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The customized fetal growth potential: a standard for Ireland

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ABSTRACT

Objective: To identify maternal and pregnancy-related physiological and pathological variables associated with fetal growth and birthweight in Ireland and to develop customized birthweight centile charts for the Irish population that will aid in appropriate identification and selection of growth-restricted fetuses requiring increased antenatal surveillance.

Study design: Prospectively collected outcome data of 11,973 consecutive ultrasound-dated singleton pregnancies between 2008 and 2009 from six maternity units in Ireland (Dublin, Galway, Limerick and Belfast) were included for analysis. Maternal weight and height at booking, parity and ethnicity were recorded and combined with birthweight, fetal gender and pregnancy outcomes. Coefficients were derived by backward multiple regression using a stepwise backward elimination approach.

Results: A total of 11,973 ultrasound-dated singleton pregnancies were included in the analysis. Over 90% of women ($n = 10,850$) were of Irish or European descent, 3.4% ($n = 407$) were African or African Caribbean, 1.7% ($n = 208$) were Indian; 42.2% ($n = 5057$) were nulliparous, 32.8% ($n = 3923$) had one previous delivery after 24 weeks' gestation, 15.6% ($n = 1872$) had two previous deliveries and 9.4% ($n = 1121$) had three or more previous deliveries. Mean term birthweight for a standard Irish mother was 3491grams. Babies of all other ethnic origins were smaller than their Irish counterparts. African Caribbean, Bangladeshi, Indian and Pakistani babies were on average 237 g, 196 g, 181 g and 181 g lighter, respectively, when compared to the average Irish offspring. Pathological factors significantly affecting term birthweight were pre-gestational diabetes (+137 g; $p < 0.001$), smoking (−225 g; $p < 0.001$), pregnancy-induced hypertension (−37.6 g; $p = 0.009$) and maternal obesity (−41.6 g; $p = 0.012$).

Conclusion: Birthweight in this Irish maternity population is subject to similar influences to those observed in studies from the UK, Sweden, USA and Australasia. The derived coefficients can be used for customized assessment of fetal growth potential in Ireland. The implementation of these customized centile charts and their free online availability will aid clinicians in Ireland in the interpretation of fetal weight estimation.

1. Introduction

An understanding of the effects of intrauterine fetal growth restriction (IUGR) on pregnancy outcome has to start with the correct definition. The terms small-for-gestational age (SGA) and IUGR are used inconsistently and synonymously by different clinicians to describe a fetus that has not reached its target weight. Fetal weight estimation is usually based on a composite of sonographic parameters of the fetal head, abdomen and femur length [1]. Depending on the definition of IUGR used, up to 10% of all pregnancies will be complicated by apparently suboptimal fetal growth. While the majority of such pregnancies will have a

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physiologically normal fetus that is simply small-for-gestational age, currently our ability to differentiate such a fetus from the pathologically growth-restricted fetus is limited. Suboptimal fetal growth is a major public health problem and the single most common contributor to antepartum stillbirth; IUGR is further associated with neonatal morbidity due to iatrogenic prematurity, impaired neurodevelopment, cerebral palsy and death [2]. Sequelae in adult life include cardiovascular disease, hypertension and diabetes [3].

The most commonly used definition for suboptimal growth is an estimated fetal weight (EFW) below the 10th centile. This does not take into account effects of fetal gender and maternal characteristics such as ethnicity, weight and height. In addition, hypertensive disease, diabetes and smoking in pregnancy have been proven to affect birthweight. In Ireland, the diagnosis of suboptimal intrauterine growth is commonly based on the Hadlock-4 ultrasound formula used to evaluate EFW [1]. Taking the arbitrary cut-off below the 10th centile for a diagnosis of IUGR, only approximately 20% of fetuses in a cohort are expected to be truly growth restricted [4]. Customization of birthweight allows better distinction between normal and abnormal smallness and reduces the false positive and false negative diagnosis of fetal growth restriction which may lead to unnecessary unwarranted investigations [5] causing anxiety for both clinicians and parents.

Fetal growth and birthweight are known to vary with maternal and pregnancy-related physiological variables [6]. We wanted to test this principle and derived a customized standard applicable for Ireland.

2. Materials and methods

This is a prospective study. The cohort consisted of prospectively collected outcome data of pregnancies between 2008 and 2009 from six maternity units in Ireland (Dublin, Galway, Limerick and Belfast) and included 11,973 consecutive case records with complete data and ultrasound-dated pregnancies. Maternal weight and height at booking, parity and ethnicity were recorded and combined with birthweight, fetal gender and pregnancy outcomes. Of the original cohort, 901 were excluded (preterm, stillbirths, congenital structural or karyotypical anomalies and cases with incomplete data), leaving 11,072 for the final analysis. Coefficients were derived by multiple regression using a stepwise backward elimination approach. The methods employed to obtain coefficients followed the Gardosi model [7]. Covariates used were fetal gender and gestation (using linear, quadratic and cubic terms), parity, ethnicity, maternal height and booking weight (both using linear, quadratic and cubic terms).

The analysis was centered on 280 days' gestation for a 'standard' mother of Irish/European origin (height 163 cm, weight at booking 64 kg) and neutral fetal gender.

3. Results

Our results have been derived from Irish population data but show striking similarities to those derived in other countries [8]. The demographic characteristics of our study population are summarised in Table 1. The majority of women in our study were of Irish or European descent (n = 10,850; 91%) with over 40% of those women in their first pregnancy. Maternal hypertensive disease and diabetes complicated 10.5% and 3.1% of pregnancies,

Table 1
Characteristics of study population.

	Mean	SD	Median	IQR
Gestation at delivery (days)	276.7	14.1	279.0	14.0
Birthweight (g)	3419.8	598.3	3460.0	685.0
Maternal height (cm)	164.0	6.5	164.0	8.0
Maternal weight (kg)	68.9	14.0	66.0	17.0
Body mass index (BMI)	25.6	5.0	24.6	5.8
		N		%
BMI				
<20		887		7.4
20–29.9		9056		75.6
30+		2030		17.0
35+		660		5.5
Parity				
0		5057		42.2
1		3923		32.8
2		1872		15.6
3+		1121		9.4
Ethnic origin				
Irish/European		10,850		90.6
Indian		208		1.7
Pakistani		61		0.5
Bangladeshi		21		0.2
African Caribbean		13		0.1
African		394		3.3
Middle-Eastern		67		0.6
Far East Asian		141		1.2
South East Asian		136		1.1
Other		82		0.7
Smoking		2103		17.6
Antepartum hemorrhage		1051		8.8
Pregnancy induced hypertension		1077		9.0
Pre-eclampsia		175		1.5
Diabetes		368		3.1
Congenital anomaly		126		1.1
Premature delivery (<37 weeks)		775		6.5
Sex				
male		6172		51.5
female		5801		48.5
Stillbirth – *n* (rate per 1000)		39		(3.3)
Neonatal death – *n* (rate per 1000)		35		(2.9)

Table 2
Coefficients from multiple regression model. Analysis centered on 280 days gestation, for a standard mother (height 163 cm, weight 64 kg at first visit, para 0, of Irish – European origin). Coefficients of model: constant: 3490.7 g, SE: 411.4, R2 0.29.

	Coefficient	Standard error	*P*-value
Gestational age (from 280 days)			
Linear term	20.852	0.505	<0.001
Quadratic term	−0.456	0.046	<0.001
Sex			
Male	66.8	7.8	<0.001
Female	−66.8	7.8	<0.001
Maternal height (from 163 cm)			
Linear	6.554	0.710	<0.001
Maternal weight (from 64 kg)			
Linear	9.031	0.551	<0.001
Quadratic	−0.093	0.012	<0.001
Ethnic origin			
African Caribbean	−236.5	114.3	0.039
African	−128.4	22.4	<0.001
Bangladeshi	−195.7	94.6	0.039
Indian	−181.4	30.1	<0.001
Middle Eastern	−170.6	52.1	0.001
Pakistani	−181.3	55.2	0.001
South East Asian	−78.9	36.9	0.032
Other	−152.8	48.1	0.002
Parity			
Para 1	130.7	9.2	<0.001
Para 2	174.3	11.9	<0.001
Para 3+	142.1	14.8	<0.001
Index pregnancy			
Smoking	−224.7	10.5	<0.001
Diabetes	137.0	23.7	<0.001
Pregnancy-induced hypertension	−37.6	14.4	0.009
BMI ≥30	−41.6	16.6	0.012

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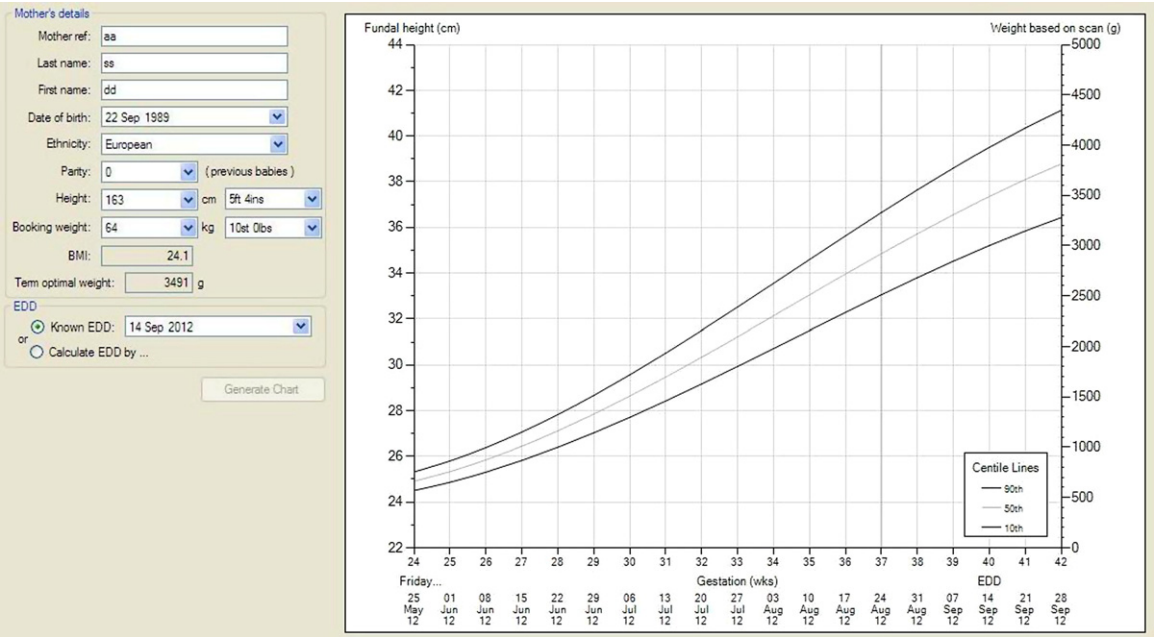

Fig. 1. Irish customized growth chart – for 'standard mother' in first pregnancy. The predicted term optimal weight is 3491 g at 40 0/7 weeks' gestation.

respectively. Antepartum hemorrhage occurred in 8.8% of pregnancies. Strikingly, over 17% of women in our cohort were smokers, which proved to negatively impact on birthweight (−225 g; $p < 0.001$). Ethnicity (other than Irish or European), hypertensive disease and obesity had a negative effect on optimal target birthweight. Birthweight increased with parity and maternal diabetes. Table 2 refers to those described coefficients and *p*-values which were derived from the multiple regression model. The model (Fig. 1) gave an expected target birthweight of 3491 g for a nulliparous European woman of height 163 cm and booking weight 64 kg delivering at 40 0/7 weeks' gestation. Sixty-seven grams is added to this birthweight for a male and subtracted for a female infant.

To illustrate the importance of birthweight customization we give an example: an Irish diabetic mother in her second pregnancy with a boy would be expected to deliver a baby weighing 3865 g, whereas, in comparison, an African primiparous woman with pregnancy-induced hypertension carrying a female fetus would be expected to deliver a baby weighing 3150 g.

Although our findings are very similar to those previously published for other countries [8], it was important to derive coefficients specifically for the Irish population first to prove their appropriateness before implementation into standard practice.

4. Comments

Defining normal and abnormal fetal growth remains a daily challenge in obstetric practice. There are significant inconsistencies in the definition, assessment and management of fetal growth restriction which need urgent attention. As customization of growth standards depends on maternal and fetal characteristics, it is not surprising that birthweight in this Irish maternity population is subject to similar factors to those observed in studies from other countries. Our study is in agreement with others that a 'standard mother' (same height, weight, parity and ethnic origin) can expect a baby with a similar birthweight, whether she is living in the UK, Sweden, Australasia, New Zealand or the USA. In particular, Mongelli et al. [9] compared analyses from Australia, New Zealand and England showing constants – that is the expected birthweight at 280 days – to be remarkably similar at 3464, 3464 and 3456 g, respectively. Similar curves have been developed for South America by Cecatti et al. [10].

Strengths of our study include the fact that it was prospective and multicenter; only ultrasound-dated singleton pregnancies with complete records were included for analysis; preterm deliveries, stillbirths and abnormally formed infants were excluded from the final analysis.

The implementation of such charts in Ireland will aid the appropriate identification of growth restriction [11] and select those fetuses which will require increased antenatal surveillance. This will result in an increased detection rate of true growth restriction and a reduction in false positive diagnoses for IUGR.

A large prospective observational study (PORTO) to assess outcomes of 1200 pregnancies affected by IUGR is currently recruiting in seven major obstetric centers in Ireland (Perinatal Ireland Research Consortium).

The development of a local population standard to assess fetal growth and the implementation of such customized birthweight centile charts into daily obstetric practice will aid clinicians in Ireland in the differentiation between physiological and pathological smallness and improve perinatal outcomes. These charts are now freely available online at www.gestation.net.

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References

[1] Hadlock FP, Harrist RB, Sharman RS, Deter RL, Park SK. Estimation of fetal weight with the use of head, body, and femur measurements – a prospective study. American Journal of Obstetrics and Gynecology 1985;151:333–7.
[2] Badawi N, Kurinczuk JJ, Keogh JM, et al. Antepartum risk factors for newborn encephalopathy: the Western Australian case–control study. BMJ 1998;317:1549–53.

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[3] Barker DJ. Adult consequences of fetal growth restriction. Clinical Obstetrics and Gynecology 2006;49(2):270–83.
[4] Eixarch E, Meler E, Iraola A, et al. Neurodevelopmental outcome in 2-year-old infants who were small-for-gestational age term fetuses with cerebral blood flow. Ultrasound in Obstetrics and Gynecology 2008;32:894–9.
[5] Gardosi J, Figueras F, Clausson B, Francis A. The customised growth potential: an international research tool to study the epidemiology of fetal growth. Paediatric and Perinatal Epidemiology 2011;25:2–10.
[6] Gardosi J, Chang A, Kalyan B, Sahota D, Symonds EM. Customised antenatal growth charts. Lancet 1992;339:283–7.
[7] Gardosi J, Mongelli M, Wilcox M, Chang A. An adjustable fetal weight standard. Ultrasound in Obstetrics and Gynecology 1995;6:168–74.
[8] McCowan L, Stewart AW, Francis A, Gardosi J. A customised birthweight centile calculator developed for a New Zealand population. The Australian and New Zealand Journal of Obstetrics and Gynaecology 2004;44:428–31.
[9] Mongelli M, Figueras F, Francis A, Gardosi J. A customized birthweight centile calculator developed for an Australian population. The Australian and New Zealand Journal of Obstetrics and Gynaecology 2007;47:128–31.
[10] Cecatti JG, Machado MR, dos Santos FF, Marussi EF. Curve of normal estimated fetal weight values by ultrasound according to gestation age. Cadernos de Saude Publica 2000;16:1083–90.
[11] Narchi H, Skinner A, Williams B. Small for gestational age neonates – are we missing some by only using standard population growth standards and does it matter? The Journal of Maternal-Fetal and Neonatal Medicine 2010;23:48–54.

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