

# GROW documentation

Updated January 2018

This document describes the application of the customised growth potential to assess fetal size and growth, using the **Gestation Related Optimal Weight (GROW)** software.

## **GROW – Customised Weight Centiles**

- to calculate birthweight centiles individually or in bulk for whole databases;

## **GROW – Customised Growth Charts**

- to plot fundal height and estimated fetal weight.

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The customised growth chart concept was developed initially in Nottingham in the early 1990s<sup>1</sup>. While recognising the importance of growth for fetal well being, we became increasingly aware that existing charts were not useful for clinical assessment in a heterogeneous maternity population.

Over time, we have been able to test the concept of adjustable or customised assessment of growth and birthweight from many different perspectives. We are constantly seeking to improve and add to the database which allows application in different populations.

The project has been fortunate to benefit from a number of dedicated researchers, statisticians and programmers over the years, who are acknowledged in various publications referenced here. I would particularly like to acknowledge the ongoing help of Andre Francis, statistician and long time friend. But while the strengths of the method, supporting evidence and implementation are thanks to the efforts of my collaborators, any weaknesses are entirely my own responsibility.

We hope that you find our software useful for the assessment of fetal growth and birth weight. We are continuing to seek to improve it, and feedback is always welcome, so please do not hesitate to get in touch!

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The software can be referenced as follows, with the relevant version ('x') of the software used:

**Birthweight or fetal weight centiles:**

Gardosi J, Francis A. Customised Centile Calculator. GROW version x, Year.  
Gestation Network, [www.gestation.net](http://www.gestation.net)

**Antenatal growth charts:**

Gardosi J, Francis A. Customised Growth Chart - GROW version x, Year.  
Gestation Network, [www.gestation.net](http://www.gestation.net)

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**Disclaimer:** GROW software makes calculations on the basis of our published principles and formulae, and is released only after rigorous testing and strict quality assurance. However the Gestation Network and the Perinatal Institute cannot accept responsibility for clinical diagnoses or decisions made on the basis of the software. For more information, please see our [terms and conditions of use](#).

**Copyright and Trademark:** To ensure quality control in the software and its application, the use and display of the principles we developed and are describing here (term optimal weight, proportionality curve etc) is protected by copyright © Gestation Network, and GROW™ and GROW-App™ are trademarked. For further information, please [contact us](#).

## 2. General concepts

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The software allows the generation of an individual or 'customised' standard by adjusting for physiological factors which are known to affect fetal growth. The pregnancy characteristics are entered to calculate the **Term Optimal Weight (TOW, Section 3)**. This is the weight that the baby is predicted to achieve in the absence of pathological influences. The calculation of TOW is centred on 40.0 weeks (280 days).

Through this point TOW, the proportionality curve is plotted to delineate how this weight is expected to be reached in a normal pregnancy (see section 5). This gives an individually adjusted **Gestation Related Optimal Weight (GROW)** curve. Around this optimal line, the normal variation can be calculated and limits such as the 10<sup>th</sup> and 90<sup>th</sup> centile lines drawn. Thus neonatal weights from previous pregnancies, as well as fundal height measurements or fetal weight estimations in the current pregnancy, can be seen in relation to individually adjusted optimal weight limits.

There are 3 underlying **principles for GROW-percentiles**:

1. Weights are assessed in reference to a standard that is **individually adjusted** for physiological pregnancy variables (maternal height, weight, parity and ethnic group); e.g. at 40 weeks, a 3000g baby is small for an average size mother but may be normal for a small mother. Postnatally, the standard is also adjusted for the sex of the baby.
2. The standard is **'optimised' to obtain the growth potential**, i.e. pathological variables such as smoking and diabetes are excluded. For example, expected term baby weight for a mother who smokes is calculated as if she was a non-smoker so that, if her baby's growth *is* affected, the growth or weight deficit is more likely to be identified.
3. Optimal weight is calculated using a **fetal** rather than a **neonatal** weight standard. Preterm neonatal weights are abnormal by definition, and have often been affected by fetal growth restriction preceding spontaneous or iatrogenic preterm delivery. Eg. at 32 weeks, a 1500g baby would fall within normal birth weight limits, but is small according to a 32 week fetal weight standard derived from pregnancies which have gone on to normal delivery at term.

## 3. Calculating the Optimal Weight

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The main non-pathological factors affecting birth weight are **gestational age, maternal height, maternal weight at booking, parity, ethnic group and sex of the baby** <sup>1</sup>. Coefficients to adjust for these variables were originally derived from a dataset of around 30,000 ultrasound dated deliveries. They allow calculation of an expected birth weight for each pregnancy, and the 'customised' percentile of a fetal or neonatal weight in relation to this expected endpoint.

An alternative method to adjust for such variables is to calculate the individual birth weight ratio (IBR). <sup>2 3 4</sup>. IBR follows principle 1 above, i.e. adjusts for individual variation, but does not optimise (principle 2) or apply a fetal weight standard (principle 3).

In pre-2009 versions, adjustment for maternal weight was made within BMI limits of 20-30 only. Since then, the limits have been widened to 18.5-30 in line with international standards.

Other physiological variables such as **paternal height** have, unless extreme, a relatively minor effect <sup>5</sup> and may in any case not always be known with certainty. **Maternal age** usually appears to play no significant role once parity is adjusted for.

Pathological factors such as **smoking, social deprivation, pre-eclampsia or diabetes** are also known to be related to birth weight but are *not* adjusted for. The purpose is to calculate the 'term optimal weight' (TOW) as an ideal standard, against which the actual fetal or neonatal weight can be assessed. Risk factors should be used as clinical prompts to increase surveillance. TOW is centred on day 280, the median and modal length of pregnancy in our population <sup>6</sup>.

## 4. Coefficients for adjusting the term optimal weight (TOW)

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Coefficients are derived from suitable databases using a multiple regression model centred on a standard gestational age (280 days), the largest ethnic group, average maternal height and weight at booking, and first pregnancy (para 0). In addition, gender is listed as an 'average' i.e. sex-neutral. The regression model has a constant to which weight is added or subtracted for each of the variables, according to the formula

$$\text{TOW} = \text{constant} + \text{htao} + \text{wtao} + \text{ethao} + \text{parao} + \text{sexao}$$

where 'ao' are add-ons, respectively, for

- ht = maternal height
- wt = maternal weight at booking (first visit)
- eth = ethnic origin
- par = parity and
- sex = gender of fetus/neonate, if known

### Coefficients

The original coefficients were derived from a Nottingham database (1987-1991; n=30,000) <sup>6</sup> and are reproduced here for illustration only, as they have **since been superseded**.

Name of coefficient	Contribution in grams
<b>Constant</b>	<b>3478.4</b>
<b>Maternal height</b> ( <i>median 162.3 cm</i> ) deviation for each cm	<b>+7.8</b>
<b>Maternal weight</b> ( <i>median 64.3 kg</i> ) deviation: for each kg for each kg <sup>2</sup> for each kg <sup>3</sup>	<b>+8.7</b> <b>-0.117</b> <b>+0.00072</b>
<b>Ethnic origin</b> ( <i>default European incl British Isles and those of European origin elsewhere. eg Australia, Canada, USA</i> ) Indian Subcontinent African Caribbean Other	<b>-186.0</b> <b>-127.5</b> <b>-65.2</b>
<b>Parity</b> at beginning of pregnancy ( <i>default para 0</i> ) Para 1 Para 2 Para 3 Para 4 or more	<b>+108.0</b> <b>+148.6</b> <b>+149.9</b> <b>+149.8</b>
<b>Sex</b> of fetus/neonate ( <i>default 'average' i.e. sex neutral</i> ) Male Female	<b>+58.4</b> <b>-58.4</b>

SE of model = 389.0, giving CV = 0.112

Since then, sets of coefficients have been developed from more recent and more detailed databases in UK and other countries, including Australia, New Zealand, United States, Ireland, Netherlands, Spain, Sweden, Brazil, and incorporated into country specific versions of GROW.

Additional / updated sets of coefficients are being developed constantly as data become available.

## 5. Proportionality curve

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Once the TOW (term optimal weight, predicted for 280 days gestation) is calculated, it is combined with a proportionality growth function to determine the optimal weight at all gestations. This function transforms the average weights at all gestations to a percent of term weight in that population. The proportionality principle can be used retrospectively (birthweight to fetal weight) or to project fetal weight to predict birth weight <sup>6 7</sup>.

Reviews of published formulae for fetal weight gain suggest that most follow a similar pattern, or growth dynamic, although the endpoints (term weights) may vary <sup>8 9</sup>. Our standard formula is derived from Hadlock's fetal weight equation <sup>10</sup> which has been converted into a proportionality equation <sup>6</sup> expressing percent term weight at different gestations, as follows:

$$\% \text{ weight} = \exp(0.578 + 0.332 * GA - 0.00354 * GA^2) / 3619.17 * 100$$

where GA is gestational age between 10 and 42 weeks.

## 6. Normal range

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The normal limits of weight for all gestations are calculated from the coefficient of variation (CV) of the TOW. It is derived from the SD and Mean (Constant) of the population through the regression model, and defined as:

$$CV (\%) = \frac{SD * 100}{Mean}$$

For the original UK database, SD = 389, Constant = 3478. Thus, in this case CV = 11%

The centile limits are derived using Z scores. For example, the 90<sup>th</sup> and 10<sup>th</sup> centiles are represented by  $z = \pm 1.28$ .

Therefore:  $z * CV = \pm 1.28 * 11\% = \pm 14\%$ ;

Thus:  $90^{\text{th}} \text{ centile} = TOW + 14\%$   
 $10^{\text{th}} \text{ centile} = TOW - 14\%$

E.g. the 10<sup>th</sup> to 90<sup>th</sup> centile range for a TOW of 3500g is  $3500 \pm 14\%$ , i.e. range 3010-3990g.

The effect of using the CV is that the range designated as 'normal' becomes narrower for lower TOWs and wider for higher TOWs. Thus a small baby is allowed a smaller range of normal variation in absolute terms. The method compensates for the positive skewness of the distribution of birth weight.

The proportionality weight equation is fitted through the three term points: TOW, TOW+14% and TOW-14%. This defines the 50<sup>th</sup>, 90<sup>th</sup> and 10<sup>th</sup> centile lines respectively for the gestation period 24 to 42 weeks. This principle is used in the applications described in the following sections.

## 7. GROW - Customised Centiles

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This module allows a customised weight-for-gestational age centile to be determined for previous babies, and for estimated fetal weights and birth weight in the current pregnancy.

The calculators are provided in two forms:

- Individual Centile Calculator (ICC), a web-based application, for case-by-case use.
- Bulk Centile Calculator (BCC), in spreadsheet format, for whole databases.

Precise gestational age (at birth, or at the time of EFW measurement) needs to be entered. Gestational age can be calculated with the 'Gestational Age Calculator' - see section 10 below.

The applications can also be used for an estimated fetal weight (EFW) centile when the sex of the baby is not known. When other variables are missing or unobtainable - e.g. maternal height - partial customisation can be undertaken by entering an estimate or population average. In the BCC, this is done automatically when a variable is omitted.

The application can also be used to investigate stillbirth weights. If outcome = fetal death is entered, the calculator automatically deducts 2 days from the gestational age, as an approximation of the average fetal death-to-delivery interval <sup>11</sup>.

The centile calculator is also integral to the customised growth chart, to calculate centiles from previous pregnancies as a history of small or large babies will be relevant for care in the current pregnancy. The centiles are calculated for the corresponding parity of the mother at the *beginning* of the respective pregnancy.

NB: No adjustment is made for maternal weight if it was different in a previous pregnancy; if the weight is considered to have been significantly different, we recommend that previous birthweight centiles are calculated for the respective maternal variables separately.

For a description and history of versions of the centile calculators developed to date, please see:

[Bulk Centile Calculator versions](#)

[Individual Centile Calculator versions](#)

## 8. GROW – Customised Growth Charts

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The GROW Customised Growth Chart module allows the generation of antenatal charts. After entering the pregnancy data through the 'Mother details', 'Baby details' and 'EDD' sub-routines, the chart is generated on screen and can be printed out in early pregnancy.

It shows

- a summary of the pregnancy details and the BMI calculated from maternal height and weight
- previous babies' birthweight centiles
- 10<sup>th</sup>, 50<sup>th</sup> and 90<sup>th</sup> centile lines, with an option to include 5<sup>th</sup> and 95<sup>th</sup>, for the current pregnancy
- on the x-axis, the EDD and the day and month for each week of gestation
- two y-axes:
  - left axis: fundal height (FH, in cm),
  - right axis: estimated fetal weight (EFW, in g)

The relationship between weight and fundal height is described by a formula derived from a study of 325 pregnancies<sup>12</sup>, showing a relationship in the third trimester of the form

$$\ln(\text{EFW}) = 10.6857 - 100.25/\text{SFH}$$

where EFW is in grams and SFH is in cms.

Linked to weight, fundal height norms are therefore also customised according to pregnancy characteristics, thereby allowing for individual variation. Multivariate analysis showed that maternal characteristics such as parity and weight were significantly associated with fundal height values in the third trimester<sup>13</sup>.

The chart can be attached to the mother's hand held maternity notes – e.g. the Pregnancy Notes [www.preg.info](http://www.preg.info) – and used for fetal growth monitoring in the community, provided the pregnancy is considered low risk. From 24-26 weeks onwards, we recommend serial (2- 3 weekly) fundal height measurement with a non-elastic tape, preferably by the same care provider. The measurement should start from the variable point (the fundus) to the fixed point (upper border of the symphysis pubis), along the longitudinal axis of the uterus (which should *not* be corrected to the mid-line).

The fundal height should be plotted using an 'x' symbol. If slope through consecutive plots is not parallel to either of the 90th, 50th or 10<sup>th</sup> centile lines on the chart, fetal biometry by ultrasound scan is recommended. It is important to assess liquor volume (which affects fundal height) and measure fetal biometry parameters to calculate estimated fetal weight (EFW). This can then be plotted using an 'o' symbol. If the baby is small, further investigation such as Doppler flow measurements are recommended. Subsequent management will depend on these results and clinical considerations, and can include repeated ultrasound and Doppler, or return to serial FH measurements.

GROW charts can be used for screening for intrauterine growth restriction (IUGR) and macrosomia. A controlled study of community growth screening suggests that serial plotting of fundal height on customised charts increases the detection rate of growth abnormalities while decreasing the rate of unnecessary referrals for further investigation.<sup>14</sup> A subsequent audit in the West Midlands has confirmed these findings<sup>15</sup>. Ultrasound EFWs plotted in normal pregnancies are more likely to stay within customised GROW limits than if general limits for the whole population are used - i.e. customisation of fetal weight reduces the false positive diagnosis of SGA/IUGR<sup>16</sup>. The use of customised charts is recommended by RCOG guidelines<sup>17</sup>.

## 9. GRAW – Population Average Growth Charts

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**GRAW** (Gestation Related Average Weight) uses a simplified version of the GROW method, to generate a **population average** growth chart for countries where there is insufficient data to derive individually adjustable coefficients. [Contact us](#) for details.

## 10. Gestational Age Calculation

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Accurate pregnancy dating is a central requirement for any weight centile assessment. The 'Calculate EDD' function within GROW has options for entering:

- 1 - the last menstrual period (LMP), to which 280 days are added to determine the expected date of delivery (EDD);
- 2 - scan measurements from which the EDD is calculated according to standard references for 1st trimester CRL<sup>18</sup>, or for 2nd trimester BPD<sup>19</sup> or HC<sup>20</sup>;

We recommend that ultrasound dates be used, where possible, *without* allowance for the LMP. There are considerable discrepancies between even 'certain' menstrual dates and scan dates <sup>21</sup><sup>22</sup>, and many analyses have suggested that ignoring menstrual history altogether improves the accuracy of pregnancy dates. <sup>23</sup> <sup>24</sup> <sup>25</sup>

## 11. References

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- <sup>1</sup> Gardosi J, Chang A, Kalyan B, Sahota D, Symonds EM. Customised antenatal growth charts. *Lancet* 1992;**339**:283-287.
- <sup>2</sup> Wilcox MA, Johnson IR, Maynard PV, Smith SJ, Chilvers CED. The individualised birthweight ratio: a more logical approach to birthweight. *Br J Obstet Gynaecol* 1993; **100**:342-7
- <sup>3</sup> Sanderson DA, Wilcox MA, Johnson IR. The individualised birthweight ratio: a new method of identifying intrauterine growth retardation. *Br J Obstet Gynaecol* 1994; **101**:310-4
- <sup>4</sup> Gardosi J, Mongelli M, Mul T. Intrauterine growth retardation in: Bailliere's Clinical Obstetrics & Gynaecology: 'Preventive care in Obstetrics'; eds. E.A.P. Steegers, T.K.A.B. Eskes, EM Symonds *Bailliere Tindall*, London 1995; pp 445-463 (Chapter 4)
- <sup>5</sup> Wilcox M, Newton CS, Johnson IR. Paternal influences on birthweight. *Acta Obstet Gynecol Scand* 1995; **74**:15-18
- <sup>6</sup> Gardosi J, Mongelli M, Wilcox M, Chang A. An adjustable fetal weight standard. *Ultrasound Obstet Gynecol* 1995; **6**:168-174.
- <sup>7</sup> Mongelli M, Gardosi J. Gestation-adjusted projection of estimated fetal weight *Acta Obstet Gynecol Scand* 1996; **75**:28-31
- <sup>8</sup> Gardosi J, Mongelli M, Wilcox M, Chang A. Screening and assessment of fetal growth. in: A critical appraisal of fetal surveillance. van Geijn HP, Copray F eds., Elsevier, Amsterdam 1994, 437-448.
- <sup>9</sup> Gardosi J. Prediction of birthweight and fetal weight gain. in: *Contemporary Reviews in Obstetrics & Gynaecology* G Chamberlain & J Drife eds., Parthenon; 1994; **6**:122-6
- <sup>10</sup> Hadlock FP, Harrist RB, Martinez-Poyer J, et al. In utero analysis of fetal growth: a sonographic weight standard. *Radiology* 1991; **181**:129-133
- <sup>11</sup> Gardosi J, Mul T, Mongelli M, Fagan D. Analysis of birthweight and gestational age in antepartum stillbirths. *BJOG* 1998;105:524-30.
- <sup>12</sup> Mongelli M, Gardosi J. Estimation of fetal weight by symphysis-fundus height measurement *International Journal of Gynecology and Obstetrics* **85**; (2004); 50-51
- <sup>13</sup> Mongelli M, Gardosi J. Symphysis-Fundus Height and Pregnancy Characteristics in Ultrasound-Dated Pregnancies. *Obstet Gynecol* 1999; **94**: 591-4.

- 
- <sup>14</sup> Gardosi J, Francis A  
Controlled trial of fundal height measurement plotted on customised antenatal growth charts  
*Br J Obstet Gynaecol*, 1999; **106**: 309-317
- <sup>15</sup> Wright J, Morse K, Kady S, Francis A.  
Audit of fundal height measurements plotted on customised growth charts. *MIDIRS Midwifery Digest* 2006;**16**:3, 341-345
- <sup>16</sup> Mongelli M, Gardosi J.  
Reduction of false-positive diagnosis of intrauterine growth restriction by application of customised fetal growth standards *Obstet Gynecol*, 1996; **88**(5):844-48
- <sup>17</sup> Royal College of Obstetricians and Gynaecologists. The investigation and management of the small-for-gestational age fetus. RCOG Green Top Guideline 2002, 2013 (No.31).  
[www.gestation.net/RCOG\\_Green\\_Top\\_-\\_SGA\\_2013.pdf](http://www.gestation.net/RCOG_Green_Top_-_SGA_2013.pdf)
- <sup>18</sup> Robinson HP, Fleming JEE.  
A critical evaluation of sonar 'crown-rump length' measurements.  
*Br J Obstet Gynaecol* 1975, **82**:702-10.
- <sup>19</sup> Mul T, Mongelli M, Gardosi J. A comparative analysis of second trimester ultrasound dating formulae in pregnancies conceived with artificial reproductive techniques.  
*Ultrasound Obstet Gynecol*, 1996; **8**:397-402
- <sup>20</sup> Altman DG, Chitty LS.  
New charts for ultrasound dating of pregnancy. *Ultrasound Obstet Gynecol*, 1997; **10**:174-191
- <sup>21</sup> Geirsson RT. Busby-Earle RM.  
Certain dates may not provide a reliable estimate of gestational age.  
*Br J Obstet Gynaecol* 1991; **98**(1):108-9
- <sup>22</sup> Gardosi J, Mongelli M.  
Risk assessment adjusted for gestational age in maternal serum screening for Down's syndrome. *Br Med J* 1993; **306**:1509-11
- <sup>23</sup> Mongelli M, Wilcox M, Gardosi J.  
Estimating the date of confinement: ultrasound biometry versus certain menstrual dates  
*Am J Obstet Gynecol* 1996; **174**:278-81
- <sup>24</sup> Gardosi J, Vanner T, Francis A.  
Gestational age and induction of labour for prolonged pregnancy  
*Br J Obstet Gynaecol* 1997; **104**:792-797
- <sup>25</sup> Gardosi J  
Dating of pregnancy: time to forget the last menstrual period (Editorial)  
*Ultrasound Obstet Gynecol* 1997; **9**:367-8

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