an individually adjusted standard to assess fetal growth:

1. Growth curves reproduce birth weight differences in physiological categories in low risk pregnancies

Mongelli M and Gardosi J (1995). Longitudinal study of fetal growth in subgroups of a low risk population. Ultrasound in Obstetrics & Gynecology 6: 340-344

Longitudinal study of fetal growth in subgroups of a low-risk population.

Mongelli M, Gardosi J.

Department of Obstetrics and Gynecology, Prince of Wales Hospital, Shatin N.T., Hong Kong.

We investigated fetal weight gain in relation to maternal characteristics within a normal, heterogeneous population in Nottingham, UK. A total of 226 low-risk pregnancies with normal neonatal outcome were examined longitudinally by serial ultrasound examination. Gestation was calculated from early measurements of biparietal diameter. A modified Hadlock's formula for fetal weight was employed, using the biparietal diameter, abdominal circumference and femur length, which was not associated with any significant systematic error. Individual curves were obtained by fitting serial fetal weight estimates and birth weight in a weighted log-polynomial model for fetal growth. The overall growth formula showed an almost linear relationship between gestational age and fetal weight at term. Maternal height and weight at the first hospital visit were positively correlated with fetal weight in the third trimester. The fetuses of parous women were also heavier in late pregnancy, as were those of European compared to Indo-Pakistani mothers. Intrauterine weight gain in the third trimester shows variation with pregnancy characteristics which need to be considered when fetal growth is assessed.

PMID: 8590205

2. Growth curves reproduce birth weight differences in physiological categories in high risk pregnancies

de Jong CLD et al (1998). Fetal weight gain in a serially scanned high-risk population. Ultrasound in Obstetrics & Gynecology 11: 39-43,

Ultrasound Obstet Gynecol 1998 Jan;11(1):39-43

Fetal weight gain in a serially scanned high-risk population.

de Jong CL, Gardosi J, Baldwin C, Francis A, Dekker GA, van Geijn HP.

Department of Obstetrics and Gynecology, University Hospital, Vrije Universiteit, Amsterdam, The Netherlands.

Physiological as well as pathological variables influence fetal growth. This study was undertaken to assess the influence of physiological variables on fetal weight gain in a high-risk population with normal outcome. A total of 121 pregnancies had 3-13 (median 8) ultrasound scans in the third trimester. Estimated fetal weight was calculated according to standard formulae. The estimated fetal weight at 30, 34 and 38 weeks and growth per day in the last 2 weeks prior to delivery were calculated and compared between subgroups defined on physiological characteristics, such as maternal height, maternal weight, parity and fetal sex. There were differences in growth curves for each of the physiological parameters studied. Maternal height and weight were significantly related to the estimated fetal weight throughout the third trimester but there were no significant differences in growth per day in the last 2 weeks before birth. In contrast, subgroups defined by parity and fetal sex did not show significant fetal weight differences in the third trimester, but the daily growth rate prior to birth was significantly higher for multiparae and male fetuses. Physiological factors affect fetal weight gain and need to be taken into account when fetal growth is monitored in high-risk pregnancies.

PMID: 9511194

3. Customised limits for fetal weight gain reduce false-positive 'IUGR' in a normal population

Mongelli M and Gardosi J (1996). "Reduction of false-positive diagnosis of fetal growth restriction by application of customized fetal growth standards". Obstetrics & Gynecology 88: 844-848

Reduction of false-positive diagnosis of fetal growth restriction by application of customized fetal growth standards.

Mongelli M, Gardosi J.

Department of Obstetrics and Gynaecology, Prince of Wales Hospital, Shatin, Hong Kong.

OBJECTIVE: To evaluate the clinical performance of fetal growth charts adjusted for individual maternal characteristics.

METHODS: The study group consisted of 267 low-risk singleton pregnancies with normal clinical outcome. Mothers were recruited prospectively after the booking visit, then underwent three to five ultrasound examinations for fetal weight estimation. Individual growth curves were generated from these data and the birth weight, based on logpolynomial growth model. Computer software was written to calculate the number of fetal growth curves that cross the tenth percentile limit, based on an unadjusted, average ultrasound standard for our population, compared with the number that cross this limit if it is customized for known pregnancy characteristics such as maternal height, booking weight, parity, and ethnic group.

RESULTS: Individual growth trajectories of this group of pregnancies with normal outcome were significantly less likely to cross below the tenth percentile for fetal weight when using customized growth charts than when the unadjusted standard was used (McNemar's test, $P < .001$).

CONCLUSION: The relationship between maternal characteristics and fetal size needs to be considered in the assessment of fetal growth. The use of a customized standard reduces the false-positive rate for the diagnosis of growth restriction in a normal population.

PMID: 8885925

C. Pilot study of feasibility of using customised charts for growth screening

Customised limits for fundal height improve the detection of small for gestational babies and reduce unnecessary investigations

Gardosi J & Francis A (1999). Controlled trial of fundal height measurement plotted on customised antenatal growth charts. Br J Obstet Gynaecol 106: 309-17.

Controlled trial of fundal height measurement plotted on customised antenatal growth charts.

Gardosi J, Francis A.

Division of Obstetrics, Midwifery and Gynaecology, University Hospital, Queen's Medical Centre, Nottingham, UK.

OBJECTIVE: The purpose of this study was to evaluate the effect of a policy of standard antenatal care which included plotting fundal height measurements on customised antenatal charts in the community.

DESIGN: Prospective, non-randomised, controlled, population-based study.

POPULATION: Two defined and separate referral areas from community to teaching hospital, with similar delivery rates and socioeconomic characteristics. A total of 1272 consecutively booked women with singleton pregnancies and dating ultrasound scans before 22 weeks of gestation.

INTERVENTION: In the study area customised fundal height charts were issued to each mother at the routine hospital booking scan, on which regular fundal height measurements were to be plotted by community midwives. The charts adjusted limits according to maternal characteristics including height, weight, parity and ethnic group. Usual management in the control area included fundal height assessment by abdominal palpation and recording on a standard co-operation card.

OUTCOME MEASURES: Antenatal detection of small and large for gestational age babies; number of antenatal investigations for fetal growth in each group.

RESULTS: The study group had a significantly higher antenatal detection rate of small for gestational age babies (48% vs 29%, odds ratio 2.2, 95% confidence interval 1.1-4.5) and large for gestational age babies (46% vs 24%, OR 2.6, CI 1.3-5.5). There was no increase in the study group in the overall number of scans per pregnancy done in the ultrasound department (1.2 vs 1.3, P = 0.14), but a slight decrease in repeat (two or more) third trimester scans (OR 0.8, CI 0.6-1.0, P = 0.08). Women in the study group had significantly fewer referrals for investigation in a pregnancy assessment centre (OR 0.7, CI 0.5-0.9; P = 0.01) and fewer admissions to the antenatal ward (OR 0.6, CI 0.4-0.7, P < 0.001). There were no differences in perinatal outcome.

CONCLUSIONS: Serial measurement of fundal height plotted on customised charts leads to increased antenatal detection of small and large babies. This is accompanied by fewer investigations, which is likely to represent increased confidence in the community to recognise normal fetal growth. With adjustments for physiological variables, fundal height measurements appear to be a cost effective screening method which can result in substantial improvements in the antenatal assessment of fetal growth.

Publication Types:

- Clinical Trial
- Controlled Clinical Trial

PMID: 10426236

D. Editorial

Leeson S and Aziz N (1997). "Customised fetal growth assessment." British Journal of Obstetrics & Gynaecology 104: 648-651

Comment in:
Br J Obstet Gynaecol. 1998 Mar;105(3):369.

Customised fetal growth assessment.

Leeson S, Aziz N.

Royal Oldham Hospital, Oldham.

Publication Types:

- Review
- Review, Tutorial

PMID: 9197866

Gardosi J (1998). The application of individualised fetal growth curves. J Perinatal Med 26: 137-42.

The application of individualised fetal growth curves.

Gardosi J.

PRAM, University Hospital, Queens' Medical Centre, Nottingham, U.K. gardosi@wmpi.net

Individually adjusted or 'customised' growth charts aim to optimise the assessment of fetal growth by taking individual variation into account, and by projecting an optimal curve which delineates the potential weight gain in each pregnancy. This results in an increased detection rate of true growth restriction and a reduction in false positive diagnoses for IUGR. An adjustable standard can apply across geographical boundaries, as individual variation exceeds that between different maternity populations.

Publication Types:
- Review
- Review, Tutorial

PMID: 9846310